Reed, Steven K. "The Information Processing Approach," in *Cognition* [Fifth Edition]. Belmont: Wadsworth/Thomson Learning, 1999.

COGNITION IS USUALLY defined simply as the acquisition of knowledge. However, both the acquisition and the use of knowledge involve many mental skills. If you glanced at the table of contents at the beginning of this book, you saw a list of some of these skills. Psychologists who study cognition are interested in pattern recognition, attention, memory, visual imagery, language, problem solving, and decision making.

The purpose of this book is to provide an overview of the field of cognitive psychology. The book summarizes experimental research in cognitive psychology, discusses the major theories in the field, and attempts to relate the research and theories to cognitive tasks that people encounter in their daily lives—for example, reading, driving, studying, judging advertising claims, evaluating legal testimony, solving problems in the classroom, and making medical decisions.

Neisser's definition of cognitive psychology quoted on the preceding page reflects how psychologists study cognition. Let me repeat it for emphasis: "**Cognitive psychology** refers to all processes by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used."

cognitive psychology The study of the mental operations that support people's acquisition and use of knowledge

This definition has several important implications. The reference to a sensory input implies that cognition begins with our contact with the external world. Transformation of the sensory input means that our representation of the world is not just a passive registration of our physical surroundings but an active construction that may involve both reduction and elaboration. Reduction occurs when information is lost. That is, we can attend to only a small part of the physical stimulation that surrounds us, and only a small part of what we attend to can be remembered. Elaboration occurs when we add to the sensory input. For example, when you meet a friend, you may recall many shared experiences.

The storage and the recovery of information are of course what we call memory. The distinction between storage and recovery implies that the storage of information does not guarantee recovery. A good example of this distinction is the "tip of the tongue" phenomenon. Sometimes we can almost, but not quite, retrieve a word to express a particular thought or meaning. Our later recall of the word proves that the earlier failure was one of retrieval rather than one of storage. The word was stored in memory; it was simply hard to get it back out.

The last part of Neisser's definition is perhaps the most important. After information has been perceived, stored, and recovered, it must be put to good use—for example, to make decisions or to solve problems. We will learn more about problem solving and decision making in Part III, after we review the progress that has been made in understanding perception and memory.

In Stephen K. Reed, *Cognition* [Fifth Edition]. Belmont: Wadsworth/Thomson Learning, 1999.

THE INFORMATION-PROCESSING APPROACH

The fact that cognitive psychology is often called **human information processing** reflects the predominant approach to the subject used by cognitive psychologists. The acquisition, storage, retrieval, and use of information comprise a number of separate stages, and the information-processing approach attempts to identify what happens during these stages (Haber, 1969). This stage approach was influenced by the computer metaphor in which people enter, store, and retrieve data from a computer.

human information processing The psychological approach that attempts to identify what occurs during the various stages (attention, perception, short-term memory) of processing information

Figure 1.1 identifies the stages that researchers most commonly include in information-processing models. The stages are arranged in temporal order; however, since information flows in both directions, as indicated by the two-headed arrows, an earlier stage can be influenced by information in a later stage. For example, to recognize a pattern in the pattern recognition stage, we need to store information about patterns in long-term memory.

A brief consideration of the model in Figure 1.1 provides a superficial account of the stages, each of which will be elaborated in later chapters. The **sensory store** provides brief storage for information in its original sensory form. Presumably, a sensory store exists for each of the senses, although the visual and auditory stores have been the most widely studied. The sensory store extends the amount of time that a person has to recognize a pattern. If a visual pattern is flashed on a screen for 5 msec (5 milliseconds, or 5/1000 of a second), the observer has more time than 5 msec to identify it if the visual information can be briefly maintained in a sensory store. Although the sensory store for vision lasts only about one-quarter of a second (250 msec), this is much longer than the 5-msec exposure.

sensory store That part of memory that holds unanalyzed sensory information for a fraction of a second, providing an opportunity for additional analysis following the physical termination of a stimulus

