The History and Science of Cognitive Science: Introductory Lectures

Chapter 3: The Rise of Empirical Psychology

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Chapter Outline

3.1 Introduction
3.2 Reaction Times and Mental Chronometry
3.3 Introspection and Introspection-Based Psychologies
- **3.3a** Introspectionist Psychology: Voluntarism
- **3.3b** Introspectionist Psychology: Structuralism
- **3.3c** Introspectionist Psychology: Act Psychology

3.4 The Downfall of Introspectionist Psychology
3.5 Functionalism
3.6 Gestalt Psychology
3.7 Ebbinghaus: The Quantified Study of Memory as a Process
3.8 Thorndike's Law of Effect
3.9 The Rise of Statistics and Quantitative Analysis of Variable Data
3.10 Behaviorism
- **3.10.a** Behaviorism: Pavlov's Discovery of Classical Conditioning
- **3.10.b** Behaviorism: John Watson

3.11 Neo-Behaviorism
- **3.11.a** Neo-Behaviorism: Hull's Methodological Behaviorism
- **3.11.b** Neo-Behaviorism: Purposive Behaviorism
- **3.11.c** Neo-Behaviorism: Radical Behaviorism

3.12 Chomsky, Skinner, and the Retreat of Behaviorism
3.13 The Mathematical Analysis of Communication and Control
3.14 Information Processing Psychology
3.15 Development as Inherently Cognitive
3.16 The Final Step
3.17 Glossary of Key Terms
3.18 Bibliography

3.1 Introduction

Chapter two suggests that oppositional substance dualists face two major challenges. On the one hand, oppositional substance dualists have problems explaining the continual, seamless interaction between the mental and the physical. On the other hand, the very nature of mental substance gives rise to the challenges in positing explanatory mechanisms for mental phenomena. What features of mental substance and/or mental properties drive the dynamic changes mental phenomena and why? Put another way, what "mental mechanisms" bring about mental properties and processes? Even if one can formulate theories about such "mental mechanisms," how does one go about investigating and confirming one's theories about "mental mechanisms"? How can one experimentally manipulate the elements of a non-physical mental substance? How can one measure such a substance or its properties?

But, do monistic physicalists fare any better? Physicalist theories must meet the challenge of formulating physical mechanisms that plausibly explain how physical substance, physical properties, and/or physical processes give rise to mental properties and processes. Chapter three outlines how psychology develops the categorizations, operationalizations, and experimental techniques that allow psychologists to gain traction in predicting, manipulating, and explaining one aspect of one mental domain—cognition. This confluence of increasingly sophisticated descriptive and experimental elements gives rise to a series of psychological schools, each making contributions that eventually lead to behaviorism in psychology and finally to the information processing model of cognition.

The switch to psychology midway through the exposition of the development of philosophy may seem somewhat out of place. However, since the developments in psychology and other sciences drive a great deal of the work in philosophy of mind during the 20th and 21st centuries, one must understand the developments in psychology and related sciences to understand the philosophy of mind during the 20th and 21st centuries. Indeed, students would have significant difficulties understanding the developments that shape philosophy during the first half of the 20th century absent some familiarity with the contemporaneous developments of empirical psychology and other sciences. This chapter and lecture, therefore, takes a detour to recount the development of empirical psychology before the next chapter returns to and finishes the discussion of philosophy.

The progression between psychological schools of thought in this brief history emphasizes three trends: First, psychology progresses towards becoming a science and ultimately towards cognitive science by developing, evaluating, and integrating several important experimental methods. The development, evaluation and integration of experimental techniques together with a clear conception of their role in theory formation and testing constitute what I call an experimental tradition. Psychology develops an experimental tradition at first through the introduction of experimental methods from other sciences. Later, as this tradition blossoms, researchers become increasingly innovative and adaptive in their use of experimental methodology. The introduction of increasingly powerful and sophisticated statistical tools proves crucial to the development of operationalizations and experimental design given the variability of psychological data. Second, psychological schools of thought move from emphasizing conscious, qualitative aspects of mind and mental processes to emphasizing characterizations of the mind and mental processes in terms of information processing and observable behavior. This change in emphasis does not merely represent a recognition by theorists of an important set of phenomena for understanding the mind and mentality—though it surely is—it represents a shift from phenomena ill-suited to the conceptual and experimental methods of the time to phenomena better understood and testable by those resources. That is, psychology progresses by shifting its categorizations and theories towards those aspects of the mind best suited to the operationalizations and experimental traditions of the time. Third, psychologists develop and adapt experimental techniques in order to more reliably explore those elements of their information processing models not directly observable by experimenters. The development of experimental methodologies, the refinement of animal and other models, increase knowledge of human mentality, development, and physiology, as well as the development of technical ideas such as information theory and computation ultimately coalesce, allowing for the conceptual framing of cognitive phenomena as well as its systematic experimental investigation. Only at this point can theoretic models of cognition based upon computation and information processing emerge.

3.2 Reaction Times and Mental Chronometry

Recall that in briefly discussing the renewed development of physiology and anatomy in the second half of the 16th century, the last chapter and lectures emphasize that physiology introduces a strong empirical and experimental emphasis to thinking about bodily functions. By the second half of the 19th century physiologists adapt tools and ideas from astronomy investigate nervous functioning. This early work in neurophysiology in turn inspires researchers to adapt and develop experimental approaches to investigating psychological functioning. Indeed, many early psychologists receive their training from physiologists and anatomists. Thus, the current chapter and lectures begins by traces those early insights and techniques from astronomy into physiology and ultimately into genesis of experimental psychology. The discussion of the development of psychology and its convergence towards cognitive science, therefore, begins with the development of an experimental technique that has proven quite central to psychology—reaction time or mental chronometry.[1]

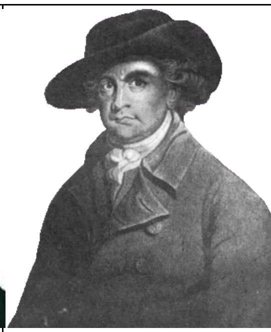
Reaction time refers to the time it takes from the initial presentation of stimulus until the subject reacts. For instance, the time between a light flashing and a subject pressing a button is that subject's reaction time for that stimulus-response pairing. The idea of reaction time and its measurement begins with Friedrich Wilhelm Bessel[2-4] (1784-1846), a German astronomer and Gymnasium drop-out. Bessel becomes intrigued by a controversy regarding disparate observations of transit times between the astronomers Nevil Maskelyne[5] and his assistant David Kinnebrook at the Greenwich Observatory.[6] While Kinnebrook is fired in 1796 on the assumption that the discrepancies result from his incompetence, when discrepancies in observations emerge in the work of Johann Franz Encke[7] and Carl Friedrich Gauss,[8] the stature of the involved parties preclude similar assumptions and open the door for some other explanation. Transit times are measurements of how long it takes stars to cross hairlines in telescopic observations. Transit times have significance because they indicate the time it takes the star to pass over the meridian of the observatory. Astronomers use transit times for a star to determine the coordinates of the star. Precise measurements of star coordinates are becoming increasingly important in the 1700s and 1800s, both for the astronomers and also because nautical tables of the time rely upon coordinate information for stars. Twenty years after the original dispute (1821), Bessel looks at the dispute using two approaches: First, Bessel analyzes the observations of different astronomers. Second, Bessel performs a simple experiment; he compares observational measurements between astronomers using the same equipment. Bessel determines that skilled astronomers will vary


Portrait of Nevil Maskelyne (1732-1811). No portraits of David Kinnebrook, who was fired as a result of the controversy, are available. From: portcities.org.uk

consistently in their observations of transit times. As a result, Bessel introduces the notion of an "involuntary constant difference," in describing his findings in the preface to the eighth volume of his *Astronomische Beobachtungen*[9] (1823).

In astronomy, the phenomena now commonly goes under the name, "personal equation," introduced by John Pond[10] (1767–1836) in 1933.[11] One can describe Bessel's work as the first experimental quantitative measurement of reaction time without fear of accusations of hyperbole. Indeed, Bessel's work eventually results in the first attempts to control both for reaction time and also for individual differences in scientific observation. These efforts manifest in two ways. On the one hand, the recognition of variability in measurements leads both to more rigorous and uniform methodologies and to refinements in instrumentation. For instance, while marine navigators already employ chronometers, increases in chronometer accuracy allow scientists to adopt them as well. In 1847 the German-born Swiss clock maker and inventor, Matthäus Hipp,[12] builds a modified chronoscope based upon the design of its inventor, Charles Wheatstone[13] (1842). Wheatstone originally designed the chronoscope for British artillery applications, but the devices allow increased accuracy in temporal measurement over pendulum clocks and other measuring devices. Scientists and inventors continue to refine chronoscopes and pair these increasingly advanced chronometers and the Control Hammer Apparatus for better time keeping and calibration.[12, 14] On the other

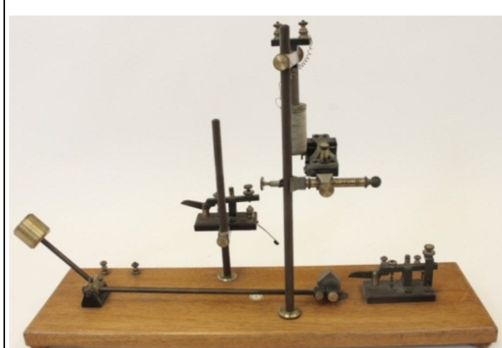

Friedrich Wilhelm Bessel (1784-1846)
From: Wikipedia


John Pond (1767-1836)
From: Wikipedia


Matthäus Hipp (1813-1893)
From: Twigsdigs.com


Charles Wheatstone (1802–1875)
From: BBC

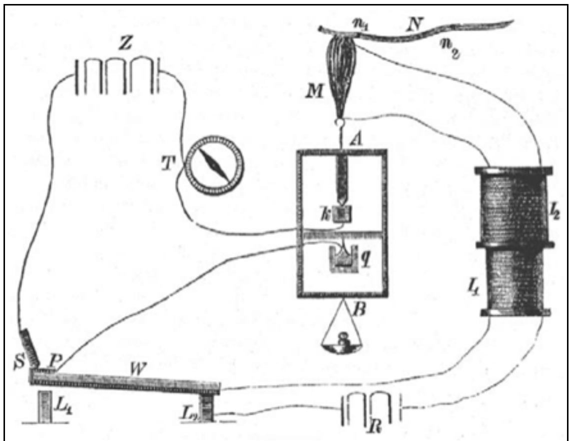

A chronoscope built by the Swiss inventor and clock maker Matthias Hipp in 1888. Early psychological and physiological researchers used chronoscopes to measure reaction times in their experiments. This chronoscope is accurate to 1/1000th of a second. From: U of Texas


Picture of a control hammer appartus used to calibrate timing devices like the chronoscope. From: U of Toronto


A mechanical marine chronometer invented by John Harrison in 1737. From: Wikipedia

hand, while methodological prescriptions and refined measurement devices help to push back the limits of scientific measurement and reduce error, the elimination of variability entirely continues to elude scientists. Thus, scientists begin the process of a slow reconciliation towards the limitations of measurement and the need to accommodate variability in data. For instance, Gauss introduces the technique of "least squares" to weight observations depending on their distance from the mean. Gauss' adoption of the technique of least square in data analysis allows him to calculate the normal distribution of the data in order to estimate a value for an observation that represents the minimum error given the variability in the data. This second development reemerges in the discussion later in this chapter and lectures.

The development of increasingly accurate chronoscopes prompts researchers to begin to utilize chronoscopes in research both within and outside of astronomy. Among the researchers who employ these increasingly accurate chronoscopes, the German physicist and physiologist, Hermann Ludwig Ferdinand von Helmholtz (1821-1894) distinguishes himself. Helmholtz is a student of pioneering physiologist Johannes Peter Müller.[15] Müller, a long-time advocate of employing insights from physics and chemistry in physiology, has recently published his highly influential *Physiologie des Menschen* or *Elements of Physiology* (1833-1840).[16, 17] Showing the influences of his mentor, Helmholtz borrows an idea from the French physicist Claude Pouillet, Helmholtz begins a series of expe riments employing both a chronoscope and a galvanometer (a device invented by Hans Oersted in 1820 that measures electric current) to measure the speed of nerve transmission.[18-22] Helmholtz publishes his results in two papers, "On the Rate of Transmission of the Nerve Impulse" and "Preliminary Report on the Reproductive Rate of Nerve Stimulation," in 1850.[23, 24] Hemholtz calculates the speed of nerve conduction as between 24.6 and 38.4 m/s in that first paper, telling readers that:[23]



Kuhn's illustration illustrating the technique used by Helmholtz. From: Handbuch der angewandten Elektricitätslehre, mit besonderer Berücksichtigung der theoretischen Grundlagen, p. 1193(1866). The technique was originally suggested by the French physicist Claude Pouillet (1790–1868).

> I have found that a measurable time passes when the stimulus exerted by a momentary electric current on the hip plexus of a frog propagates itself to the nerves of the thigh and enters the calf muscle. In large frogs whose nerves were 50 to 60 millimetres long, and which I had kept at 2–6 degrees Celsius (whereas the temperature of the observation room was between 11 and 15 degrees), this length of time amounted to 0.0014 and 0.0020 of one second. (p. 71)

Helmholtz also uses human subjects to measure simple reaction times which he reports in a paper, "As to the Methods , to Measure the Smallest Part Time, and Their Application for Physiological Purposes," in 1850.[25] In the last paper Helmholtz tells readers:[25]

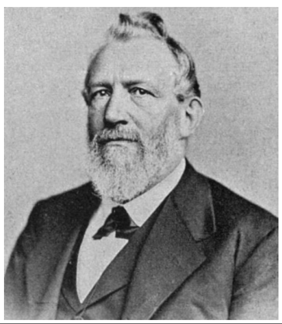
> In a human being, a very weak electric shock is applied to a limited space of skin. When he feels the shock, he is asked to carry out a specific movement with the hand or the teeth, interrupting the time measurement as soon as possible. (p. 878)

Together with the work of Müller and another of Müller's students, Emil du Bois-Reymond, with Helmholtz's work helps to give rise to a body of work on the physiology of the nerve fibers and sensory systems.[26, 27] In describing du Bios-Reymond's work, for instance, Finkelstein observes,[28]

> Perhaps the greatest of du Bois-Reymond's innovations was an experimental design that solved three problems that vexed the study of animal electricity. First, du Bois-Reymond devised neutral means of coupling instruments to tissue, most notably “non-polarizable” electrodes formed from an amalgam of zinc, zinc sulfate, and modeling clay. Second, he invented devices like the “magneo-electrometer” (AC generator) and the “rheocord” (potentiometer) that delivered graded shocks to his preparations. Last, he constructed a galvanometer sensitive enough to record the results of his protocols. These breakthroughs allowed him to detect action currents in frog muscles in 1843; 4 years later the addition of a Wheatstone bridge circuit to his set-up let him to demonstrate the same electrical signals in human subjects.

