CHAPTER 2

Making Sense of the Environment

Read This Chapter to Learn About

- Attention
- Cognition
- Culture, Environment, and Biology in Cognitive Development
- Problem Solving
- Decision Making
- Intelligence
- Nature, Nurture, and Intelligence
- Measuring Intelligence
- Memory
- Language

ATTENTION

The human brain may have a seemingly unlimited capacity to process sensory inputs, but the individual can focus only on a small percentage of those sensations at any one time. Attention must occur before cognition. **Selective attention** occurs when an individual focuses on one element in an environment while ignoring others. Attentional focus can be voluntary (such as reading this paragraph) or involuntary (roommate slamming a door).

COGNITION

Cognition has not been fully explained by science. Some researchers, such as cognitive psychologists, engage in a "top-down" approach by approaching cognition as a wholistic function, attempting to understand how cognitive processes occur in the brain and then examining how neural networks are used in that process. Other researchers, such as neuroscientists, use a "bottom-up" approach by attempting to understand how neurons create neural networks that lead to thought. It is hoped that researchers will eventually meet in the middle by approaching the problem from each direction.

Stages of Cognitive Development

The following table summarizes the stages of cognitive development identified by the Swiss psychologist Jean Piaget (See Table 2-1).

TABLE 2-1 Piaget's Stages of Cognitive Development.

Stage	Age*	Purpose	Key Terms for This Stage
Sensory Motor	Birth–2 years	Coordination of sensations with voluntary motor movement	**Object permanence:** knowledge that an object continues to exist even if hidden from view
Preoperational	2–7 years	Increased use of mental images and symbols	**Egocentrism:** difficulty sharing another person's viewpoint **Animism:** the belief that all things are living
Concrete Operational	7–11 years	Increased problem-solving abilities; mastery of conservation; much of cognition and mental operations are limited to tangible objects and actual events	**Conservation:** the amount inside a container is the same even if the dimensions of the container change **Reversibility:** the ability to understand that actions can be reversed **Decentration:** the ability to focus on multiple aspects of a problem simultaneously
Formal Operational	11–Adult	Begin to understand and mentally manipulate abstract constructs (e.g., ethics, free will, love)	**Hierarchical classification:** the ability to focus on multiple types of classification simultaneously

* Cross-culturally, children progress through the stages in the same order, but the timeline/ages may be different.

Other researchers have identified the **information processing approach** as an alternative to Piaget's developmental stages. According to this cognitive development theory, people are active problem solvers who make decisions based on environmental demands. The theory attempts to explain how the same biological brains can lead people to take very different approaches to life. It also explains how cognitive development can continue into adulthood. After age 60, the human brain shrinks both in size and in the number of active neurons. While that loss sounds concerning, it is not directly correlated to dementia. On average, cognitive speed declines. However, problem-solving ability remains steady. The higher the original cognitive capacity and the more cognitively active an older individual stays, the slower the cognitive decline; this is true for both age-related and disease-related (e.g., Alzheimer's) decline.

CULTURE, ENVIRONMENT, AND BIOLOGY IN COGNITIVE DEVELOPMENT

A number of biological factors may impact a child's cognitive development. Some of these may be genetic (e.g., trisomy 21), due to the health of the mother (e.g., nutrition status or drug use), or environmental (e.g., exposure to lead paint in the home). However, beyond these factors, there continues to be a great deal of argument about how much of cognitive development is innate and how much is learned or environmental.

Cultural environment certainly plays a role in cognitive development. The stages of cognitive development appear to occur in the same order cross-culturally, but the timeline for developing various cognitive processes may be different across cultures because different cultures provide different learning opportunities for cognitive development. A culture that values reading will expose children at a young age to the skills and learning experiences that develop the ability to read, whereas hunter-gatherer cultures will expose children to experiences to help them develop spatial reasoning and psychomotor skills.

PROBLEM SOLVING

There are two general problem-solving methods. The first is the **generate-test method** (also known as "trial and error"). This can be useful when there is a small set of possible solutions, but it is very time-consuming for large possible solution sets. The second is **means-end analysis**. This method uses heuristics and breaks larger problems into subgoals. The solver then works each subgoal to completion.

The American psychologist James Greeno has identified the following three basic types of problems:

1. *Problems that require inducing structure* (e.g., analogies, pattern series). This type requires the solver to identify patterns and relationships among parts of the problem.
2. *Problems that require arrangement of problem items* (e.g., anagrams). This problem type requires a rearrangement of visual or spatial parts of the problem in order to form a solution. The solver often uses the generate-test problem-solving approach.
3. *Problems that require transformation to change aspects of the problem from an initial state to a final state* (e.g., the Tower of Hanoi problem in cognitive psychology). For this type of problem, the solver often uses the means-end problem-solving approach.

There are cultural differences in problem solving. Generally, Eastern Asian cultures are more likely to rely on a holistic cognitive style that focuses on context and relationships. Western European cultures are more likely to use an analytical cognitive approach that focuses on individual aspects of the problem.

