Anderson, Cognitive Psychology and its implications, 7th edition

enterprise as a scientific study of human cognition. Such research seems like the mind studying itself.

Only in the last 150 years has it been realized that human cognition could be the subject of scientific study rather than philosophical speculation.

Psychology in Germany: Focus on Introspective Observation

The date usually cited as marking the beginning of psychology as a science is 1879, when Wilhelm Wundt established the first psychology laboratory in Leipzig, Germany. Wundt's psychology was cognitive psychology (in contrast to other major divisions, such as comparative, clinical, or social psychology), although he had far-ranging views on many subjects. Wundt, his students, and a large number of the early psychologists used a method of inquiry called **introspection.** In this method, highly trained observers reported the contents of their own consciousnesses under carefully controlled conditions. The basic belief was that the workings of the mind should be open to self-observation. Drawing on the empiricism of the British philosophers, Wundt and others believed that very intense self-inspection would be able to identify the primitive experiences out of which thought arose. Thus, to develop a theory of cognition, a psychologist had only to account for the contents of introspective reports.

Let us consider a sample introspective experiment. Mayer and Orth (1901) had their participants perform a free-association task. The experimenters spoke a word to the participants and then measured the amount of time they took to generate responses to the word. Participants then reported all their conscious experiences from the moment of stimulus presentation until the moment of their response. To get a feeling for this method, try to come up with an association for each of the following words; after each association, think about the contents of your consciousness during the period between reading the word and making your association.

coat

book

dot

bowl

In Mayer and Orth's experiment, many participants reported rather indescribable conscious experiences. Whatever was in consciousness, it did not always seem to involve sensations, images, or other concrete experiences that participants in these laboratories were accustomed to reporting. This result started a debate over the issue of imageless thought—whether conscious experience could really be devoid of concrete content. As we will see in Chapters 4 and 5, modern cognitive psychology has made real progress on this issue, but not by using introspective methods.

At the turn of the 20th century, German psychologists tried to use a method of inquiry called introspection to study the workings of the mind.

Psychology in America: Focus on Behavior

Wundt's introspective psychology was not well accepted in America. Early American psychologists engaged in what they called "introspection," but it was not the intense analysis of the contents of the mind practiced by the Germans. Rather, it was largely an armchair avocation in which the only self-inspection was casual and reflective rather than intense and analytic. William James's *Principles of Psychology* (1890) reflects the best of this tradition, and many of the proposals in this work are still relevant today. The mood of America was determined by the philosophical doctrines of pragmatism and functionalism. Many psychologists of the time were involved in education, and the demand was for an "action-oriented" psychology that was capable of practical application. The intellectual climate in America was not receptive to a psychology focused on such questions as whether or not the contents of consciousness were sensory.

One of the important figures of early American scientific psychology was Edward Thorndike, who developed a theory of learning that was directly applicable to classrooms. Thorndike was interested in such basic questions as the effects of reward and punishment on the rate of learning. To him, conscious experience was just excess baggage that could be largely ignored. As often as not, his experiments were done on animals such as cats. Research on animals involved fewer ethical constraints than research on humans. Thorndike was probably just as happy that such participants could not introspect.

While introspection was being ignored at the turn of the century in America, it was getting into trouble on the continent. Various laboratories were reporting different types of introspections—each type matching the theory of the particular laboratory from which it emanated. It was becoming clear that introspection did not give one a clear window into the workings of the mind. Much that was important in cognitive functioning was not open to conscious experience. These two factors—the "irrelevance" of the introspective method and its apparent contradictions—laid the groundwork for the great behaviorist revolution in American psychology that occurred around 1920. John Watson and other behaviorists led a fierce attack not only on introspectionism but also on any attempt to develop a theory of mental operations. **Behaviorism** held that psychology was to be entirely concerned with external behavior and was not to try to analyze the workings of the mind that underlay this behavior:

> Behaviorism claims that consciousness is neither a definite nor a usable concept. The Behaviorist, who has been trained always as an experimentalist, holds further that belief in the existence of consciousness goes back to the ancient days of superstition and magic. (Watson, 1930, p. 2)

> The Behaviorist began his own formulation of the problem of psychology by sweeping aside all medieval conceptions. He dropped from his scientific vocabulary all subjective terms such as sensation, perception, image, desire, purpose, and even thinking and emotion as they were subjectively defined. (Watson, 1930, pp. 5–6)

The behaviorist program and the issues it spawned pushed research on cognition into the background of American psychology. The rat supplanted the human as the principal laboratory subject, and psychology turned to finding out what could be learned by studying animal learning and motivation. Quite

a bit was discovered, but little was of direct relevance to cognitive psychology. Perhaps the most important lasting contribution of behaviorism is a set of sophisticated and rigorous techniques and principles for experimental study in all fields of psychology, including cognitive psychology.