The successes of physiology slowly progress towards more psychological phenomena both within physiology and within other disciplines. In 1860 Gustav Fechner expands physiology beyond studies of nerve sensory system function into psychophysics when he publishes his *Elemente der Psychophysik* or *Elements of Psychophysics*.[29-31] In this work Fechner offers multiple formulations of the Weber–Fechner law that quantitatively relates changes in qualitative sensation to changes in the intensity of a physical stimulus (originally formulated as S = c log R, where S is the sensation, R is the stimulus intensity, and c is and experimentally determined constant).[32]

Hermann von Helmholtz (1821-1894)
From: NDSU.edu



Emil du Bois-Reymond (1818 - 1896)
From: Wikipedia

Adolph Hirsch (1830-1901)
From: Wikipedia

Franciscus Cornelis Donders (1818-1889)
From: Wikipedia

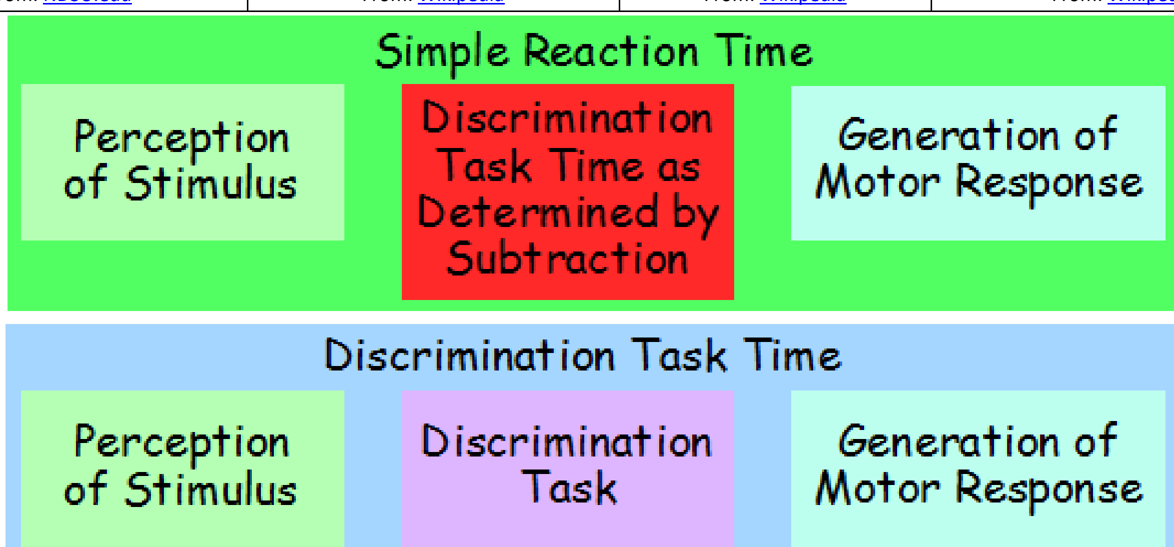


Diagram illustrating the subtraction technique. A researcher takes two tasks that differ only by one component task. In this case, the first task is a simple reaction task composed of a perception task and a motor response task. The second task is a discrimination task composed of a perception task, a motor response task, and the discrimination task. The researcher determines the mean time for subjects to complete each task. Subtraction of the simple reaction time from the discrimination task time to yield the time of the discrimination task alone.

As researchers like Fechner expand physiology into psychophysiology, other researchers continue efforts to understand reaction times. In 1862 the Swiss astronomer, Adolphe Hirsch, (1830-1901) publishes his "Sur l'equation Personnelle dans les Observations Astronomiques" (On Personal Equation in Astronomical Observations) and his "Experiences Chronoscopiques sur la Vitesse des différentes Sensations et de la Transmission Nerveuse" (Chronoscopes Experiments on the Speed of Different Sensations and Nerve Transmission)"[33, 34] In the latter work Hirsch [35]

> …was the first (1) to use Hipp's chronoscope in scientific literature, (2) to study reaction time in connection to psychological interest, and (3) to study velocity of conduction in humans with appropriate techniques. Using Hipp's apparatus, Hirsch showed differences in time for manual response (1) to auditory, visual, and tactile stimulation; (2) between observers; (3) in Hirsch's own results when fresh and when fatigued; (4) according to the locus of tactile stimulation and the hand used for response; and (5) according to whether the stimulus was expected or unexpected. Moreover, observations made on one of his colleagues relate the conduction speed in nerves, from which he concludes that the differences in reaction time were due to the varying lengths of nerves. The speed of transmission in sensory nerves was evaluated by Hirsch at about 34 m/s. (p.261)

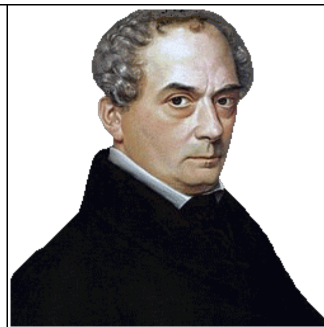
Historians usually cite the Dutch physiologist and ophthalmologist Franciscus Cornelis Donders (1818-1889) as the first researcher to use differences in human reaction time to infer differences in cognitive processing time.[36] Building on the work of his graduate student, Johan Jacob De Jaager, and with an awareness of earlier work by Helmholtz and Hirsch, Donders uses the same subtraction method employed by Helmholtz, to make inferences about the times of various mental processes.[37] In 1868, Donders publishes "On the Speed of Mental Processes," in which he shows that
a simple reaction time is shorter than a recognition reaction time, and that the choice reaction time is longest of all.[38] Using these times, Donders makes inferences as to the speed of mental processes through subtraction: recognition = (recognition reaction time - simple reaction time). Donders' results are an instance of mental chronometry,[1] i.e., the study of the relative speed and temporal sequencing of mental process under some specified set of conditions. The ideas of subtraction, mental chronometry, and reaction time are now part of the central methodological framework of cognitive psychology. The next experimental technique, introspection, has a less venerable history.

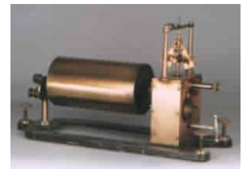
3.3 Introspection and Introspection-Based Psychologies

The development of the categorization of phenomena through reaction time and the invention of devices for precise quantification of reaction time in experimentation represent a significant success in the development of an experimental tradition within physiology and what would eventually become psychology. The next example of the development of an operationalization (measurement procedure) proves less definitely positive. One difficulty theorists face in developing theories of mind lies in finding ways to categorize and measure qualitative conscious experiences. Qualitative aspects of mentality consist in the phenomenal aspect of mental states that Thomas Nagel aptly described as "what it feels like."[39] Beginning in the latter half of the 19th century some researchers turn to introspection, an individual's (seeming) observations of their own conscious states such as beliefs, desires, emotions, and sensations as a means of gathering observations of such phenomena. The technique of introspection enters psychology through the work of Wilhelm Maximilian Wundt,[40] (1832-1920) a German physician, psychologist, physiologist, and university professor. Wundt, Edward Titchener,[41] (1867-1927) and Franz Brentano[42] (1838-1917) are often portrayed together under the title of Introspectionist Psychology. However, as we will see, these theorists differ significantly in their theoretical perspectives as well as their use of introspection as a means of collecting data for experimental psychology.


Wilhelm Wundt (1832-1920)
From: Europeword


Edward Titchener (1867-1927)
From: Allaboutpsychology


Franz Brentano (1838-1917)
From: 50watts.com


(Above) A Kymograph first used by physiologists, but adapted by psychologists to record response times, stimulus presentations and other temporal events. The drum rotates and events are recorded on sheet of paper. Picture and caption adapted from: University of Indiana

(Far Left) An Aerometer used by Wundt to investigate pressure sensitivity. Experimenters put weights on the left side of the device, and the subject's had rested beneath the adjustable pole on the right-hand side of the device. From: North Taiwan University **(Left)** A tachistoscope used to present images from a fixed period of time. The images where loaded on the wheel which psychologists placed behind a screen. The screen had a single slit through which an image would become visible as its place on the wheel rotated in front of the opening. From: North Taiwan University

3.3a Introspectionist Psychology: Voluntarism

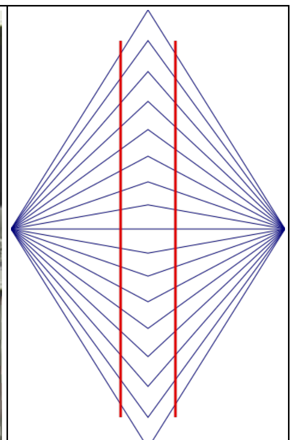
Wundt creates the first laboratory explicitly dedicated to psychological research (as opposed to labs for teaching demonstrations) at the University of Leipzig in 1879. He also begins the first journal for psychological research in 1881. If Freud is the "father of Psychiatry," Wundt likely deserves the title of the "father of Experimental Psychology." The experimental tradition begun by Wundt spreads throughout Europe as well as the United States.[43]

Wundt studies under the German anatomist Heinrich Müller and under Helmholtz prior to writing his first book, *Contributions to the Theory of Sense Perception* (1862).[44] He follows this book with his second, *Lectures on Human and Animal Psychology* (1863).[45] This second book results from lectures Wundt gives for the first ever psychology course. Nevertheless, Wundt still teaches and conducts research primarily in physiology. He publishes a physiology textbook in 1865, and is promoted to assistant professor of physiology at Heidelberg in 1864. Not until around 1867 does Wundt seem to devote his teaching and research primarily to psychology, when he begins lecturing regularly on physiological psychology. Wundt founds the first school of psychological thought by 1874, when he publishes *Principles of Physiological Psychology*.[46] Ironically, Wundt's success at training a new group experimental psychologists leads to a distortion of his own views. One Wundt's students, Edward Titchener[41] (1867-1927), actively, but misleading, associates Wundt's view with Titchener's own view, structuralism. Wundt names his view voluntarism, and as we will see, it differs somewhat from the typical views attributed to structuralism.

Wundt equates mentality with consciousness in that all mental phenomena are conscious phenomena, and only mental phenomena are conscious phenomena. Wundt thereby distinguishes pure physiology from psychology. For Wundt studying the reflex arc fall unders physiology, while studying how and to what extent painful sensations (conscious experiences of pain) arise from stimuli would fall under psychology. Wundt further holds that experimentation can help one to understand how simple conscious sensory phenomena combine to create more complex conscious sensory experiences. However, on Wundt's view the methods of scientific psychology cannot provide insight into other types of complex conscious phenomena such as higher order psychological processes like reasoning. Essentially, Wundt limits psychology to studying the phenomena that contemporary psychologists classify as sensation and perception. Contemporary psychologists use the term sensation to refer to the processes that generate our qualitative sensory experiences in response to the environment. Contemporary psychologists use the term perception to refer to the significance that we attach to our qualitative sensory experiences. For instance, the light reflected from an apple can create a qualitative experience of red (sensation), we may interpret that red experience as an apple or as food (perception).

For Wundt, psychology represents an extension of the techniques of physiology into the domain of conscious experiences. However, Wundt precisely and modestly limits the scope of such an extension of physiological techniques to the scientific investigation of conscious experiences associated with what we now classify as sensation and perception. Wundt excludes higher order processes like conscious problem solving from the domain of scientific psychology, holding that one must employ historical analysis and naturalistic (non-experimental) observation to understand higher mental functioning. Thus, reasoning, problem solving, and similar processes typically associated with mentality in the contemporary understanding of the mind fall outside the purview of psychology under Wundt's conception.

Picture of Wundt together with his research associates at the Leipzig laboratory. From: [Wikipedia]



A diagram depicting the Wundt illusion discovered by Wundt in 1858. From: [Wikipedia]

Reaction-time enters Wundt's experimental repertoire from Helmholtz and Donders. However, he eventually abandons the use of reaction time as too unreliable. Unlike many other psychologists who follow him, Wundt uses introspection in a highly constrained fashion in keeping with its use in physiology and psychophysiology. Wundt's subjects provide only simple, unreflective answers (e.g., yes or no) reported concurrent with their conscious sensory experiences. Wundt likewise seeks to design replicable experiments that carefully control the presentation of experimental stimuli. However, Wundt does train subjects in introspection, ostensively so that the subjects can learn the appropriate categories. For Wundt, when properly used introspection can provide an unbiased and effective operationalization of relatively simple conscious sensory experiences in that introspection facilitates the reliable, immediate, and direct observation of conscious mental phenomena. In other words, Wundt holds that when properly used introspection allows subjects to reliably categorize their conscious sensory experiences.