Psychologists have identified a number of specific approaches that humans use cross-culturally to solve problems. The use of **algorithms** and **heuristics** allows for mental "shortcuts" based on the individual's previous knowledge. A similar approach is using **analogies** to previous experiences or to turn abstract ideas into more concrete problems to solve the problem (e.g., "achieving world peace is like trying to reduce sibling rivalry"). These analogies are not always appropriate to the problem at hand, but they can give the individual a jump start on problem solving. Another common approach is breaking down a larger problem into subgoals and working toward solutions to the subgoals. When an outcome is known, working backward from the outcome to the current state can be useful. One more common approach is changing the representation of the problem, such as changing written word problems to visual diagrams.

Barriers to Problem Solving

A number of barriers to effective problem solving have been identified. Some of these are external and some are internal to the problem solver. Externally, irrelevant or **extraneous information** can interfere with the efficient solution of a problem, and there may be **unnecessary constraints** that reduce the number of possible solutions. Internally, the individual may have **rigid mental sets** that reduce the ability to view a problem from another perspective. Another internal cognitive bias that interferes is **functional fixedness**, in which an individual has difficulty manipulating aspects of the problem and can use objects or ideas only in a traditional way.

DECISION MAKING

Decision making is more than simple logic. Often emotion and previous experiences create biases and heuristics that play a role in how an individual makes and maintains a decision. **Heuristics** and **algorithms** are cognitive shortcuts that involve scripts and "mental flow charts" that an individual has developed from previous experiences. Research has shown that the more tired people are, the more heavily they rely on these mental shortcuts to base their decisions on because the shortcuts reduce the cognitive load. However, the chosen heuristic may not be appropriate to the situation. By contrast, **intuition** and **insight** are more likely to occur when people have the capacity for a greater cognitive load because these techniques may use subconscious processing of information that informs their decision making and problem solving. You also cannot underestimate the impact (both positive and negative) of emotion on decision making, including allowing the person to make a rapid decision in line with his or her values (e.g., running into the street to save a child from an oncoming car), altering the ability to make any decision (e.g., paralysis from fear), or altering the ability to maintain a decision once it is made (e.g., being either resistant to change or unable to maintain a decision). It is also noteworthy that recent research has suggested that individuals are best at making decisions when only three or four options are available. When choosing among more than three or four options, individuals take longer in their decision making and are not necessarily happier with their choice. This is referred to as the "paradox of choice."

Cognitive Dissonance

Cognitive dissonance occurs when a person's beliefs are not in line (discongruant) with his or her actions or with reality. This dissonance is uncomfortable for most individuals, so the brain develops an explanation to bring beliefs and actions into harmony. The psychologists Amos Tversky and Daniel Kahneman produced a famous series of studies examining how individuals develop explanations for their behavior even when no real explanation exists. Once an individual develops an explanation for his or her behavior, that individual will often be hesitant or uncomfortable with changing that reason even when faced with factual information that conflicts with it. This can lead to extremely strong belief perseverance, overconfidence, and even occasional belligerence.

INTELLIGENCE

Multiple researchers have developed a number of differing theories on intelligence.

- The **triarchic theory of intelligence**, proposed by the American psychologist Robert Sternberg, focuses on intelligent "behavior" as the measurable component

of intelligence. Sternberg identified three critical components to intelligence: (1) **contextual**, culturally based determination of intelligent behavior; (2) **componential**, the cognitive processes that determine intelligent behavior; and (3) **experiential**, how the environment and intelligent behavior interact and how the person learns from this interaction.

- The theory of **eight intelligences**, proposed by the American psychologist Howard Gardner, identified eight different domains: logical/mathematical, linguistic, musical, spatial, interpersonal, intrapersonal, naturalist, and bodily-kinesthetic. Gardner's theory has not yet been widely supported in the research literature.
- In cognitive testing, the integration of multiple areas of intelligence is referred to as the "G-factor," or simply "g," and identifies the domain of **general intelligence** across multiple dimensions. This idea was developed in the early 1900s by the British psychologist Charles Spearman, who noted most people who do well in one area of testing do well in multiple areas of testing (and similarly, those who do poorly are also likely to do poorly across multiple areas of testing). The British psychologist Raymond Cattell broke down the G-factor into **crystallized G(*c*) intelligence** and **fluid G(*f*) intelligence**. G(c) is the ability to use information already learned and includes skills, knowledge, and vocabulary. G(c) improves with age. G(f) is the ability to analyze complex situations, use logical reasoning, and solve problems. This type of intelligence decreases with age and is more susceptible to loss through stroke or brain injury.
- A small but growing understanding of intelligence also involves **emotional intelligence (EI)**. EI involves the ability to understand emotional expression (within a culture) and to use emotion as an effective tool to engage in social interactions. EI research has gained more momentum recently due to the rise in diagnosis of autism spectrum disorders.