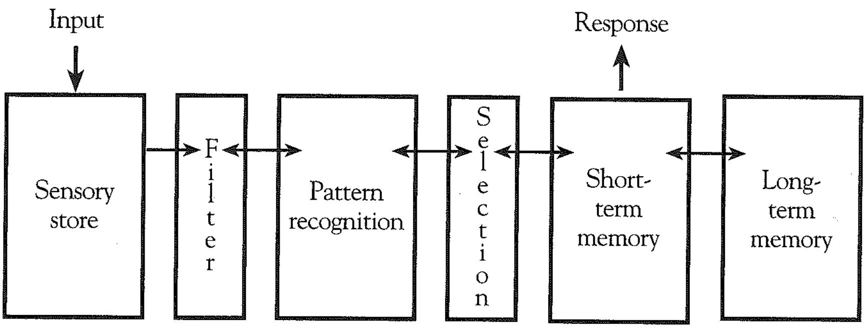


Figure 1.1 *Stages of an information-processing model*

pattern recognition The stage of perception during which a stimulus is identified

The information in the sensory store is lost at the end of this time unless it can be identified during the **pattern recognition** stage. Most of the patterns we encounter are familiar, and recognition consists in identifying a pattern as a cat, the letter *a*, the word *ball*, and so on. When we recognize a familiar pattern, we are using information that we have previously stored in memory. If the description does not match a description of a familiar pattern, the observer may want to store the new description in memory if it is important.

filter That part of attention in which some perceptual information is blocked (filtered) out and not recognized, while other information receives attention and is subsequently recognized

selection stage The stage that follows pattern recognition and determines which information a person will try to remember

The relation between pattern recognition and attention has been a topic of much debate. Some theorists have claimed that we can recognize only one pattern at a time. They argue that attention acts as a **filter** that determines which patterns will be recognized when many patterns arrive simultaneously. Other theorists have argued that simultaneous patterns can all be recognized but that only some of the recognized patterns will be remembered, while others are immediately forgotten. That is, this latter view states that attention selects the patterns that will be remembered. Since the most popular current view is that both theories are correct, depending on the circumstances, attention is represented in Figure 1.1 by both filter and **selection stages.** The filter limits the amount of information that can be recognized at one time, and the selection stage limits the amount of material that can be entered into memory.

short-term memory (STM) Memory that has limited capacity and that lasts only about 20–30 seconds in the absence of attending to its content

long-term memory (LTM) Memory that has no capacity limits and lasts from minutes to an entire lifetime

Memory is represented in Figure 1.1 by short-term and long-term memory. We use **short-term memory (STM),** for example, to remember a telephone number as we are dialing it. This form of memory is limited in both the amount of information it can hold (capacity) and the length of time it can hold the information (duration). Most adults can remember a seven-digit number, but they find it very difficult to remember a ten-digit number, such as an unfamiliar area code in addition to the telephone number. The limited duration of STM is illustrated by our quickly forgetting the number if we don't repeat it to ourselves by using verbal rehearsal. **Long-term memory (LTM)** has neither of the two limitations of STM. It has no limitations on the amount of information it can hold, and forgetting occurs relatively slowly, if at all.

The "higher" cognitive skills, such as decision making and problem solving, do not have a stage in our information-processing model. However, they depend greatly on the other stages. For example, pattern recognition skills are important in playing chess, a very demanding intellectual task. The limited capacity of STM is a major determinant of performance on tasks that require complex decision making or problem solving. The role of problem solving in learning new information is receiving increasing emphasis as cognitive psychologists discover more about the active nature of learning. Specifying the interactions among perception, memory, and thought is one of the challenges that confront cognitive psychologists.

THE GROWTH OF COGNITIVE PSYCHOLOGY

It is difficult to pinpoint the exact beginning of any field of study, and cognitive psychologists would likely offer a wide variety of dates if asked when cognitive psychology began. James's *Principles of Psychology*, published in 1890, included chapters on attention, memory, imagery, and reasoning. Kohler's *The Mentality of Apes* (1925) investigated processes that occur in complex thinking. He and other Gestalt psychologists emphasized structural understanding—the ability to understand how all the parts of a problem fit together (the Gestalt). Bartlett's book *Remembering: A Study in Experimental and Social Psychology* (1932) contained a theory of memory for stories that is very consistent with current views. There are some other important articles or books that seem modern but did not cause a major shift toward the way cognitive psychology is currently studied.