Wundt's research uses categorizations that specify two different processes acting to combine simpler conscious sensory experiences into more complex conscious sensory experience. On the one hand, Wundt studies perception—the passive and involuntary combination of multiple simple conscious sensory experiences like sensations and feelings into more complex conscious sensory experiences. On the other hand, Wundt studies apperception—an active process with a volition component involving attention that synthesizes more complex conscious sensory experiences from simpler conscious sensory experiences. Thus, Wundt seeks the fundamental constitutive elements of conscious sensory mentality as well as the rules by which these elements combine into more complex conscious sensory experiences. In this way, Wundt follows

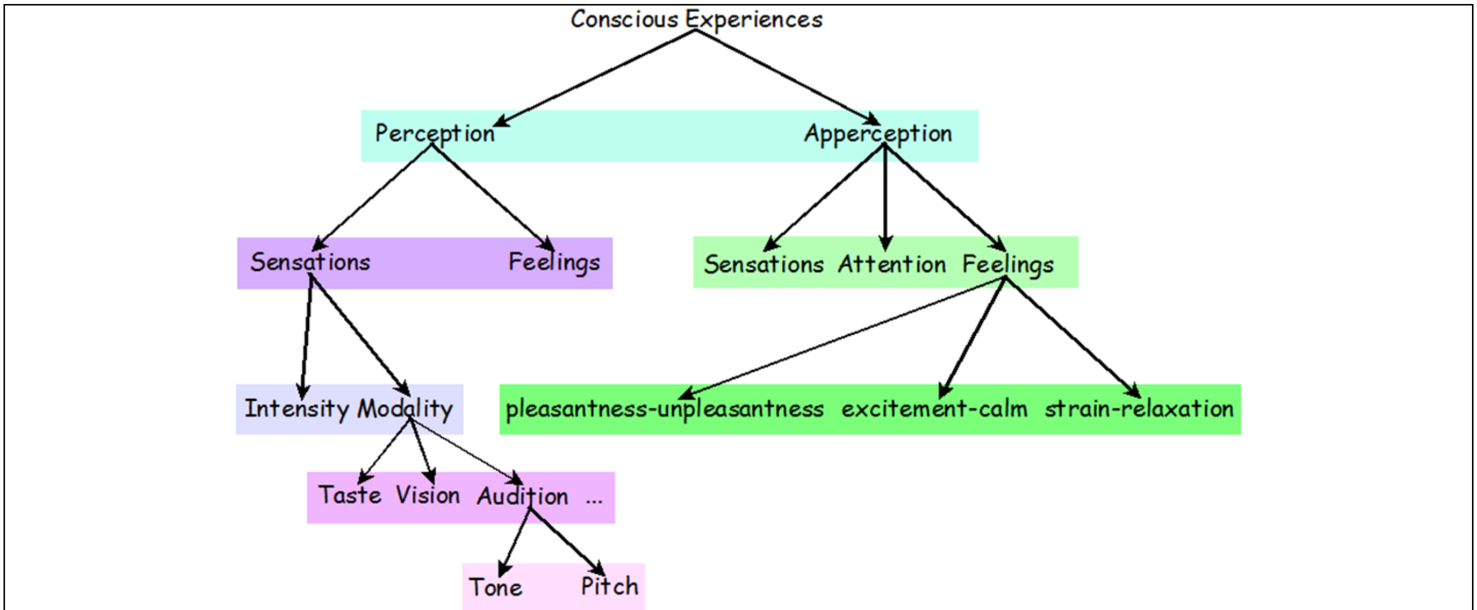


Diagram depicting Wundt's theory of conscious experience. Wundt divides conscious experiences into two kinds; passive perception and active apperception. Perception consists to two elements; sensations and feelings. Apperception consists of the elements of sensations and feelings together with attention. Sensations have two components (depicted on the right); intensity and modality. Each modality has qualities; in this case, audition has tone and pitch. Feelings (depicted on the left) vary along three orthogonal dimensions; pleasantness-unpleasantness, excitement-calm, and strain-relaxation.

the mental chemistry model of the mind that one finds in the British Empiricists. However, for Wundt attention and the will act as a sort of catalyst, making apperception active.

Thus, Wundt differentiates himself from the British Empiricists, in part, because of his introduction of an active, volitional component to the mental chemistry account. Likewise, Wundt's exclusion of higher mental functioning from the domain of scientific studies of the mind differs from the atomism of earlier thinkers.

Within perception Wundt breaks mental elements into two categories; sensations and feelings. Sensations result from stimulation of the sense organs. Each sensation has an intensity value (ex. bright vs dim) and a modality (touch, taste, etc.). Each modality has associated qualities such as sweet and sour for taste. Feelings are distinct from sensations but co-occur with sensations. Wundt proposes a tridimensional account of feelings in which feelings have values along three orthogonal (opposing and independent) dimensions; pleasantness-unpleasantness, excitement-calm, and strain-relaxation. Correspondingly, Wundt breaks apperception into sensations, feelings, and attention.

3.3b Introspectionist Psychology: Structuralism

Edward Titchener[41] (1867-1927) is an English student of Wundt who comes to Cornell University where he continues Wundt's general project of trying to identify the elements of simple human consciousness and their interactions. However, Titchener's views and methods differ significantly from Wundt's. Unlike Wundt, Titchener seeks to apply the lens of experimental psychology to higher order mental phenomena as well as simpler conscious phenomena. Titchener views experimental psychology as generating a morphological account of mental experiences—that is, an account of the elements and composite structure of conscious mental experiences. In his article, "The Postulates of a Structural Psychology,"[47] (1898), Titchener tells readers that,

> The primary aim of the experimental psychologist has been to analyze the structure of mind; to ravel out the elemental processes from the tangle of consciousness, or (if we may change the metaphor) to isolate the constituents in the given conscious formation. His task is a vivisection, but a vivisection which shall yield structural, not functional results. He tries to discover, first of all, what is there and in what quantity, not what it is there for. (p.450)

Likewise, Titchener differs from Wundt in that Titchener rejects the idea of an active volitional component of mental experiences. Titchener rejects as unscientific volitional, functional and teleological descriptions of mental processes at the psychological level. Instead, Titchener follows the British Empiricists in supposing that psychology should create an account of mental experiences in terms of structures created through the combination of basic elements through the mechanism of association. Similarly, Titchener holds that mental elements can only be known through their attributes. Titchener distinguishes three kinds of mental elements; sensations, images, and affections. Titchener associates ideas with images, following Hume in supposing that ideas are formed from perceptions. Thus, perceptions are composed of sensations, ideas are composed of images, and emotions are composed of affections. Titchener further analyzes sensations and ideas into intensity, quality, duration, and extent. He also distinguishes modalities like touch and vision. Affections also possess intensity, quality, and duration. However, affections lack clearness and extent. Titchener's primary mechanism of association is the law of contiguity. The law of contiguity states that occurrent mental states will tend to cause other mental states that have co-occurred with that state in past experiences.

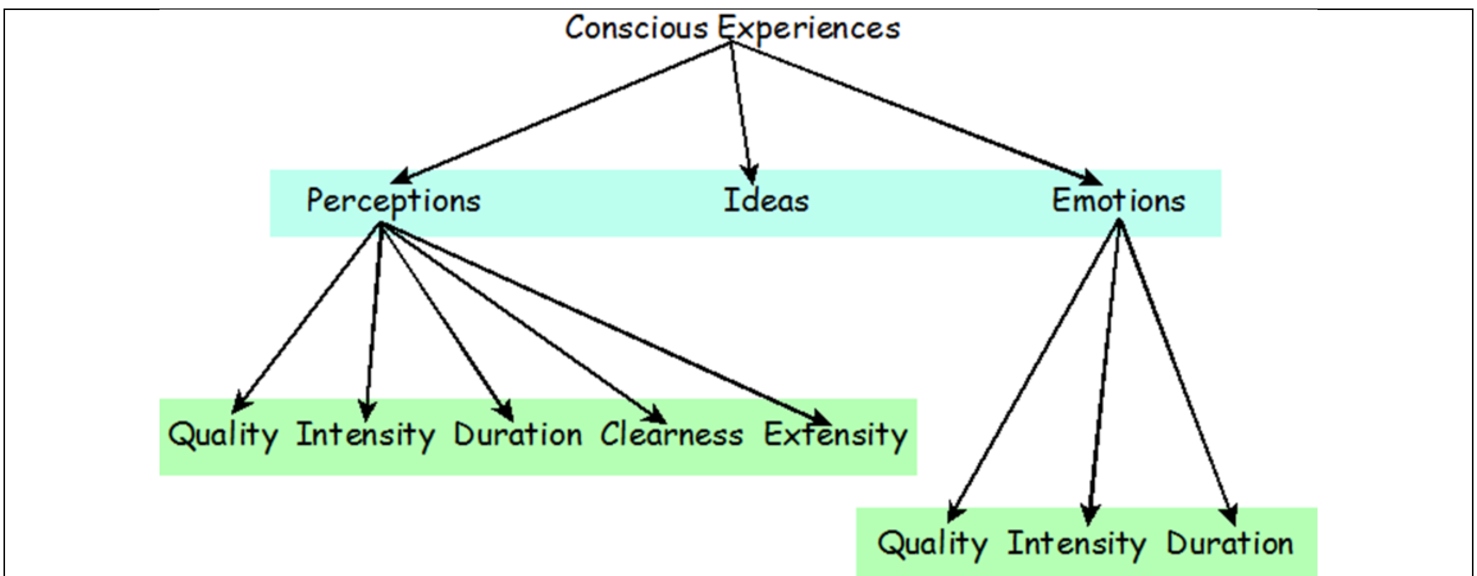


Diagram depicting the Titchener's structuralist account of conscious experiences. Conscious experiences are composed of elements from three categories (in blue); perceptions, ideas, and emotions. Each element has attributes (in green) that differentiates it and through which it is known. Perceptions and ideas have the attributes of quality, intensity, duration, clearness, and extensity. Emotions have the attributes of quality, intensity, and duration.

Titchener's use of introspection differs from Wundt's in that Titchener requires subjects to actively probe or analyze their experiences to formulate reports. This requires extensive training. Titchener intends his training to cultivate an ability to observe and describe conscious experiences without the tincture of "stimulus error." Stimulus error occurs when subjects report their perceptions--reporting the meaning of the stimulus (or its conceptualization). For instance, if a subject saw an apple, the subject must report the hues, shapes, etc. of their experience—they should not report seeing an apple or a fruit. This combination of indoctrination into descriptive categories and active, even retroactive, analysis by subjects renders introspection even more methodologically problematic as an experimental tool.

In addition to the difficulties surrounding Titchener's use of introspection, he also ignores as irrelevant numerous research areas in which researchers enjoy significant progress. For instance, Titchener discounts animal behavior and evolution, abnormal behavior, learning, development, and inter-subjective variation.

3.3c Introspectionist Psychology: Act Psychology

If one seeks a true Introspectionist villain, Franz Clemens Honoratus Hermann Brentano[42] (1838-1917) probably best fits that description. In his major work, *Psychologie vom Empirischen Standpunkte*[48] or *Psychology from an Empirical Standpoint* (1874), Brentano coins the term "intentionality" to characterize his view that every mental act has an object to which it refers. For example, when someone sees an apple, they see it as an apple, an object, and not merely as a qualitative experience. Brentano tells readers:[49]

> Every mental phenomenon is characterized by what the Scholastics of the Middle Ages called the intentional (or mental) inexistence of an object, and what we might call, though not wholly unambiguously, reference to a content, direction towards an object (which is not to be understood here as meaning a thing), or immanent objectivity. Every mental phenomenon includes something as object within itself, although they do not all do so in the same way. In presentation something is presented, in judgement something is affirmed or denied, in love loved, in hate hated, in desire desired and so on. This intentional in-existence is characteristic exclusively of mental phenomena. No physical phenomenon exhibits anything like it. We could, therefore, define mental phenomena by saying that they are those phenomena which contain an object intentionally within themselves. (p.88-89)

Brentano also eschews the study of static simple conscious experiences, framing mentality in terms of acts, that is, in terms of the mind being directed towards an object in order to perform some function. Indeed, he holds that psychology should study mental processes in order to determine their function.

Though Brentano never practices experimental psychology, he does employ and advocate "phenomenological introspection," in his theorizing about the nature of the mind and its processes. In employing phenomenological introspection, the researcher either asks the subject to analyze temporally extended processes such as inferences, or performs such an analysis themselves. Though Brentano publishes very little, he influences many people, for instance, Freud.

3.4 The Downfall of Introspectionist Psychology

Introspectionist approaches to psychology make several contributions to the development of psychology. To start, these theorists all attempt to stretch the experimental tradition of physiology to the study of psychological states. Wundt's work represents an attempt to systematically disentangle what we now know as sensation and perception and to systematically categorize sensations and perceptions. Brentano's work emphasizes the relationship between conscious experience and objects, properties, events, and relations that give rise to those experiences. Through a combination of approaches, devices, and experimental techniques introspectionist psychologists likewise make tremendous inroads into the development of operationalizations and experimental design.

However, in the end the introspectionist tradition falls out of favor for three general reasons related to their use of introspection. **First**, the overreliance upon introspection as their experimental methodology overshadows other techniques and experimental designs. **Second**, the extensive training of subjects in formulating their introspective reports introduces implicit biases into experimental results. **Third**, allowing extended and retroactive introspective analysis introduces a much greater potential for error and biases. Together these features of the use of introspection ultimately doom the methodological side of introspective psychology. Its practitioners make little to no effort to assess the accuracy or to calibrate introspective reports. Similar failures with regard to recognizing and controlling for subject and experimenter bias serve only to amplify their methodological difficulties. Instead, perhaps naturally, theorists assume introspection proves perfectly reliable across all of its methodological uses. Quite to the contrary, **systematic studies assessing the reliability of introspective reports reveal that under a wide range of conditions and tasks introspection proves relatively unreliable, poorly calibrated, and susceptible to massive subject and experimenter bias**.

The behaviorists heavily criticize introspection as part of their rejection of the various forms of introspective psychology. The contemporary uses of introspection, as a result, are highly constrained and subject to extensive cross-validation. Indeed, Richard Nisbett and Timothy Wilson publish an influential literature review in 1977, which still serves to highlight the perils of introspection as a means of data collection regarding psychological processes.[50] Nisbett and Wilson tell their readers,[50]

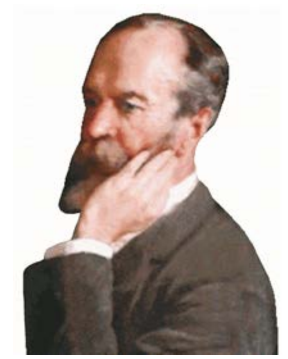
> Evidence is reviewed which suggests that there may be little or no direct introspective access to higher order cognitive processes. Subjects are sometimes (a) unaware of the existence of a stimulus that importantly influenced a response, (b) unaware of the existence of the response, and (c) unaware that the stimulus has affected the response. (p.231)

They follow their review with an experimental paper published in 1978 that specifically investigates and confirms the conclusions their earlier literature analysis.[51] Researchers following Nisbett and Wilson likewise find numerous issues with introspective data. For instance, Eric Schwitzgebel publishes two articles in 2002 that note errors introspection.[52, 53] Schwitzgebel notably reports that many psychologists in the 1950s supposed that people dream in black and white—a view contradicting earlier consensus and that changed with the introduction of color television.[53] Though subsequent researchers—Ericsson's and Simon's 1980 paper, for example--have developed specific methodologies for employing introspection as an indirect source of data on mental functioning so as to minimize error.[54-58] In more recent work, researchers who draw upon introspective reports usually seek to cross-validate such introspective data through behavioral and other methods.