Behaviorism was not as dominant in Europe. Psychologists such as Frederick Bartlett in England, Alexander Luria in Russia, and Jean Piaget in Switzerland were pursuing ideas that are important in modern cognitive psychology. Cognitive psychology was an active research topic in Germany, but much of it was lost in the Nazi turmoil. A number of German psychologists immigrated to America and brought **Gestalt psychology** with them. Gestalt psychology claimed that the activity of the brain and the mind was more than the sum of its parts and as such conflicted with much of the introspectionist program in Germany. In America, Gestalt psychologists found themselves in conflict with behaviorism on this point but also because they were concerned with mental structure at all. In America, Gestalt psychologists received the most attention for their claims about animal learning, and they were the standard targets for the behaviorist critiques, although some Gestalt psychologists became quite prominent. For example, the Gestalt psychologist Wolfgang Kohler was elected to the presidency of the American Psychological Association. Although not a Gestalt psychologist, Edward Tolman was an American psychologist who did his research on animal learning and anticipated many ideas of modern cognitive psychology. Again, his ideas were frequently the target for criticism by the dominant behaviorist psychologists, although his work was harder to dismiss because he spoke the language of behaviorism.

In retrospect, it is hard to understand how American behaviorists could have taken such an anti-mental stand and clung to it for so long. Just because introspection proved to be unreliable did not mean that it was impossible to develop a theory of internal mental structure and process. It meant only that other methods were required. In physics, for example, a theory of atomic structure was developed, although that structure could only be inferred, not directly observed. But behaviorists argued that a theory of internal structure was not necessary to an understanding of human behavior, and in a sense they may have been right (see Anderson & Bower, 1973, pp. 30–37). A theory of internal structure, however, makes understanding human beings much easier. The success of modern cognitive psychology shows that understanding mental structures and processes is critical to understanding human cognition.

In both the introspectionist and behaviorist programs, we see the human mind struggling with the effort to understand itself. The introspectionists held a naïve belief in the power of self-observation. The behaviorists were so afraid of falling prey to subjective fallacies that they refused to let themselves think about mental processes. Modern cognitive psychologists seem to be much more at ease with their subject matter. They have a relatively detached attitude toward human cognition and approach it much as they would any other complex system.

Behaviorism, which dominated American psychology in the first half of the 20th century, rejected the analysis of the workings of the mind to explain behavior.

The Cognitive Revolution: AI, Information Theory, and Linguistics

Cognitive psychology, as we know it today, took form in the two decades between 1950 and 1970 in the cognitive revolution that overthrew behaviorism. Three main influences account for its modern development. The first was research on human performance, which was given a great boost during World War II, when governments badly needed practical information about how to train soldiers to use sophisticated equipment and how to deal with such problems as the breakdown of attention under stress. Behaviorism offered no help with such practical issues. Although the work during the war had a very practical bent, the issues it raised stayed with psychologists when they went back to their academic laboratories after the war. The work of the British psychologist Donald Broadbent at the Applied Psychology Research Unit in Cambridge was probably the most influential in integrating ideas from human performance research with new ideas that were developing in an area called information theory. Information theory is an abstract way of analyzing the processing of information. Broadbent and other psychologists, such as George Miller, Fred Attneave, and Wendell Garner, initially developed these ideas with respect to perception and attention, but such analyses soon pervaded all of cognitive psychology.

Second, and closely related to the development of the information-processing approach, were developments in computer science, particularly AI, which tries to get computers to behave intelligently. Allen Newell and Herbert Simon at Carnegie Mellon University spent 40 years educating cognitive psychologists about the implications of AI (and educating workers in AI about the implications of cognitive psychology). The direct influence of computer-based theories on cognitive psychology has always been minimal. The indirect influence, however, has been enormous. A host of concepts have been taken from computer science and used in psychological theories. Probably more important, observing how we can analyze the intelligent behavior of a machine has largely liberated us from our inhibitions and misconceptions about analyzing our own intelligence.