One book that had a major negative impact was Watson's *Behaviorism* (1924). The book's central theme was that psychologists should study only what they could directly observe in a person's behavior. Watson's argument lent support to a **stimulus-response (S-R)** approach, in which experimenters record how people respond to stimuli without attempting to discover the thought processes that cause the response. The S-R approach is consistent with Watson's view because the stimulus and the response are both observable. The problem with this approach is that it does not reveal exactly what the person does with the information presented in the stimulus. By contrast, the information-processing approach seeks to identify how a person transforms information between the stimulus and the response. Psychologists who follow the latter approach seek to understand what occurs during each of the stages shown in Figure 1.1. Finding out what occurs during each of these stages is particularly important when a person has difficulty performing a task, for the psychologist can then try to identify which stage is the primary source of the difficulty.

stimulus-response (S-R) The approach that emphasizes the association between a stimulus and a response, without identifying the mental operations that produced the response

Information Processing Gathers Momentum

The change from the S-R to the information-processing approach began to gather momentum in the middle-to-late 1950s, stimulated by the growing popularity of computers and computer programs that illustrated the different operations in the processing of information. Psychologists became interested in using the computer as an analog of how people process information and tried to identify how different stages of processing influence performance.

Broadbent (1958) proposed one of the first models based on an information-processing analysis—a filter model to account for performance on selective listening tasks. When subjects were asked to listen simultaneously to different messages played in each ear, they found it difficult. Broadbent proposed that many sensory inputs can simultaneously enter the sensory store, but only a single input can enter the pattern recognition stage. The filter model proposes that the listener can attend to only one message at a time; attention is controlled by the filter. Two simultaneous messages can both be recognized only if the unattended message passes through the filter before it decays from the sensory store. The filter model implies that a perceptual limitation prevents people from comprehending two messages spoken at the same time.

The year after Broadbent's filter model appeared, Sperling completed his doctoral dissertation at Harvard. In one of Sperling's tasks (1960), observers viewed a very brief exposure of an array of letters and were required to report all the letters in one of the rows of the display. The pitch of a tone signaled which row was to be reported. Sperling designed the procedure to determine whether perception or memory limited the number of letters people could report from the brief exposure. His analysis of this task resulted in an information-processing model that proposed how the sensory store, pattern recognition, and STM combined to influence performance on the task (Sperling, 1963).

Both Broadbent's and Sperling's models had an important influence on subsequent information-processing theory, the former on models of auditory attention and the latter on visual recognition.

Higher Cognitive Processes

The information-processing analysis of perceptual tasks was accompanied in the late 1950s by a new approach to more complex tasks. The excitement of this new approach is described by Newell and Simon (1972). The development of digital computers after World War II led to active work in **artificial intelligence,** a field that attempts to program computers to perform intelligent tasks such as playing chess and constructing derivations in logic. A seminar was held at the RAND Corporation in the summer of 1958 with the aim of showing social scientists how computer-simulation techniques could be applied to create models of human behavior. The RAND seminar had a major impact on integrating the work on computer simulation with other work on human information processing.

artificial intelligence The study of how to produce computer programs that can perform intellectually demanding tasks

One consequence of the RAND seminar was its influence on three psychologists who spent the 1958–1959 academic year at the Center for Advanced Study in the Behavioral Sciences at Stanford University. The three—George Miller, Eugene Galanter, and Karl Pribram—shared a common dissatisfaction with the then-predominant theoretical approach to psychology, which viewed human beings as bundles of S-R reflexes. Miller brought with him a large amount of material from the RAND seminar, and this material—along with other recent work in artificial intelligence, psychology, and linguistics—helped shape the view expressed in their book, *Plans and the Structure of Behavior* (Miller, Galanter, & Pribram, 1960).