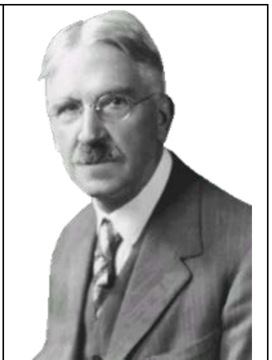
As we'll see, the failure of introspection and the various schools of psychological thought that rely heavily upon it also serves to shift the emphasis from understanding the mind through conscious experience towards understanding the mind through behavior and eventually cognition. However, difficulties in experimental methodology do not in themselves lay the groundwork for an alternative and successful psychology. Many different schools of psychological thought arise during the latter half of the 19th century and the beginning of the 20th century. Though none of these schools exist today, they do make contributions that help to prepare the field for significant scientific progress. Indeed, even as Wundt opens his laboratory in Leipzig, the beginnings of a systematic psychological treatment of learning and memory are emerging in the work of Hermann Ebbinghaus.

3.5 Functionalism

Most historians consider William James[59] (1842–1910) the first figure in the first school of psychology in the United States--functionalism. Functionalism overlaps significantly with both structuralism and behaviorism. James' text, *The Principles of Psychology*[60] (1890), actually predates by two years Titchner's arrival at Cornell.



William James (1842–1910)
From: Litkicks.com



John Dewey (1859-1952)
From: Pragmatism.org

The Principles, a two volume twelve hundred page text, makes James as famous and widely studied as Wundt. Though James' textbook has a greater influence at the time, the first textbook articulating functionalism in psychology comes from John Dewey at the University of Michigan. Dewey publishes his book, *Psychology*,[61] in 1887. Dewey's book elaborates upon a conception of psychology he articulates in his article, *The New Psychology*,[62] three years earlier.

Functionalism, much like pragmatism, the philosophical movement with which James is also associated, has no central figure, nor a clear-cut doctrine. However, functionalists make important criticisms and contributions to other schools of psychological thought, and do share several common general commitments. (1) Functionalists oppose the search for the basic elements of thought that characterizes Wundt's and Titchener's views. In fact, *Principles* portrays mentality as a stream of consciousness incapable of analysis into elements. (2) Functionalists, in contrast to voluntarists and structuralists, think of the mind as dynamic and mental processes as serving functions. (3) Functionalists view the function of mind through the lens of evolution. Thus, functionalists understand mental processes and behavior in terms of the general goals of adaptation and selectional advantage. (4) Unlike the rather rigid determinism of structuralism and behaviorism, functionalism tends to emphasize adaptation and differential responses driven by motivation. (5) Methodologically, functionalists tend to accept both introspection and behavioral observation as methodological tools. Though few early functionalists conduct experiments, later functionalists do conduct experiments. Functionalists also support psychological research on animals, children, and abnormal populations as a means to understand normal human mentality. (7) Finally, unlike Wundt, who views psychology's mission as pure basic research, functionalists tend to see psychology as a means to improve society and people's lives.

The functionalists act as a counterweight to both structuralism and behaviorism. For instance, historians often cite John Dewey's "The Reflex Arc Concept in Psychology,"[63] (1896) as the beginning of functionalism. In this article Dewey criticizes the notion of the reflex arc as consisting of discrete stages; stimulus and response. He also anticipates challenges facing behaviorists by noting the difficulties in specify a context-free notion of stimulus and response, i.e., specifications capturing the relevant features of particular stimuli and responses as well as specifications which predict the generalizations of such stimuli and responses to future cases. Furthermore, the functionalist emphasis on practical applications in psychology, evolution, and diversity in methodology as well as research areas help to plant the seeds for cognitive science.

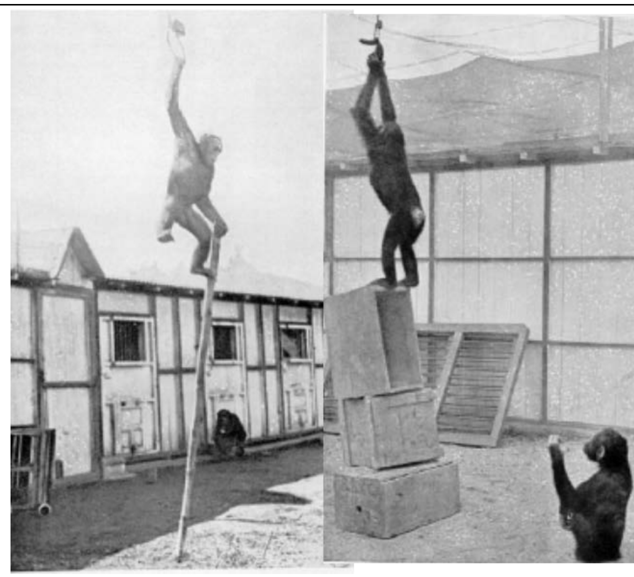
3.6 Gestalt Psychology

Historians generally trace the start of Gestalt psychology to the 1912 publication of "Experimentelle Studien über das Sehen von Bewegung" or "Experimental Studies on the Perception of Motion"[64] by Max Wertheimer (1880-1943). Wertheimer conducted this research with his two research assistants, Kurt Koffka and Wolfgang Köhler. The emphasis of their work is the study of perception, particularly the rules by which perceptual inputs are organized into meaningful wholes. Wertheimer articulates the central doctrines and insights of Gestalt psychology in his classic paper, "*Untersuchungen zur Lehre von der Gestalt*" or "*Laws of Organization in Perceptual Forms*"[65] (1923). Gestalt psychology contributes to the development of cognitive science in two ways. First, Gestalt psychology marks a shift in the study of perception away from pure physiology and psychophysiology towards the cognitive. Second, Gestalt psychologists argue that insight and problem solving drive behavior as much as classical and operant conditioning. The influence of gestalt psychologists manifests itself less through a theory than through an ever-increasing body of perceptual and learning phenomena that resist explanation by either introspective techniques or by the reflexive techniques of behaviorists. For

Max Wertheimer (1880-1943)

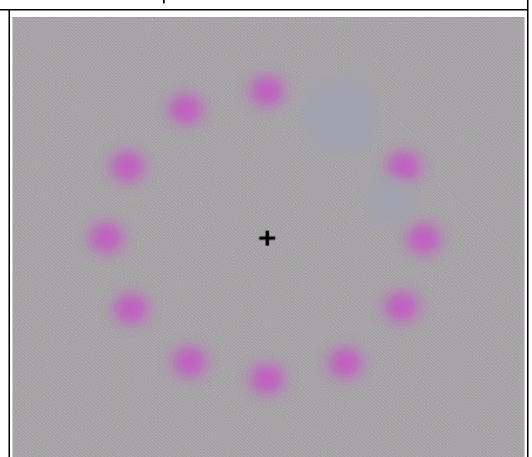
Kurt Koffka (1941)
Adapted From: Athenaeum

Wolfgang Köhler (1887-1967)
Adapted from: Ecured



Pictures taken from *The Mentality of Apes* showing chimpanzees using various techniques like stacking boxes to reach suspended fruit.

Examples illustrating the law of closure in which objects grouped together in perception are seen as a whole. Adapted from: Wikipedia



Animated movie illustrating the phi phenomenon explored in "Experimental Studies on the Perception of Motion." In the phi phenomena properly sequenced lights give rise to the perception of motion. Click on picture to view animation Adapted from: Wikipedia instance, Wertheimer articulates several basic principles by which perceptual forms seem to be organized in *Laws of Organization*,[65] such as the factor of closure (below). However, Wertheimer does not offer an overarching framework for understanding vision.

After Wertheimer, perhaps the two most famous psychologists in the Gestalt tradition are [Wolfgang Köhler][66] (1887-1967) and [Kurt Koffka][67] (1886-1941). Both Koffka and Köhler travel and teach widely. Koffka spends a year at University of Edinburgh in 1904. He also teaches at both Cornell University and the University of Wisconsin-Madison before settling at Smith College in Massachusetts, where he remains until his death in 1941. Koffka earns his degree in 1909 after having switched his research from philosophy to psychology. His dissertation (*Experimental-untersuchungen zur Lehre vom Rhythmus* or *Experimental Studies on the Theory of Rhythm*) complete; Koffka takes a position in psychology at the University of Frankfurt. When Wertheimer arrives at Frankfurt in 1910 Koffka joins him in his research. Koffka edits many works and promotes Gestalt psychology extensively with Wertheimer and Köhler. His interests center on development and learning.

Specifically, in books like *The Growth of the Mind*[68] (1921) Koffka defines development by telling readers that,

> We speak of development whenever an organism or any special organ becomes larger, heavier, more finely structured, or more capable of functioning. One must, however, differentiate two types of development: development as growth or maturation, and development as learning. (p.40)

In discussing learning, Koffka tells readers that,[68]

> By learning, however, we understand a change in ability resulting from quite definite individual activities. In learning to play cards it is not enough that one should grow up amid favourable circumstances, or that one's fingers should have attained a certain degree of technical facility; but, first of all, it is necessary to understand the significance of a pack of cards, and of each card for *itself*. (p.41)

Thus, for Koffka early development consists primarily in sensorimotor learning. Koffka further integrates learning, perception, memory, action, and development in his *Principles of Gestalt Psychology* (1937).[69] Like Koffka, Wolfgang Köhler contributes greatly to the development of Gestalt psychology. However, it is through his book, *Intelligenzprüfungen an Anthropoiden* or *The Mentality of Apes*[70] (1917), that he makes his greatest contribution to the development of cognitive science. Beginning in 1913 Köhler spends a total of 6 years at the Prussian Academy of Sciences anthropoid research station located on the island of Tenerife in the Canary Islands. In *The Mentality of Apes* Köhler describes the behaviors of various chimpanzees at the anthropoid research station, arguing that these animals seem to learn by insight and problem solving more than by the method of Thorndike's trial and error discussed below. Indeed, Köhler tells his readers that,[70]

> …it is just these differences which are the starting-point of a strict association psychology; it is they which need to be theoretically accounted for; they are well known to the association psychologist. Thus for instance, we find a radical representative of this school (Thorndike) stating the conclusion, drawn from experiments on dogs and cats: "I failed to find any act that even seemed due to reasoning." ….
>
> Accordingly, if we are to inquire whether the anthropoid ape behaves intelligently, this problem can for the present be treated quite independently of theoretical assumptions, particularly those for or against the association theory. It is true that it then becomes somewhat indefinite; we are not to inquire whether anthropoid apes show something well defined, but whether their behaviour approximates to

> a type rather superficially known by experience, and which we call "intelligence" in contrast to other behaviour-especially in animals. (p.3)

Among the researchers Köhler influences is a young Edward Chace Tolman, whose two review papers called "Habit Formation and Higher Mental Processes in Animals,"[71, 72] incorporate the idea of insightful learning, and analyze results of researchers who replicate and extend Köhler's experiments. Tolman, as noted below, eventually makes a significant contribution to understanding cognition in both animals and humans.

Like the functionalists, Gestalt theorists emphasize problem solving. They help to extend and shape the boundaries of psychology beyond its physiological origins, and they help to amass a larger body of data. However, their experimental and theoretic efforts fail to yield sufficient predictive and manipulative success to fuel their continued momentum.

3.7 Ebbinghaus: The Quantified Study of Memory as a Process

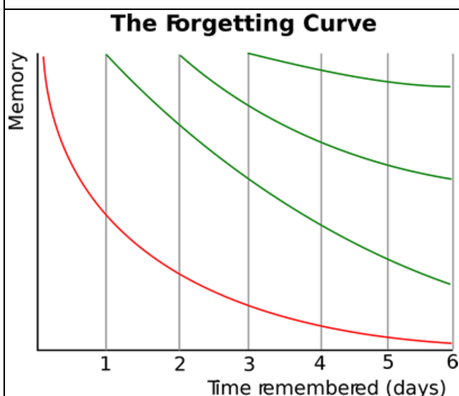
Hermann Ebbinghaus[73] (1850-1909), begins one of the first systematic studies of memory in 1879. He studies only the ability to memorize nonsense syllables by rote. He selects nonsense syllables since previous learning will not influence learning of these meaningless sounds. This choice represents one of his contributions to memory research, namely, that ease of memorization is increased by meaningfulness and relevance to the memorizer, and vice versa. Ebbinghaus might have used some of his students as subjects, but he seems primarily to use only himself as a subject. Ebbinghaus publishes his results in his book, *Über das Gedächtnis Untersuchungen zur Experimentellen Psychologie* [74] or *On Memory* (1885), which is later translated and published as *Memory: A Contribution to Experimental Psychology*[75] (1913).