The third influence on cognitive psychology was **linguistics,** which studies the structure of language. In the 1950s, Noam Chomsky, a linguist at the Massachusetts Institute of Technology, began to develop a new mode of analyzing the structure of language. His work showed that language was much more complex than had previously been believed and that many of the prevailing behaviorist formulations were incapable of explaining these complexities. Chomsky's linguistic analyses proved critical in enabling cognitive psychologists to fight off the prevailing behaviorist conceptions. George Miller, at Harvard University in the 1950s and early 1960s, was instrumental in bringing these linguistic analyses to the attention of psychologists and in identifying new ways of studying language.

Cognitive psychology has grown rapidly since the 1950s. A milestone was the publication of Ulric Neisser's *Cognitive Psychology* in 1967. This book gave a new legitimacy to the field. It consisted of 6 chapters on perception and attention and 4 chapters on language, memory, and thought. This chapter division contrasts sharply with this book's, which has only 2 chapters on perception and attention and 11 on language, memory, and thought. My chapter division

reflects the growing emphasis on higher mental processes. Following Neisser's work, another important event was the beginning of the journal *Cognitive Psychology* in 1970. This journal has done much to define the field.

In the 1970s, a related new field called cognitive science emerged that attempts to integrate research efforts from psychology, philosophy, linguistics, neuroscience, and AI. This field can be dated from the appearance of the journal *Cognitive Science* in 1976, which is the main publication of the Cognitive Science Society. The fields of cognitive psychology and cognitive science overlap. Speaking generally, cognitive science makes greater use of such methods as logical analysis and the computer simulation of cognitive processes, whereas cognitive psychology relies heavily on experimental techniques that grew out of the behaviorist era for studying behavior. This book draws on all methods but makes most use of cognitive psychology's experimental methodology.

- *Cognitive psychology broke away from behaviorism in response to developments in information theory, AI, and linguistics.*

Information-Processing Analyses

The various factors described in the previous section converged in a particular approach to studying human cognition—the **information-processing approach**—that became the dominant approach in cognitive psychology. It attempts to analyze cognition as a set of steps in which an abstract entity called "information" is processed. Probably the best way to explain this approach is to describe a classic example of it.

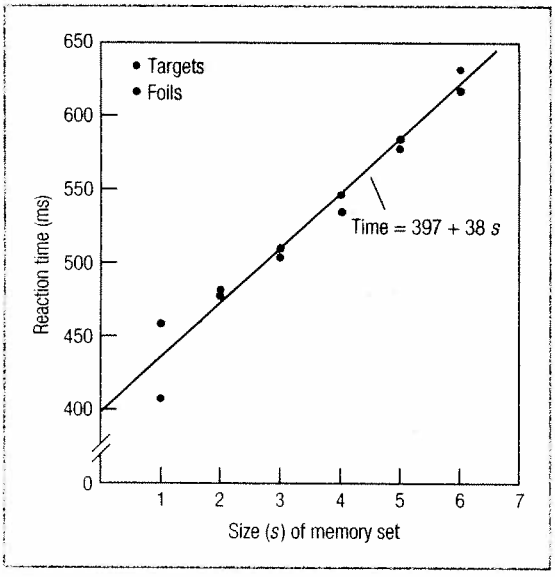

FIGURE 1.1 The time needed to recognize a digit increases with the number of items in the memory set. The straight line represents the linear function that fits the data best.
(From S. Sternberg, 1969. Reprinted by permission of the publisher. © 1969 by *American Scientist*.)

In 1966, Saul Sternberg described an experimental paradigm and proposed a theoretical account of it that proved to be quite influential. In what has come to be called the **Sternberg paradigm,** participants were shown a small number of digits, such as "3 9 7," to keep in mind. Then they were shown a probe digit and asked whether it was in the memory set, and they had to answer as quickly as possible. For example, 9 would be a positive probe for the "3 9 7" set; 6 would be a negative probe. Sternberg varied the number of digits in the memory set from 1 to 6 and measured how quickly participants could make this judgment. Figure 1.1 shows his results as a function of the size of the memory set. Data are plotted separately for positive probes, or targets, and for negative probes, or foils. Participants could make these judgments quite quickly; latencies varied from 400 to 600 milliseconds (ms)—a millisecond is a thousandth of a second. Sternberg found a nearly linear relationship between judgment time and the size of the memory set. As shown in Figure 1.1, participants took about 38 ms extra to judge each digit in the set.