The authors argue that much of human behavior is planned. A **plan,** according to their formulation, consists of a list of instructions that can control the order in which a sequence of operations is to be performed. A plan is essentially the same as a program for a computer. Since the authors found it difficult to construct plans from S-R units, they proposed a new unit called TOTE, an abbreviation for Test-Operate-Test-Exit. A plan consists of a hierarchy of TOTE units.

plan A temporally ordered sequence of operations for carrying out some task

Consider a very simple plan for hammering a nail into a board. The goal is to make the head of the nail flush with the board. At the top of the hierarchy is a test to determine whether the goal has been accomplished. If the nail is flush, one can exit. If the nail sticks up, it is necessary to test the position of the hammer. The position of the hammer determines which of two operations, lifting or striking, should be performed.

The ideas expressed by Miller, Galanter, and Pribram were influenced by earlier work in two areas outside psychology. The work of Newell, Shaw, and Simon (1958a) in the area of artificial intelligence identified strategies that people use to perform complex tasks such as playing chess. A second major influence came from the linguist Noam Chomsky, who argued that an S-R theory of language learning could not account for how people learn to comprehend and generate sentences (Chomsky, 1957). His alternative proposal—that people learn a system of rules (a grammar)—was consistent with Miller, Galanter, and Pribram's emphasis on planning. We will return to both contributions, as well as to the contributions of Miller, Broadbent, and Sperling, in the following chapters.

COGNITION'S RELATION TO OTHER FIELDS

The ideas expressed by these theorists have continued to be developed and refined. Neisser's *Cognitive Psychology* (1967) brought many of these ideas together into a single source; other books on cognition have followed. Cognitive psychology currently has widespread appeal among psychologists. Almost all psychologists studying perception, attention, learning, memory, language, reasoning, problem solving, and decision making refer to themselves as cognitive psychologists even though the methodology and theories vary widely across these topics. In addition, other disciplines, such as educational psychology (Gagne, 1985; Mayer, 1987) and social psychology (Devine, Hamilton, & Ostrom, 1994), have been greatly influenced by the cognitive approach.

The increasing prominence of cognitive psychology is documented in Figure 1.2. The data contrast four of the most influential and widely recognized schools within psychology: psychoanalysis, behaviorism, cognitive

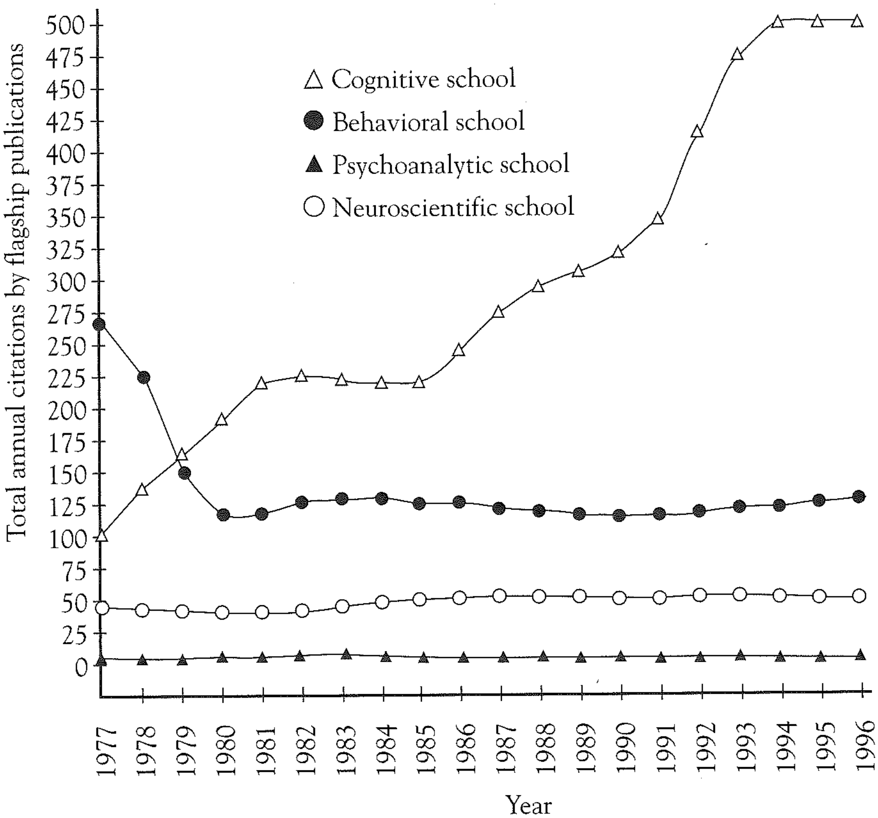


Figure 1.2 *The total number of citations per year to articles published in cognitive, behavioral, psychoanalytic, and neuroscientific journals*

Note: A smoothing function was used to transform the raw data.