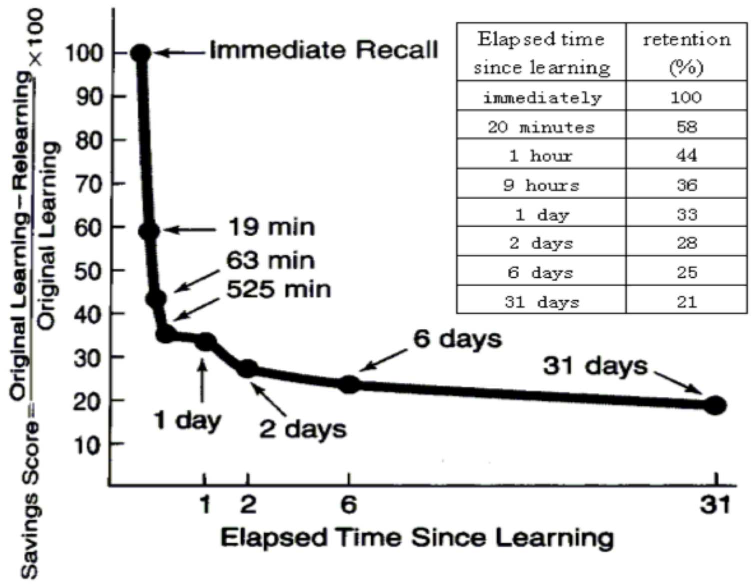
In *On Memory* Ebbinghaus reports results that are the basis for the "learning curve" and the "forgetting curve." The learning curve shows that learning time, measured as number of repetitions, increases exponentially with the number of items memorized. Likewise, the increase in retention for each repetition decreases exponentially so that in most cases mere repetition approaches complete retention asymptotically. In other words, though each repetition increases retention, the increase in retention gets smaller and smaller for each successive repetition so that merely repeating a list results in smaller and smaller improvements in retention. The forgetting curve is similarly exponential, showing the forgetting decreases at an exponential rate, so as to approach complete failure of retention asymptotically. In other words, people forget a lot relatively quickly, but the rate at which they forget any remaining information slows so that they retain some information for much longer. Specifically, the forgetting curve can be expressed as a power function: $R = e^{-t/s}$ (where R = retention, e = mean rate of error, t = elapsed time, and s = strength of original memory). Ebbinghaus also documents the serial position effect, viz. the recency and primacy effects (subjects are more likely to remember the last item in a series [recency] and the first item in a series [primacy]). Likewise, Ebbinghaus documents "savings." If one memorizes a list and then waits until recall is zero, one will still generally relearn the list at a faster rate despite the initial seeming lack of recall. Ebbinghaus terms the difference between the first and second memorization the savings.

Ebbinghaus proves neither prolific nor strongly aligned with any particular school of psychology. He, in fact, does not identify himself with any psychological school of thought, and does not seek out pupils. Nevertheless, his work spurs research on memory. Ebbinghaus' careful, well-designed experiments, his rigorous quantified results, statistical analysis, and systematic presentation prove extremely influential. Of equal importance, Ebbinghaus has found a way to study psychological (mental) processes that has highly reliable operationalizations (methods for categorizing and quantifying phenomena). He likewise has developed a set of categorizations that allow for the formulation of dynamic changes in those same mental phenomena.

Hermann Ebbinghaus (1850-1909) From: [Wikipedia](#)

(Right top) Graph depicting data Ebbinghaus' data on savings and forgetting. From: [Student Sri Lanka](#) **(Right bottom)** Table from Ebbinghaus' [*Memory*](#) presenting data on savings. **(Below)** A typical representation of the forgetting curve. Description and graph from [Wikipedia](#).



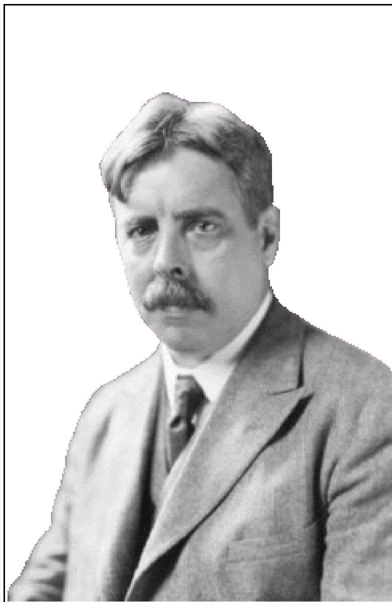


	Repetitions for the learning and recital of 6 series	Immediately successive repetitions for the sake of greater surety	Total number of repetitions used for the 6 series	After 24 hours the memorization of the series required	Thus the work saved by the total number of repetitions amounted to
	104	294	398	41	63
	101	285	386	39	62
	114	324	438	46	68
	109	309	418	38	71
$m =$	107	303	410	41	66 P.E.$_m$ = 1.4

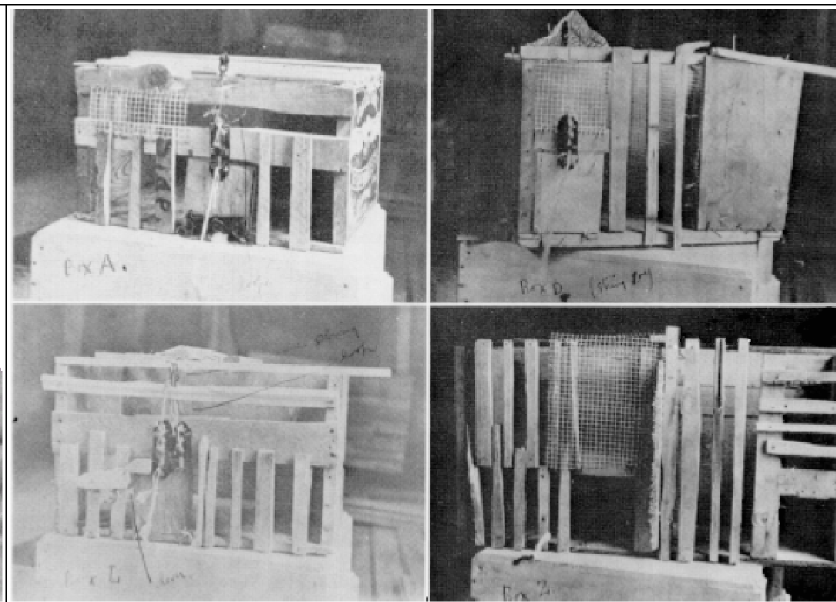
3.8 Thorndike's Law of Effect

Historians classify [Edward Lee Thorndike](#)[76] (1874-1949) as a functionalist. However, much of his work is arguably the first research on conditioning and is certainly the first work on operant conditioning. Thorndike publishes his dissertation, "Animal Intelligence: An Experimental Study of the Associative Processes in Animals," in 1898--predating Pavlov's first public reference to conditioned reflexes by approximately a year. Thorndike republishes this work in 1911 as [*Animal Intelligence*](#).[77]

Thorndike studies a number of animals, but he is most famous for his studies of learning in cats using homemade puzzle boxes (above). Thorndike puts a cat in a box, and lets it behave randomly until it stumbles upon the release mechanism. He repeats this procedure until the cat can release itself in negligible time. Thorndike then plots the decline in time to escape relative to times in the box, using this ratio to characterize



Edward Lee Thorndike (1874-1949)
From: Wikipedia



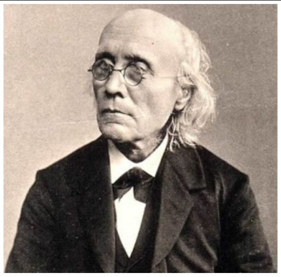
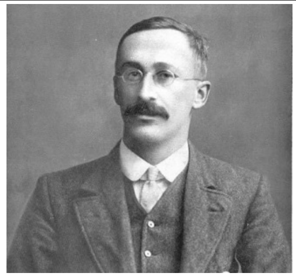
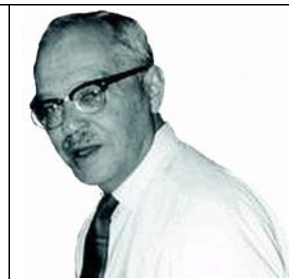
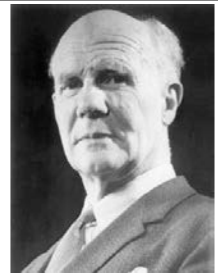
Four of Thorndike's puzzle boxes From: cwu.edu

learning by "learning curves." He formulates his generalized results in terms of the law of effect:[77]

> The Law of Effect is that: Of several responses made to the same situation, those which are accompanied or closely followed by satisfaction to the animal will, other things being equal, be more firmly connected with the situation, so that, when it recurs, they will be more likely to recur; those which are accompanied or closely followed by discomfort to the animal will, other things being equal, have their connections with that situation weakened, so that, when it recurs, they will be less likely to occur. The greater the satisfaction or discomfort, the greater the strengthening or weakening of the bond. (p.244)

3.9 The Rise of Statistics and Quantitative Analysis of Variable Data

The discussion of astronomy notes that the recognition of individual variation in recording observations results in attempts both to introduce more systematic and rigorous methodologies and to further refine measuring instruments like the chronoscope. Nevertheless, some variability persists even in the face of such efforts. Scientists like Gauss begin to recognize the necessity of developing tools for analyzing such variable data and introduce statistical analysis to tease out uniformities within the seeming variability. Such efforts in other sciences prove crucial to the sciences of the mind. One of the most difficult challenges facing psychologists and eventually cognitive scientists lies in the highly variable nature of behavioral responses. Indeed, given a particular experimental design a cognitive psychologist will suspect that he or she has failed to find a real result if they recorded reactions do not vary among subjects. Thus, in order to operationalize categorizations and tie theoretic models to phenomena researchers need to find a way to measure the world that differentiates significant from insignificant variability in responses. The introduction of statistical techniques by the physicist-turned-psychologist Gustav Fechner[31] and especially their use by Hermann Ebbinghaus[73] marks a turning point in psychological research. Statistics helps theorists to analyze data with significant intersubjective variability and better measure the fit of theoretic models with data.[29, 31, 73-75, 78-82] Ultimately, much more powerful statistical tools for both data analysis and experimental design enter the experimental tradition through the works several researchers. For instance, the English statistician and Guinness brewery chemist William Sealy Gossett (aka student) introduces one of the most famous and widely used significance

				
Gustav Fechner (1801-1887) From: Wikipedia	Ronald Fisher (1890-1962)	William Sealy Gosset (1876-1937) From: Wikipedia	Jerzy Neyman (1894-1981) Adapted from: Wikipedia	Egon Pearson (1895-1980) From: uprm.edu

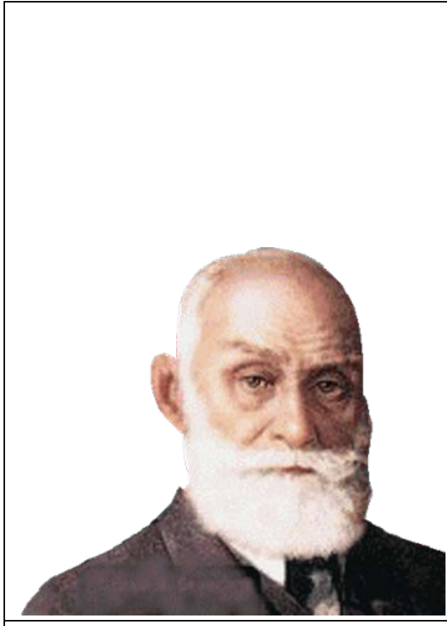
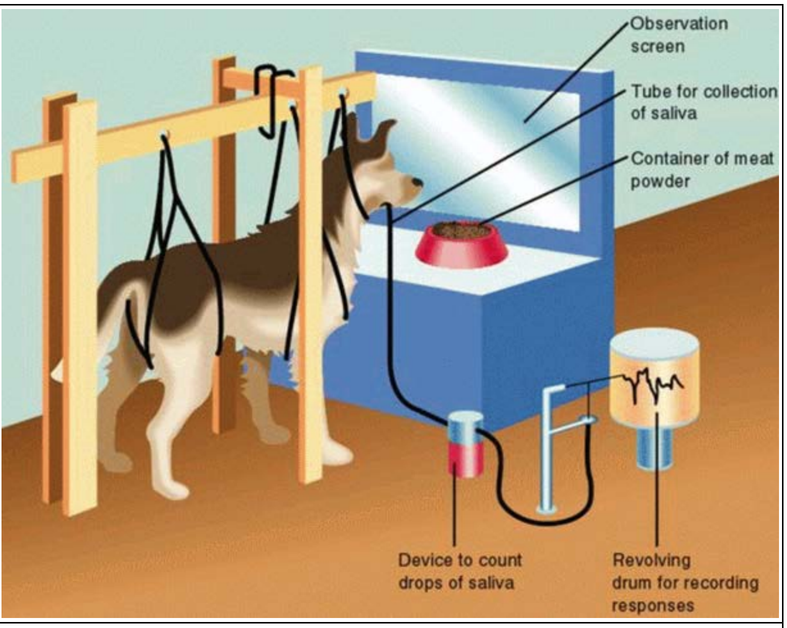
test, t-testing, in his 1908 paper (published under the pseudonym "Student"), "The Probable Error of a Mean."[83-86] Though not used as often today, the t-test allows researchers of the time to determine if two sets of data differ significantly from one another. The t-test has the particular virtue of working for small sample sizes. Another English statistician and biologist Ronald Fisher first introduces the term variance in his 1918 paper "The Correlation between Relatives on the Supposition of Mendelian Inheritance."[87, 88] He outlines his analysis of variance in his 1922 paper, "On the Mathematical Foundations of Theoretical Statistics."[89] Fisher perhaps exerts his greatest influence on the development of statistics and on psychology through his two books, *Statistical Methods for Research Workers* (1925)[90] and *The Design of* Experiments (1935).[90] Fisher's textbooks serve as reference works for statistics throughout the sciences during this period. A short list of Fisher's contributions would include the introduction of null hypothesis testing,[91] z-distribution,[92] as well as the refinement and advocacy of frequentist interpretations and methods in statistics.[93, 94] Unfortunately, Fisher's life-long advocacy of Eugenics casts a shadow over an otherwise impressive body of work.[95] The Polish-born mathematician and statistician Jerzy Neyman[96-106] initiates studies on randomized experimental design and stratified sampling of significant subpopulations,[99] which lead to the eventual adoption of modern sampling methods. Together with Egon Pearson, Neyman publishes "On the Problem of the Most Efficient Tests of Statistical Hypotheses" in 1935 in which they propose The Neyman-Pearson lemma for hypothesis testing.[98, 103] In 1937 Neyman publishes "Outline of a Theory of Statistical Estimation Based on the Classical Theory of Probability" which allows for the construction of a the confidence interval within a frequentist interpretation.[105, 107] Karl Pearson[108-112] develops the Chi-squared distribution,[113] and his son, Egon Pearson,[98, 102, 103, 106, 114-116] makes multiple important contributions, including The Neyman-Pearson lemma for hypothesis testing[98] and Pearson's chi-squared test.[116] This confluence of descriptive and experimental techniques from Gossett and others during the first half of the 20th century provides experimental psychology and the sciences generally with powerful tools for theory testing and data analysis. These tools begin to find full realization in the works of the neo-behaviorists Hull, Tolman, and Skinner.