Sternberg developed a very influential account of how participants made these judgments. This account exemplifies what an abstract information-processing

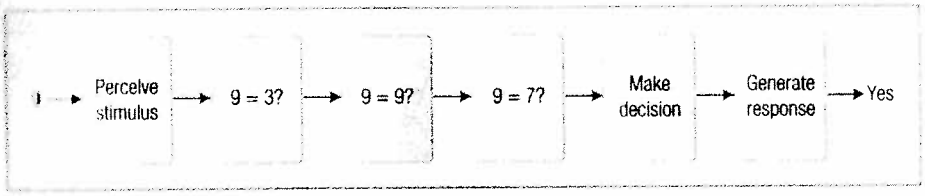

FIGURE 1.2 Sternberg's analysis of the sequence of information-processing stages in his task.

theory is like. His explanation is illustrated in Figure 1.2. Sternberg assumed that when participants saw a probe stimulus such as a 9, they went through the series of information-processing stages illustrated in that figure. First the stimulus was encoded. Then the stimulus was compared to each digit in the memory set. Sternberg assumed that it took 38 ms to complete each one of these comparisons, which accounted for the slope of the line in Figure 1.1. Then the participant had to decide on a response and finally generate it. Sternberg showed that different variables would influence each of these information-processing stages. Thus, if he degraded the stimulus quality by making the probe harder to read, participants took longer to make their judgments. This did not affect the slope of the Figure 1.1 line, however, because it involved only the stage of stimulus perception in Figure 1.2. Similarly, if he biased participants to say yes or no, the decision-making stage, but not other stages, was affected.

It is worth noting the ways in which Sternberg's theory exemplifies a classic abstract information-processing account:

1. The information processing that is going on is discussed without any attempt to conceptualize it in terms of brain location or brain processes.
2. The processing of the information has a highly symbolic character. Thus, we speak of the system as comparing the symbol 9 against the symbol 3. There is no consideration of possible neural representations of these symbols.
3. Sternberg called upon the computer metaphor in justifying his theory of information processing. He thought that information processing in this task could be compared to the way computers do high-speed scanning.
4. The measurement of time to make a judgment is a critical variable, because the information processing is conceived to be taking place in discrete stages. Flowcharts such as the one in Figure 1.2 have been a very popular means of expressing the steps of information processing. Flowcharts are themselves imported from computer science.

Each of these four features listed reflects a kind of narrowness in the classic information-processing approach to human cognition. Cognitive psychologists have gradually broadened their approach as they dealt with more complex phenomena and as they began to pay more attention to the nature of information

processing in the brain. For instance, this textbook has evolved over its editions to reflect this shift.

Information-processing analysis breaks a cognitive task down into a set of abstract information-processing steps.

Cognitive Neuroscience

The field of cognitive psychology is in the midst of a change that may turn out to be as significant as the cognitive revolution. This change is the infusion of considerations of brain processes into almost all analyses of human cognition. There is a field called **cognitive neuroscience** that is devoted to the study of how cognition is realized in the brain. The rise of cognitive neuroscience feels less like a revolution because most cognitive psychologists are welcoming it. For instance, in my own psychology department at Carnegie Mellon, the cognitive program and the cognitive neuroscience program merged as we all find ourselves concerned with the same issues.

The study of perception (see Chapter 2) always had a strong basis in physiology, but the other elements of cognition seemed too complex to be studied by physiological methods. The steady development of knowledge about the brain and methods for studying brain activity, however, has slowly eroded this complexity barrier. Even for the most complex thought processes, there are exciting new findings related to their realization in the brain. I will describe new techniques for imaging brain activity later in this chapter. In various ways (and with various limitations), we are now able to see how cognition unfolds in the brain. As an example of the new power of cognitive neuroscience techniques, I will describe a study of the neural processes that are involved as one solves a mathematical equation.

Until recently, the information-processing approach described in the previous section was viewed as having little to do with cognitive neuroscience, but we are now seeing a developing synergy between cognitive neuroscience and information-processing analysis. Neuroscience data can be used to discriminate between alternative information-processing models, and information-processing models can be used to organize neuroscience data. We will see an example of the latter when we talk about the brain imaging of equation solving.

Cognitive neuroscience is developing methods that enable us to understand the neural basis of cognition.

Information Processing: The Communicative Neurons

The brain is just one part of the nervous system. The full nervous system includes the various sensory systems that gather information from parts of the body and the motor systems that control movement. In some cases, considerable