From "An empirical analysis of trends in psychology," by R. W. Robins, S. D. Gosling, and K. H. Craik, 1999, *American Psychologist, 54,* 117–128.

psychology, and neuroscience. One of the measures of prominence, displayed in Figure 1.2, is the number of citations to journal articles in each of these fields. These citations were found in four "flagship" journals: *American Psychologist, Annual Review of Psychology, Psychological Bulletin,* and *Psychological Review.* These are widely read journals that represent the entire field of psychology. As is shown in Figure 1.2, citations of articles in cognitive psychology journals have greatly increased over the 20-year period from 1977 to 1996. Other measures, such as dissertation topics, also show the current prominence of cognitive psychology.

Cognitive psychology is also having an increasing impact on applied psychology (Hoffman & Deffenbacher, 1992). Much research funding is now directed toward applied projects, and many recent doctoral graduates are hired for applied positions. The increasing application of cognitive theory is also evident in the emergence of new journals such as *Applied Cognition* and the *Journal of Experimental Psychology: Applied*. The title of this book, *Cognition: Theory and Applications*, indicates that I believe these applications are important. We will look at many applications throughout this book, including facilitating perceptual learning, predicting the accident rate of drivers, improving eyewitness recall, using memory strategies, recognizing the biasing effects of language in advertising and legal testimony, improving the readability of text, and using problem-solving strategies.

The influence of ideas does not move in only one direction. Other fields of study have also influenced cognitive psychology and led to a combined field of study called cognitive science, characterized by its own society, journal, and even major at some universities. **Cognitive science** is the study of intelligence in humans, computer programs, and abstract theories, with an emphasis on intelligent behavior as computation (Simon & Kaplan, 1989). It is also an attempt to unify views of thought developed by studies in psychology, linguistics, anthropology, philosophy, artificial intelligence, and the neurosciences (Hunt, 1989).

cognitive science The interdisciplinary attempt to study cognition through such fields as psychology, philosophy, artificial intelligence, neuroscience, linguistics, and anthropology

Unification is theoretically possible because some issues, such as knowledge representation, are important in all fields within cognitive science (Davis, Shrobe, & Szolovits, 1993; Stillings, Weisler, Chase, Feinstein, Garfield, & Rissland, 1995). For instance, we will see in Chapter 9 that cognitive psychologists borrowed a concept from artificial intelligence (semantic networks) to describe how people organize ideas in LTM. Another concept borrowed from artificial intelligence (production systems) explains how we use rules to perform cognitive tasks. We will learn about production systems in Chapter 13.

An important field receiving increasing study is that of **cognitive neuroscience,** which examines where cognitive operations occur in the brain. Figure 1.3 shows the four lobes of the cerebral cortex with their primary functions (Kalat, 1995). The primary visual cortex is located in the *occipital lobe*. A person who has damage to this area has normal pupillary reflexes and some eye movements, but no pattern perception or awareness of visual information. The *parietal lobe* is specialized for dealing with body information, including touch. Common symptoms that follow from damage to this area include impairment to identify objects by touch and clumsiness on the side of the body opposite the damage. The *temporal lobe* is essential for understanding language and contributes to recognizing complex visual patterns such as faces. The *frontal lobe* receives sensations from all the sensory systems and contributes to planning motor movements. Damage to this area can also interfere with memory.

cognitive neuroscience The study of the relation between cognitive processes and brain activities

Advances in technology have made it possible to more precisely localize which parts of the brain are used to perform a variety of cognitive tasks. Imaging techniques, such as **functional magnetic resonance imaging**

functional magnetic resonance imaging (fMRI) A diagnostic technique that uses magnetic fields and computerized images to locate mental operations in the brain