3.10 Behaviorism

Just as the figures in introspectionist psychology do not adhere to a single ideological doctrine, the interests and approaches of individual behaviorists differ remarkably. One important division among behaviorists consists between the figures historians call behaviorists and those that historians refer to as neo-behaviorists. The doctrines that people most commonly associate with behaviorism--classical conditioning and the restriction of psychology to overt behavioral stimuli and response--are already giving way by the time Hull, Tolman and Skinner seek to extend the paradigm established by Pavlov and Watson.

3.10.a Behaviorism: Pavlov's Discovery of Classical Conditioning

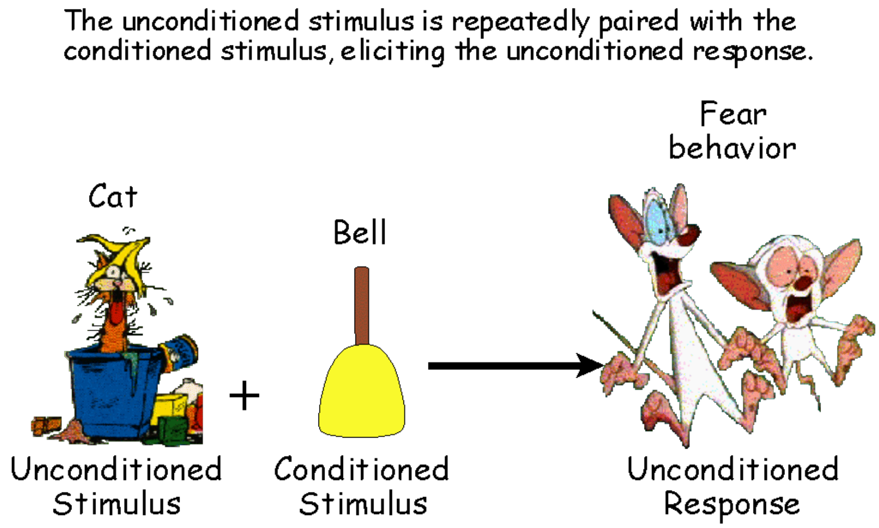
Ironically, it is Ivan Pavlov (1849-1936), a Russian physiologist studying digestion, who provides the key finding around which Behaviorism evolves--classical conditioning. Pavlov's research includes the physiology and the neurophysiology of temperament, conditioning, and involuntary reflex actions; but the bulk of his work focuses on digestion. Pavlov's experimental research on digestion was innovative and sophisticated—so much so that he won the Nobel Prize for his work on digestion. Pavlov's techniques include surgical removal of components of the digestive system from animals to facilitate observations of their functions, lesioning nerve fibers to trace their function by observing the lesion's effects, and implanting fistulas (tubes or holes) draining into pouches to examine the organ's contents. In the 1890's Pavlov's lab is performing experiments on

	
Ivan Pavlov (1849-1936) Adapted from: Exploring the Mysteries of Behavior	Depiction of Pavlov's experimental apparatus for his studies of digestion. From: Simply Psychology

digestion using dogs. Specifically, Pavlov's group is studying the salivary functions of dogs by surgically externalizing a salivary gland so that the saliva could be collected and analyzed. During their research Pavlov notices that the dogs begin to salivate before receiving food. He calls this phenomena "psychic secretion"[117] (p.7), and the lab begins to investigate this phenomena. The researchers soon realize that these "psychic secretions" result from associations formed by the dogs between the food and other stimuli. Eventually, Pavlov's investigations eventually reveal what he calls "conditioned reflexes," and we now call classical conditioning.

Pavlov first mentions his discovery in a lecture to the Society of Russian Doctors of St. Petersburg in 1899. Printed accounts of the research appear in a dissertation by Pavlov's student, Wolfson, and in a report to the 1903 Congress of Natural Sciences by Ivan Tolochinov,[118] Pavlov's collaborator. However, the discovery does not receive significant attention until Pavlov discusses it in his Nobel Prize acceptance speech in 1904. Pavlov's own account does not emerge until he publishes, *Conditioned reflexes: An Investigation of the Physiological Activity of the Cerebral Cortex*[117] in 1927.

One of Pavlov's dogs complete with a fistula and collection chamber. From the [Pavlov Museum in Russia](#).



Animation depicting the elements and process of classical conditioning. To play movie, click on the picture.

As illustrated in the diagram below, classical conditioning works by associating a stimulus (the unconditioned stimulus) that triggers a specific response with a novel stimulus (the conditioned stimulus). Specifically, the unconditioned stimulus is a stimulus that elicits a particular response called the unconditioned response. The conditioned stimulus is paired with the unconditioned stimulus repeatedly, so that the pairing elicits the unconditioned response. This repeated pairing increases the association between the conditioned stimulus and the unconditioned response, as reflected in the increasing likelihood of the conditioned stimulus eliciting the response in and of itself, making the unconditioned response a conditioned response.

Pavlov also discovers and studies extinction and spontaneous recovery. When one elicits the conditioned response using only the conditioned stimulus, the association between the conditioned stimulus and conditioned response weakens over time. This weakening is called extinction. After an association between a conditioned stimulus and a conditioned response reaches extinction, the conditioned stimulus can sometimes elicit a conditioned response at a later time; such cases are called spontaneous recovery.

3.10.b Behaviorism: John Watson

John Watson[119](1878-1958) adapts the work of Pavlov into a general approach to psychology, which he presents in his 1913 paper, "Psychology as the Behaviorist Views It".[120] Watson embraces the idea of classical conditioning and sets the goal of psychological investigation as the prediction and control of behavior. Additionally, Watson explicitly rejects the project of analyzing conscious experience, and the methodological tool of introspection. Watson describes his view as follows:[120]

> Psychology as the behaviorist views it is a purely objective experimental branch of natural science. Its theoretical goal is the prediction and control of behavior. Introspection forms no essential part of its methods, nor is the scientific value of its data dependent upon the readiness with which they lend themselves to interpretation in terms of consciousness. The behaviorist, in his efforts to get a unitary scheme of animal response, recognizes no dividing line between man and brute. The behavior of man, with all of its refinement and complexity, forms only a part of the behaviorist's total scheme of investigation. (p.158)

While Watson emphatically distances behaviorism from Introspectionist psychologies, there are strong similarities under the surface. Watson limits the appropriate phenomena of psychology to behavior, and sets the goals of behaviorism as prediction and control of behavior. However, Watson does allow verbal reports of behavior. In “Is thinking Merely the Action of Language Mechanisms?” Watson tells readers that:[121]

> The present writer has often felt that a good deal more can be learned about the psychology of thinking by making subjects think aloud about definite problems, than by trusting to the unscientific method of introspection. … It is only when we ask him to think aloud…that we begin to grasp how relatively crude is the process of thinking. Here we see typified all of the errors made by the rat in the maze: false starts appear; emotional factors show themselves, such as the hanging of the head and possibly even blushing when a false scent is followed up. (p.172)

Additionally, in practice Watson’s treatment of behavior is quite atomistic. Watson divides behavior into four classes; explicit learned behavior such as riding a bicycle, implicit learned behavior such as a rumbling stomach when smelling someone else’s dinner cooking, explicit unlearned behavior such as pulling your hand away when it is hurt, and implicit unlearned behavior such as sweating when it is hot. For the purposes of this chapter and lecture, we’ll focus upon Watson’s theoretical framework for the prediction and control of learned behavior. Watson hypothesizes that explicit, complex learned behaviors--such as chess playing or language—can be understood as a series of simpler learned and unlearned behaviors performed in a sequence. These sequences get cultivated in the organism by imitation and classical conditioning. Thus, the environment, unlearned behaviors, and conditioning history combine to explain complex behaviors as the result of the combination (through associative learning) of simple learned and unlearned behaviors. For

John Broadus Watson (1878-1958)
From: Furman.edu

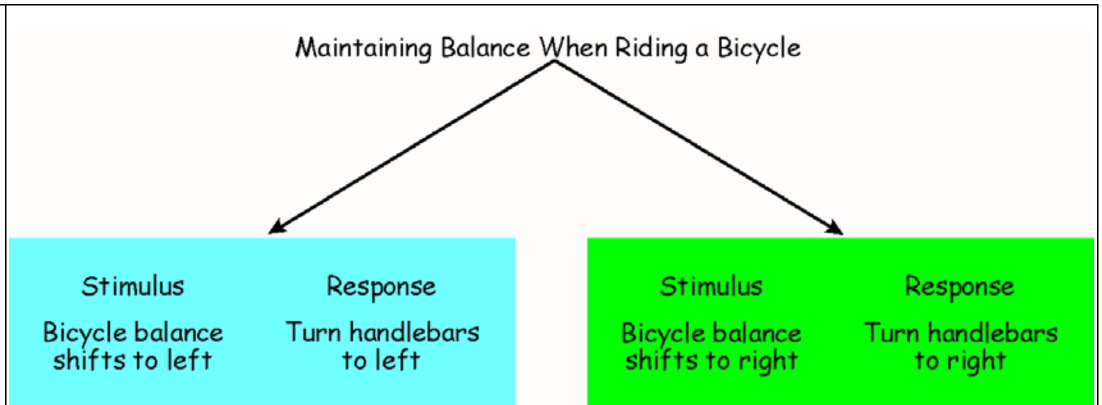


Diagram depicting how a more complex overt behavior, maintaining balance when riding a bicycle, might be analyzed into simpler overt behaviors.

instance, implicit learned behaviors (like a fear response) develop from simple conditioning and appropriate environmental ques. As Watson tells readers of his text, *Behavior: An Introduction to Comparative Psychology*[122] (1914):

> It is useless to ask young children to imitate acts as wholes where the elementary coördinates [these are the basic habit units] are lacking or are ill-formed. There must be complete mastery of simple habits,--a readiness to respond to a difficult and complex environmental setting in a variety of ways—the ability to change responses ever so slightly to meet the slightest change in a heretofore well-known object. In order to do this our stock in trade of acts must be much more numerous than the objects to which we respond. … Apparently new coördinations are not established by imitation either in man or in

> animal. What is new is the combination or method of grouping. Where imitation appears there are found always groups of flexible responses to every object worked with. (p.49)

If this general approach seems familiar, it should. Watson, in effect, proposes an atomistism for behavior; a set of elemental behaviors—unlearned behaviors—from which all learned behaviors are generated and combined through a process of association based upon contiguity and frequency.

3.11 Neo-Behaviorism

Historians classify the behaviorists that follow Watson as neo-behaviorists. One can find the general motivation behind the neo-behaviorist research in the above quote from Watson. On the one hand, Watson seeks to provide a highly mechanistic/deterministic account of the generation of behavior. On the other hand, Watson wants to use his account to explain complex, flexible behavior, including behavior in novel circumstances. Neo-behaviorists seek to expand the basic behaviorist framework to allow for increased flexibility and complexity. For instance, suppose that a researcher trains a rat to associate food with a blue box. Sometimes when presented with the box, the rat does not try to eat. Why doesn't the rat respond all the time? Will the rat respond to the box when the researcher changes the color or the shape slightly? How much change to the box can occur before the conditioned response is no longer triggered?

Neo-behaviorists continue to view overt behavior as the central phenomena for psychology. They also hold that the prediction and control of behavior is the central goal of psychology. Learning remains central to psychology. Finally, neo-behaviorists share Watson's conviction that animal models of learning and perception are easily and robustly transferable to humans.

Neo-behaviorists commonalities go beyond Watson as well. For example, neo-behaviorists share Watson's general commitment to grounding psychology in observation. However, unlike Watson, neo-behaviorists seek to tie all theoretical terms to experimental operations for the measurement and/or application of those terms. Researchers call this view about the treatment of unobservable theoretical terms operationalism. Operationalists refer to the specification of a set of operations for a theoretical term as an operational definition. Watson and the neo-behaviorists see animal experimentation as essential to psychological research because of the continuity of animal learning and perception with human learning and perception. However, neo-behaviorists see additional value in animal experimentation because it allows for more rigorous controlled experiments.

Lastly, neo-behaviorists differ from Watson and one another in the manner in which they seek to extend behaviorism. Radical behaviorists like B.F. Skinner hold that the prediction and control of behavior must eschew internal, unobservable mental and physiological events. Methodological behaviorists allow for appeal to internal states so long as those terms are tied to observation.

3.11.a Neo-Behaviorism: Hull's Methodological Behaviorism

Clark Leonard Hull (1884-1952) represents a bridge between behaviorism and cognitive psychology. Specifically, Hull and Tolman (next) come to view behavior as goal-oriented, and introduce "intervening variables" between stimulus and response in order to explain behavior. For Hull, unlike Tolman, experimenters must characterize and understand intervening variables physiologically. Hull articulates his vision for psychological theories in an early paper:[123]

…sound scientific theory has usually led not only to prediction but to control; abstract principles in the long run have led to concrete application. With powerful deductive instruments at our disposal we should be able to predict the outcome of learning not only under untried laboratory conditions, but under as yet untried conditions of practical education. We should be able not only to predict what rats will do in a maze under as yet untried circumstances, but what a man will do under the complex conditions of everyday life. In short, the attainment of a genuinely scientific theory of mammalian behavior offers the promise of development in the understanding and control of human conduct in its immensely varied aspects which will be comparable to the control already achieved over inanimate nature, and of which the modern world is in such dire need. (p.516)

Clark Leonard Hull (1884-1952)
Adapted from: Wikipedia

In his *Principles of Behavior*[124] (1943) Hull introduces a mathematical formulation to capture the relationship between environmental situations, intervening variables, and learned responses. The elements of this equation are as follows: Drive, D, (fueled by biological need), Habit Strength, ${}_{S}H_{R}$, (the connection between environmental situation and response measured as the number of pairings), and Reaction Potential, ${}_{S}E_{R}$, (the probability of the subject manifesting a learned response). These yield the equation: ${}_{S}E_{R} = {}_{S}H_{R} \times D$.