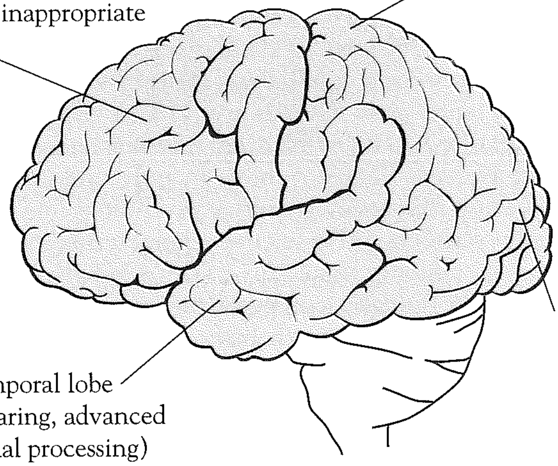


Figure 1.3 *Some major subdivisions of the left hemisphere of the cerebral cortex, with a few of their primary functions*

Adapted from *Biological Psychology* (5th ed.), by J. W. Kalat. Copyright 1995. Reprinted by permission of Wadsworth Publishing, a division of Thomson Learning. Fax 800-730-2215.

positron-emission tomography (PET) A diagnostic technique that uses radioactive tracers to study brain activity by measuring the amount of blood flow in different parts of the brain

event-related potential (ERP) A diagnostic technique that uses electrodes placed on the scalp to measure the duration of brain waves during mental tasks

(fMRI) and **positron-emission tomography (PET),** measure cerebral blood flow by sensing either a magnetic signal (fMRI) or low-level radiation (PET) to determine activity levels in various parts of the brain (Posner, DiGirolamo, & Fernandez-Duque, 1997). Box 1.1 shows how such technology is greatly enhancing our understanding of cognitive problems.

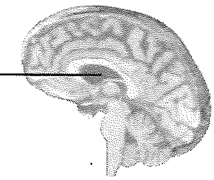
A limitation of spatial imaging techniques is that they do not provide the kind of precise temporal information that is important in analyzing many cognitive tasks in which fractions of a second are theoretically important. But recording electrical activity from the scalp does provide more precise temporal information. The use of these **event-related potentials (ERPs)** allows scientists to link mental operations recorded in reaction-time tasks to brain activity. By combining PET and ERP studies, it is possible to take advantage of the more precise spatial localization of imaging techniques and the more precise temporal resolution of electrical potentials (Posner & Rothbart, 1994).

Figure 1.4 illustrates how the PET and ERP techniques can be combined to help us understand how people understand written words (Snyder, Abdullaev, Posner, & Raichle, 1995). The different shades of grey inside the outline of the left hemisphere show changes in blood flow when

Brain images: New windows to illness

FLOYD BLOOM AND ROBERT POOL

BOX 1.1



When Nancy Andreasen reaches into her appointment calendar to pull out a photo, you expect to see a son or daughter, perhaps even a pet, but certainly not this. It is a photo of a living brain, and it is her brain.

The picture is a calling card of sorts. Andreasen, a well-known research psychiatrist, uses pictures like this to study what goes wrong in the brains of people with schizophrenia, manic depression, and other mental illnesses.

Not long ago, the only way to get such detailed images of a brain was to wait until the person died and remove the brain during an autopsy. Now doctors and medical scientists can get pictures of a brain while the person is still very much alive....

Andreasen, for example, has been examining the brains of people with schizophrenia. Using magnetic resonance imaging, or MRI, she and her colleagues have shown that schizophrenics who experience auditory hallucinations tend to have abnormalities in the parts of the brain devoted to hearing. Schizophrenics with disorganized speech often have abnormalities in the parts of the brain devoted to language and memory....

Imaging techniques also are being used to study the normal brain to shed light on brain disorders. With the newest techniques, for example, researchers can watch different parts of the brain in action as they demand more blood flow and oxygen. As people learn a complicated new task, the brain learns to do the job more efficiently, and fewer parts of the brain are required.

This research and other investigations are showing that the brain is much more flexible than was thought just a few years ago. In some cases, adjacent or related parts of the brain can take over functions from parts that are damaged. By studying this rewiring process, researchers hope to mend spinal cord injuries, and perhaps even block the neural degeneration caused by Alzheimer's disease.

The general impression from this work is one of great optimism. Just a few years ago, scientists thought that brain cells formed fixed circuits early in life that remained largely unchanged. Now they have discovered that these cells are constantly forming new connections in response to input from the outside world. If researchers can unravel and eventually learn how to influence this process, powerful new treatments for brain disorders will be possible.

SOURCE: From "Brain images: New windows to illness," by Floyd Bloom and Robert Pool, *San Diego Union-Tribune*, May 26, 1994. Reprinted by permission.

a person is asked to generate uses of visually presented nouns (such as *pound* for the word *hammer*), over and above the changes caused by simply reading aloud the same nouns. The lighter areas show the largest increases in blood flow, indicating that these areas of the brain are important for understanding the meaning of the words. Notice that these increases are particularly evident in the frontal and temporal areas of the left hemisphere.

⇒ context/function, not meaning!

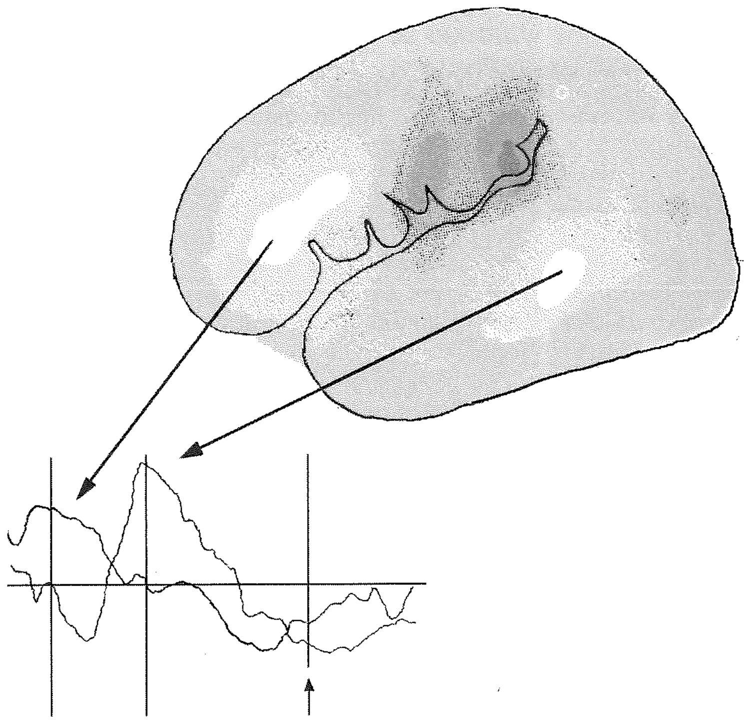


Figure 1.4 *A PET scan showing changes in blood flow in the left hemisphere during a cognitive task*

Adapted from photo provided by Marcus E. Raichle, M.D., Washington University School of Medicine.

The arrows in Figure 1.4 connect PET blood-flow changes with the ERP waveforms recorded at the nearest overlying electrode on the scalp. The activation in the frontal part of the left hemisphere leads the activation in the temporal part of the left hemisphere by several hundred milliseconds. An implication of these findings is that the earlier, frontal activation is important for encoding the meaning of individual words and the later temporal activation may be more important for the integration of word meanings to obtain the overall meaning of phrases and sentences (Snyder et al., 1995). This hypothesis is consistent with the finding that damage to the temporal area of the left hemisphere often produces a language deficit that leaves the person unable to combine words to produce meaningful ideas. We will later learn more about this deficit in Chapter 10 on language.

Cognitive neuroscience is particularly interesting to cognitive psychologists when it helps them evaluate cognitive theories. For instance, we will see in Chapter 7 that one of the classic debates in cognitive psychology is the role of visual imagery in cognition. How do we know when people are using visual imagery to perform a task? Cognitive neuroscience has been helpful in answering this question by allowing psychologists to study which part of the brain is active when people perform spatial reasoning tasks. Evidence for the use of visual imagery occurs when the same part of the brain is activated (the occipital lobe) as is activated during visual perception.

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