Hull operationally defines habit strength as the number of pairings between environmental situation and the response. Drive is operationally defined in terms of the length of deprivation. Hull continues to introduce additional operationally defined variables to his basic framework throughout his career.

3.11.b Neo-Behaviorism: Purposive Behaviorism

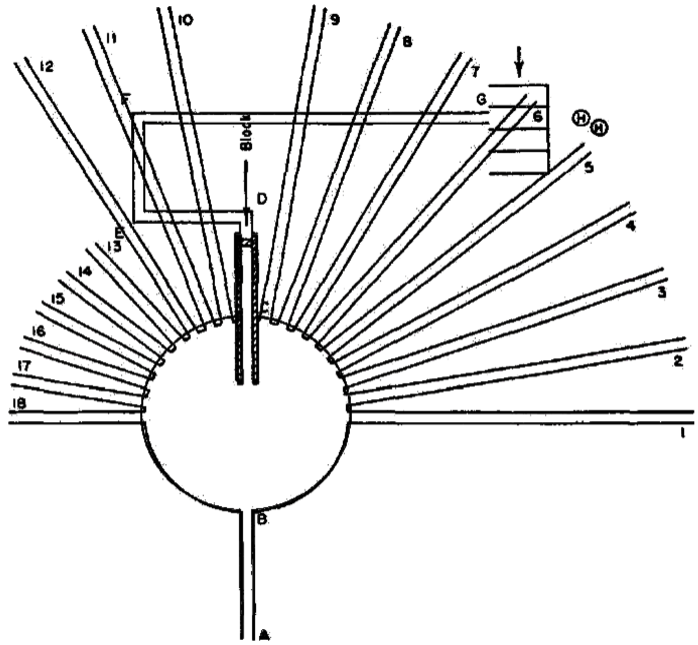
Like Hull, Edward Chace Tolman (1886-1959), espouses the use of intervening variables in the explanation of behavior. However, Tolman differs from Hull in that Tolman supposes animals have internal states characterizable in terms of their purpose, for instance, expectations and representations. In his article, "A New Formula for Behaviorism,"[125] (1922) Tolman explains his perspective to readers:

> The two essential theses which we wish to maintain in this paper are, first, that such a true non-physiological behaviorism is really possible; and, second, that when it is worked out this new behaviorism will be found capable of covering not merely the results of mental tests, objective measurements of memory, and animal psychology as such, but also all that was valid in the results of the older introspective psychology. And this new formula for behaviorism which we would propose is intended as a formula for *all* of psychology--a formula to bring formal peace, not merely to the animal worker, but also to the addict of imagery and feeling tone. (pp.46-47)

In several of his works Tolman develops and defends three important concepts; expectation, cognitive maps, and latent learning. In his 1932 book, *Purposive Behavior in Animals and Men*,[126] Tolman further refines his view, arguing against Watson that behavior should not be understood in terms of individual conditioned reflexes and their ordered chains. Rather, Tolman suggests that researchers need to understand behaviors as goal-directed acts in which component elements are organized to accomplish a purpose.

In *Purposive Behavior* and in an earlier paper, "Introduction and Removal of Reward, and Maze Performance in Rats,"[127] Tolman also argues that learning can occur without reward or punishment. Specifically, Tolman demonstrates that rats learn the location of food in a maze, and later utilize that knowledge, as a result of wandering around within the maze when they are not hungry. A phenomenon he calls latent learning (p.344).[126, 127]

Edward Tolman (1886-1959)
Adapted from: Philweb



Animation showing 1 the original training maze, 2 the testing maze with the arm blocked, and 3 an overlay of both mazes showing how the choice of arm 6 by rats illustrates their knowledge of the relative position of the room where the food is located. Click on the diagram to play the movie.

In the first of an influential series of papers published in the *Journal of Experimental Psychology*,[128-132] (1946-1949) Tolman and colleagues argue that rats learn to negotiate radial mazes in virtue of their developing expectancies. Which they define as:[128]

> When we assert that a rat expects food at location *L,* what we assert is that if (1) he is deprived of food, (2) he has been trained on path *P,* (3) he is now put on path *P,* (4) path *P* is now blocked, and (5) there are other paths which lead away from path *P,* one of which points directly to location *L, then* he will run down the path which points directly to location *L.*
>
> When we assert that he does *not* expect food at location *L,* what we assert is that, under the same conditions, he will *not* run down the path which points directly to location *L.* (p.430)

In "Cognitive Maps in Rats and Men"[133] (1948) Tolman introduces the idea of a cognitive map:

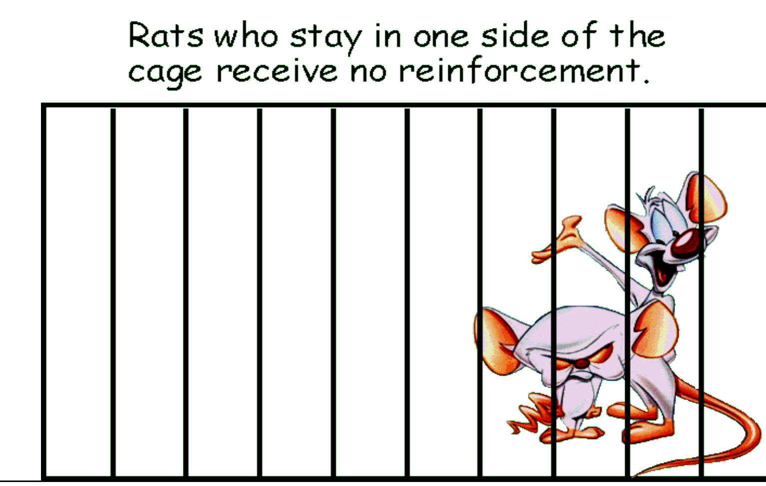
> Rather, the incoming impulses are usually worked over and elaborated in the central control room into a tentative, cognitive-like map of the environment. And it is this tentative map, indicating routes and paths and environmental relationships, which finally determines what responses, if any, the animal will finally release. (p.192)

3.11.c Neo-Behaviorism: Radical Behaviorism

Historians classify Burrhus Frederic "Fred" Skinner[134] (1904-1990) as a neo-behaviorist, though Skinner is very strongly associated with behaviorism in the popular mind. Skinner's association with behaviorism is due in part to his theoretical approach. Like Watson, Skinner insists that theorists focus on predicting and controlling overt behavior. Likewise, Skinner also supposes that conscious mental states have no part to play in psychological theorizing, insisting instead that environment and conditioning history provide sole basis for the psychological understanding of human conduct.

However, Skinner's theoretical perspective diverges from Watson on several key points. Skinner adopts an approach called "functional analysis" that he traces to Ernst Mach. Functional analysis has a quite different meaning for Skinner than for the theorists we will discuss later. For Skinner functional analysis characterizes dependencies--not meticulously detailed step-wise causal relationships--between observable phenomena. In other words, Skinner does not seek to decompose complex actions into chains of simple associations, rather he seeks to explain behaviors--even more complex behaviors--through conditioning histories, environments, and reinforcement. Specifically, Skinner understands functional analysis as a method for establishing relationships between stimuli and responses through the application of operant conditioning. Skinner's analysis is often called a "three-term contingency" analysis in that it characterizes the environmental features that act as a trigger for the behavior (sometimes called the discriminative stimulus), the response (the specific rigorously characterized behavior), and reinforcement (the consequence of the behavior that positively or negatively influences the probability of the behavior in the eliciting conditions). While Watson rejects

B. F. Skinner (1904-1990) Adapted from: nndb.com



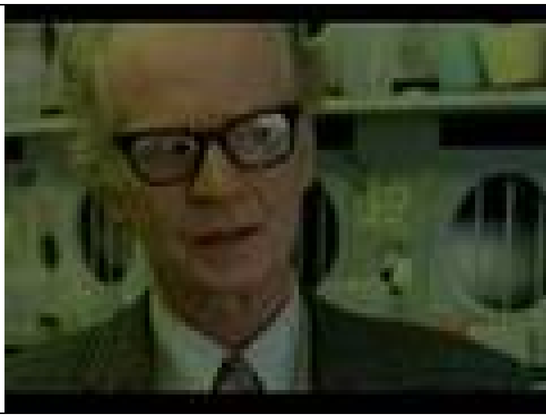
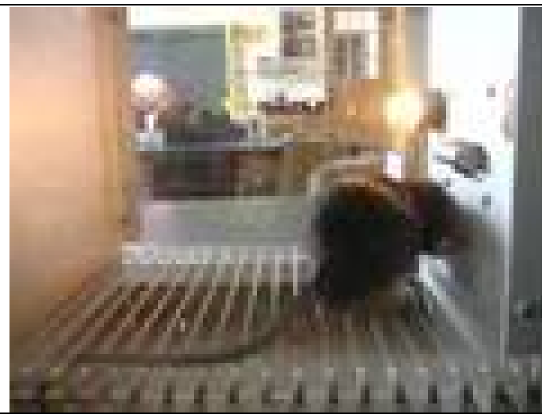
Animation depicting operant conditioning with a negative reinforcer. To play movie, click on the picture.

Thorndike's law of effect as too subjective, Skinner creates a systematic, objective formulation of the learning paradigm--operant conditioning. Unlike Watson, Skinner does not understand behavior as something exclusively elicited by environmental stimuli. Rather, Skinner views the majority of behavior as active operations on the environment. Likewise, Skinner sees patterns of behavior emerging as a result of those behaviors being selected by contingent environmental reinforcement.

Skinner writes his famous book, *The Behavior of Organisms*[135] (1938), while at his first job at the University of Minnesota. In that book Skinner reformulates Thorndike's law of effect so that it describes environmental selection of behavior through the reinforcement resulting from the behavior. Skinner makes no reference to subjective states like desires, drives, etc. in characterizing reinforcement.

In operant conditioning a creature's behavior--often random behavior--is either positively or negatively reinforced (rewarded or punished). The probability of the behavior occurring again in the relevant eliciting conditions increases or decreases in proportion to the number of behavior/reinforcement pairings. For example, as depicted in the animation above, a cage might be divided into two sections. Whenever a rat wanders into one section, experimenters administer an electric shock. Over time, the probability that the rat will, for instance, leave that section of the cage whenever placed there increases.

Operant conditioning together with classical conditioning broaden the range of learned organism-environment interactions. Classical conditioning provides a mechanism whereby stimuli from the environment can elicit a response, i.e., stimuli cause organism responses. Operant conditioning provides a mechanism whereby behavior becomes part of the organism's repertoire as a function of its consequences, i.e., consequences elicit behaviors.

	
Video of Skinner discussing operant conditioning. From: Youtube	Video of rat in a skinner box. From: Youtube

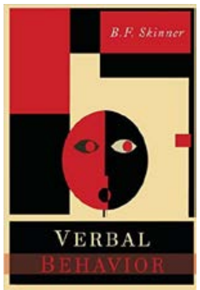
Thus, one sees in the rise of behaviorism a meeting of experimental method, categorization, and theory building that comes to dominate universities, particularly in the United States. Between the period of 1914 and 1950 behaviorists continue to elaborate and expand their research. Their results on conditioning-based learning and memory exhibit the rigor and experimental sophistication that allows them to stand as solid results of scientific practice.

3.12 Chomsky, Skinner, and the Retreat of Behaviorism

Indeed, behaviorists seek to apply their approach to all aspects of mentality. In 1957 Skinner publishes a book, *Verbal Behavior*,[136, 137] based upon lectures originally given at the University of Minnesota, and further refined both at Columbia and as the William James lectures at Harvard University. In *Verbal Behavior* Skinner argues that verbal behavior has no significant differences from other sorts of behavior. For instance, Skinner denies that verbal behavior results from an innate capacity. Given that verbal behavior lacks any essential differences from other sorts of behavior, Skinner proposes to treat verbal behavior using his functional analysis method. Skinner's book marks the peak of behaviorism as a psychological school. Its meteoric rise and intersubjectively verifiable results have given psychology the status as a "special science," for many philosophers of the time.

Skinner's book has come to hold an iconic position in the lore of cognitive science and behaviorism. In 1959

Noam Chomsky[138] publishes a review[139, 140] of Skinner's book. Often accounts of the development of cognitive science portray Chomsky's review as a refutation of behaviorism and the beginning of cognitive science. Chomsky's review represents an informed, articulate, and forward-looking indictment of the promise of Skinner's functional analysis as a methodology for investigating language. Few authors could hope improve upon Chomsky's articulate formulation of the task facing anyone who seeks to understand language and language acquisition:[140]



The Cover of the 2015 reprint of *Verbal Behavior*

Noam Chomsky (1928-)
Adapted from: Laist.com

> We constantly read and hear new sequences of words, recognize them as sentences, and understand them. It is easy to show that the new events that we accept and understand as sentences are not related to those with which we are familiar by any simple notion of formal (or semantic or statistical) similarity or identity of grammatical frame. Talk of generalization in this case is entirely pointless and empty. It appears that we recognize a new item as a sentence not because it matches some familiar item in any simple way, but because it is generated by the grammar that each individual has somehow and in some form internalized. …
>
> The child who learns a language has in some sense constructed the grammar for himself on the basis of his observation of sentences and nonsentences (i.e., corrections by the verbal community). Study of the actual observed ability of a speaker to distinguish sentences from nonsentences, detect ambiguities, etc., apparently forces us to the conclusion that this grammar is of an extremely complex and abstract character, and that the young child has succeeded in carrying out what from the formal point of view, at least, seems to be a remarkable type of theory construction. Furthermore, this task is accomplished in an astonishingly short time, to a large extent independently of intelligence, and in a comparable way by all children. Any theory of learning must cope with these facts. (pp. 56-57)

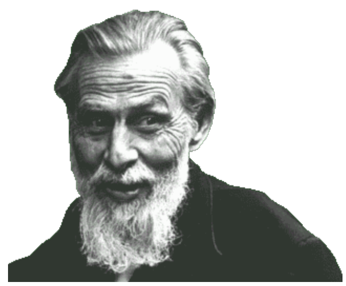
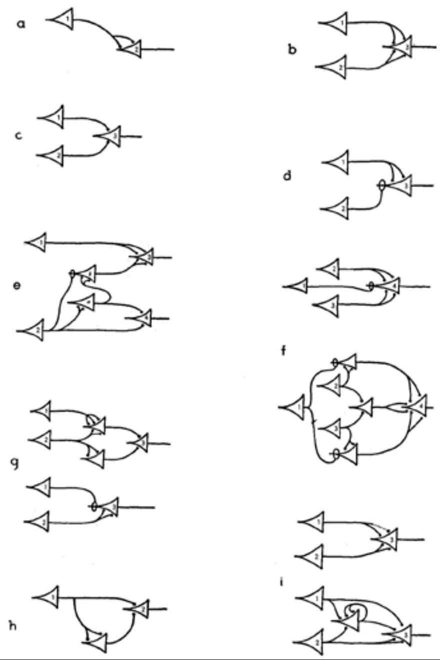
Similarly, Chomsky's authoritative and tightly argued paper compels the reader's assent to his evaluation:[140]

> Anyone who seriously approaches the study of linguistic behavior, whether linguist, psychologist, or philosopher, must quickly become aware of the enormous difficulty of stating a problem which will define the area of his investigations, and which will not be either completely trivial or hopelessly beyond the range of present-day understanding and technique. In selecting functional analysis as his problem, Skinner has set himself a task of the latter type. (p.55)

However, as we shall see, Chomsky's insightful analysis reflects thinking among many theorists of the time—including behaviorists--with regard to many areas of research. Indeed, other neo-behaviorists seek to further extend the scope of behaviorism, not by finding new learning mechanisms, but by opening the black box in which Skinner's functional analysis places the mind.

3.13 The Mathematical Analysis of Communication and Control

A number of factors come together at the end of the Second World War to make computational theories of cognitive functioning increasingly plausible. The development and proliferation of computational devices as well as the ever-increasing sophistication of mathematical treatments of computation and information transmission provide a conceptual basis for such theories. As we will see in the chapters on the development of the formal treatment of computing and the development of computers, mathematical and technical developments greatly facilitate the emergence of an information processing account of cognition. This section of the chapter and lecture considers four figures central to the development of information theory and cybernetics. The work of these theorists plays a central role in early information processes accounts because the researchers intended their research to have wide applicability, including both artificial and biological systems.

		
Norbert Wiener (1894-1964) Adapted from: [fotosimagenes.org]()	Warren McCulloch (1898-1969) Adapted from: [Cybernaticians.com]()	
		
Walter Pitts (1923-1969) Adapted from: [Mindhacks]()	Claude Shannon (1916-2001) Adapted from: [netzspannung.org]()	Diagram of neuronal circuits from McCulloch and Pitts

Norbert Wiener (1894-1964), a mathematician, represents an important influence as well as a general trend; after WWII research on human performance of skill-based tasks increases dramatically. These tasks lend themselves to characterization as information processing tasks. Wiener's 1943 article, "[Behavior, Purpose and Teleology]()"[141] and his 1948 book, *Cybernetics: or Control and Communication in the Animal and the Machine*[142] represent one important and influential first step in this direction.

In *Cybernetics* and *Behavior* Wiener introduces such terms as "input" and "output" in outlining his interdisciplinary approach to the study of complex, goal-oriented systems. Cybernetics views such systems as complex systems interacting continuously with the environment through such mechanisms as communication, control, feedback, and self-organization.

Historians often cite the publication of "Behavior, Purpose and Teleology" together with the publication of "[A Logical Calculus of the Ideas Immanent in Nervous Activity]()"[143] by Warren Sturgis McCulloch (1898-1969) and Walter Pitts (1923-1969) as the beginning of the Cybernetics movement in the 20th century. In their paper McCulloch and Pitts demonstrate that, by interpreting neuronal activity as on-off (or binary), one can show how[143]

> The "all-or-none" law of nervous activity is sufficient to insure that the activity of any neuron may be represented as a proposition. Physiological relations existing among nervous activities correspond, of

> course, to relations among the propositions; and the utility of the representation depends upon the identity of these relations with those of the logic of propositions. To each reaction of any neuron there is a corresponding assertion of a simple proposition. This, in turn, implies either some other simple proposition or the disjunction or the conjunction, with or without negation, of similar propositions, according to the configuration of the synapses upon and the threshold of the neuron in question. (p.117)

From these results McCulloch and Pitts conclude:[143] "Thus, in psychology, introspective, behavioristic, or physiological the fundamental relations are those of two-valued logic." (p.131) In addition, McCulloch and Pitts show how logical functions could be computed by circuits created from neurons (see above).

Claude Shannon (1916-2001), yet another mathematician, lays the foundations of information theory in his 1948 paper, "A Mathematical Theory of Communication."[144] The theory is specifically intended to address the problem of transmitting information over a noisy channel. However, it influences theories of perception and mental representation as well as adding to the general conception of information processing as a central feature of mentality.

These four men have an additional connection in that they were all at MIT in 1956, when one of the significant conferences in the development of cognitive science occurs—The Second Symposium on Information Theory. While there are a number of important conferences during this period in both the United States and Britain, many historians point to the MIT conference in particular.

3.14 Information Processing Psychology

Donald Eric Broadbent (1926-1993), an English experimental psychologist publishes his book, *Perception and Communication*,[145] in 1958. It outlines theories of selective attention and short-term memory using computer analogies. Among the contributions in Broadbent's book is his filter theory of attention and memory. On Broadbent's theory, the brain holds simultaneously presented sensory input in a short-term sensory memory that acts like a recurrent circuit. These sensory inputs can be retained through rehearsal, but will disappear once allowed to degrade. Input in the sensory memory can pass through a filter selecting for specific physical signal characteristics, at which point the input enters a limited capacity channel for additional processing. Once analyzed for meaning, sensory information enters conscious awareness. Broadbent's model proves important in two respects: First, it suggests that the brain actively selects among information. Second, it suggests that the brain has real limitations in the amount of information it can process.

Such information processing inspired theories of psychological functioning benefit from the increasingly rich experimental tradition in psychology that allows theorists to devise experiments that can test these theories. For instance, George Armitage Miller (1920-), presents a paper at the 1956 MIT conference, "The Magical Number Seven, Plus or Minus Two,"[146] which he publishes later that year. The paper outlines experimental work by Miller and others showing that short-term memory (STM) has a capacity of seven items plus or minus two items. Miller also determines that chunking--linking individual items together--allows more complex items to be stored as single items, and improves recall. Miller's paper, though framed within information theory, is tested through behavioral measures and statistical analysis.

Donald Eric Broadbent (1926-1993)

George Armitage Miller (1920-)
Adapted from: Princeton.edu

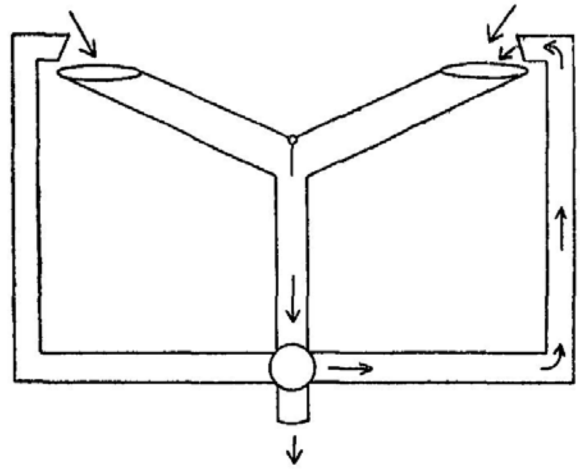


FIG. 2. The model modified to illustrate the theory of immediate memory as a recurrent circuit; or, in other terms, as a fading trace periodically revived by rehearsal.

A figure from Broadbent's "A Mechanical Model for Human Attention and Immediate Memory"[147] illustrating his theory.

In the paper's summary, Miller tells readers that

> ...the span of absolute judgment and the span of immediate memory impose severe limitations on the amount of information that we are able to receive, process, and remember. By organizing the stimulus input simultaneously into several dimensions and successively into a sequence or chunks, we manage to break (or at least stretch) this informational bottleneck. (p.95)

Miller goes on to co-found the Center for Cognitive Studies at Harvard. Together with Eugene Galanter and Karl Pribram Miller publishes an important book, *Plans and the Structure of Behavior*,[148] in 1960. *Plans* explores the potential of cybernetics in psychology by formulating many basic psychological process in terms of plans. The authors begin their first chapter by telling readers:[148]

> The authors of this book believe that the plans you make are interesting and that they probably have some relation to how you actually spend your time during the day. You imagine what your day is going to be and you make plans to cope with it. A Plan is any hierarchical process in the organism that can control the order in which a sequence of operations is to be performed. The image is all the accumulated, organized knowledge that the organism has about itself and its world. This chapter considers what modern psychology has to say about images and plans. (p.5)

3.15 Development as Inherently Cognitive

Jean Piaget[149] (1896-1980), a Swiss "natural scientist" (that was his Ph.D. title) studies intellectual development in children as early as 1927. Piaget uses his knack for the invention of experimental paradigms and demonstration to create a body of research into development that resists both introspective and behavioral explanation. Piaget suggests that the human intellect develops through a series of stages. According to Piaget's theory, humans progress through a series of developmental stages. Each stage represents a movement towards more abstract symbolic forms of reasoning, and is characterized by a particular schema or structure through which the person interacts with, and understands, the world.


Jean Piaget (1896-1980)
Adapted from:
thegreatdecide.com

Piaget considers himself an epistemologist, and writes an number of works in epistemology. His orientation in investigating development through schemas for understanding the world represents a European tradition with its origins in Kant. Similar research in other areas of development, for instance, in language acquisition, likewise challenge introspective and behaviorist perspectives both in terms of the breadth and robustness of development as well as regular timeframes in which development seems to occur.

3.16 The Final Step


Ulric Neisser (1928-2012)
Adapted from:
psychologicalscience.org

Ulric Neisser (1928-), a student of Miller, helps to catalyze and popularize cognitive psychology when his book, *Cognitive Psychology*,[150] is published in 1967. In that book, Neisser tells readers that[150] "Cognitive Psychology refers to all processes by which the sensory input is transformed, reduced elaborated, stored, recovered, and used." (p.4) Neisser attempts to integrate work from areas like perception, thinking, concept formation, and linguistics within a general information-processing framework. For instance, Niesser characterizes the research project of the cognitive psychologists by telling readers that:

> The task of a psychologist in trying to understand human cognition is analogous to that of a man trying to discover how a computer has been programmed. In particular, if the program seems to store and re-use information, he would like to know by what "routines" or "procedures" this is done. Given this purpose, he will not care much whether his particular computer stores information in magnetic cores or in thin films; he wants to understand the program, not the "hardware". By the same token, it would not help the psychologist to know that memory is carried by RNA as opposed to some other medium. He wants to understand its utilization, not its incarnation. (p.6)

Three years after Neisser publishes his book, *Cognitive Psychology,* the journal *Cognitive Psychology* comes into being in 1970. Needless to say, single events like Neisser's book or the founding of a journal do not mark a sudden transformation in psychology. Rather, such events are merely indicative of widespread and temporally extended changes within psychology. Likewise, the cognitive psychology envisioned by Niesser in the above quote differs from the cognitive psychology and cognitive science we find today. For example, the idea that one can ignore the "hardware" in understanding the software has proven incorrect.

As we have seen, the development of cognitive psychology requires several factors to come together; the development of experimental methodologies, the refinement of animal and other models, and increased knowledge of human mentality, development, and physiology creates the scientific apparatus necessary to rigorously test psychological theories. The development of technical ideas such as information flow and computation introduce concepts and models of psychological processing for theorist to investigate. The coalescing of these factors allows for the conceptual framing of cognitive phenomena as well as its systematic experimental investigation.

3.17 Key Concepts

Introspection: Introspection is a mental process whereby people come to gain insights into or form beliefs regarding their own mental states such as conscious thoughts, desires and sensations. There are at least three general models of introspection: The perceptual or observational model construes introspection as a sort of perceptual capacity, an inner sense, allowing one to view the contents of one's own mind. The constitutive or immediate model supposes that many mental states are such that one cannot have the state without also having the ability to form beliefs about it. The inferential or theory-based view suggests that introspection is a sort of inferential process through which one comes to form beliefs about one's mental states. Philosophers have often held that introspection has the properties of being infallible, unmediated or direct, and/or self-justifying. Additionally, philosophers have often also held that many states are completely and universally transparent to introspection.

Mental Chronometry: In psychology and related sciences mental chronometry is the study of the relative speed and temporal sequencing of mental process under some specified set of conditions. For instance, when vision researchers determine the time it takes to recognize an object, they are engaging in mental chronometry.

Reaction Time: Reaction time (RT) is the time it takes for an organism to generate a behavioral response once presented with sensory stimulus. For instance, the time between a light flashing and a subject pressing a button is that subject's reaction time for that stimulus-response pairing.

Skinner's Concept of Functional Analysis: Skinner adopts a methodology for psychology called functional analysis. The goal of functional analysis is to characterize dependencies between observable behaviors--not meticulously detailed step-wise causal relationships. That is, functional analysis specifies relationships between observable phenomena, i.e., between conditioning histories and environments. Specifically, Skinner understands functional analysis as a method for establishing relationships between stimuli and responses through the application of operant conditioning. Skinner's analysis is often called a "three-term contingency" analysis in that it characterizes the environmental features that act as a trigger for the behavior (sometimes called the discrimative stimulus), the response (the specific rigorously characterized behavior), and reinforcement (the consequence of the behavior that positively or negatively influences the probability of the behavior in the eliciting conditions).

Subtraction Method: The subtraction method in psychology and related fields determines a value for some variable in a complex phenomenon by subtracting the values of other components of the phenomena. For instance, one might determine the time it takes to read a word by subtracting the time it takes to press a button in response to a flash of a light from the time it takes to press a button after reading the word. That is, word reading time = the time it takes to respond after reading the word--the time it takes to respond to a stimulus would reading.

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