NATURE, NURTURE, AND INTELLIGENCE

Genetics/heredity and the environment work together to determine the individual's adult level of intelligence. However, measuring intelligence across cultures can be difficult because of the need to determine what is being defined as "intelligence." The use of a Western education – based definition and poor testing methods were responsible for the spread of a number of incorrect racial and ethnic stereotypes during the 20th century.

Identical twins who were adopted separately at birth are often studied in an attempt to determine how much of intelligence is due to genetics and how much is due to environment. However, research has shown a wide range of estimates on how much of intelligence is attributable to genetics (estimates vary from 40 to

80 percent) and how much is attributable to the environment (from 20 to 60 percent). A few environmental factors are known to affect intelligence, including socialization and gender roles, observational learning, and operant conditioning (being rewarded for some behaviors, such as those that support and increase intelligence, and not for others). Genetically, abnormalities such as trisomy 21 (Down's syndrome) can have a known effect on intelligence. However, there seems to be evidence that each subsequent generation does better on intelligence testing than the previous generation. While this phenomenon has been most widely studied in the United States, there is evidence that it is also occurring in multiple cultures around the world. This is known as the Flynn effect, named for the researcher, James Flynn, who discovered it.

MEASURING INTELLIGENCE

IQ, or **intelligence quotient**, is an attempt to quantify the intelligence of an individual. Modern IQ test scores are based on a normal bell curve where the score of 100 is always the mean and the standard deviation is 15 (see Figure 2-1). Therefore, a person of "average" intelligence is anyone who scores between 85 and 115. This indicates that the person's intelligence quotient lies within the normal distribution of intelligence. Individuals who score two standard deviations below the mean (<70) are classified as intellectually disabled. Individuals scoring two standard deviations above the mean (>130) are classified as gifted. One definition of an individual with a learning disability

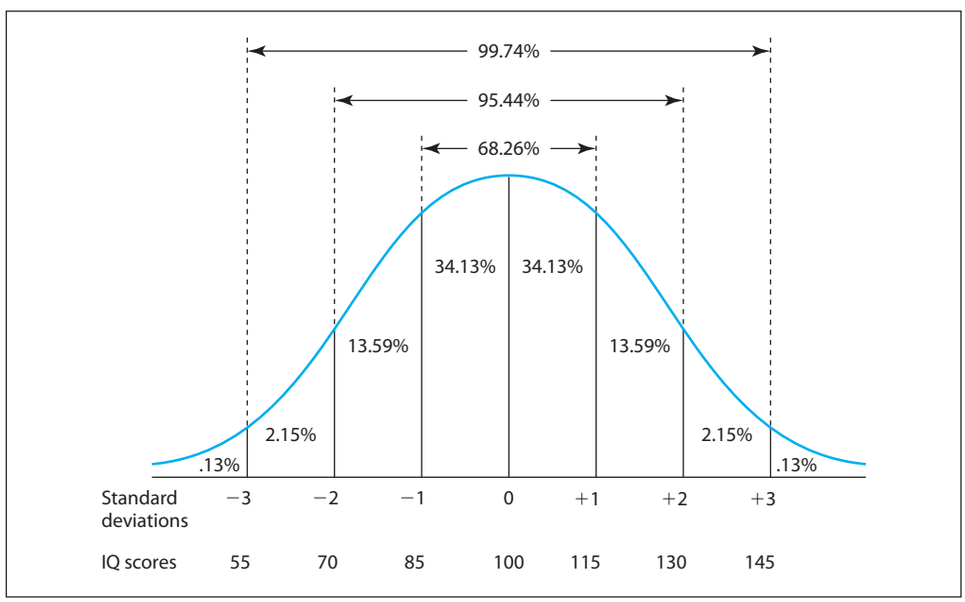

FIGURE 2-1 Distribution of IQ scores along a normal bell curve.

is a person demonstrating average or above-average intelligence who scores 1.5 to 2 (varies based on state law and educational standards) standard deviations below his or her IQ in one specific domain (e.g., IQ = 100, verbal processing = 65 would be a verbal processing disability).

MEMORY

There are a number of different types of memory:

- **Declarative memory** handles factual information. Within declarative memory, there is a separation between **episodic memory** and **semantic memory**. Episodic memory is focused on personal facts and chronological information connected to your individual recollections (e.g., you can recall and consciously reexperience the birthday party where your friends sang "Happy Birthday" to you for the first time). By contrast, semantic memory is more focused on factual information that is not connected to individual recollection (e.g., you can remember the words to "Happy Birthday" but not recall and consciously reexperience the first time you heard the song).
- **Procedural memory** is more focused on psychomotor memory and the ability to recall psychomotor skills (e.g., throwing a baseball).

Synaptic connections are selectively strengthened during the process of encoding, and these changes in synaptic connections form the basis for memory and learning. Unlike what was once thought, the brain does continue to grow new neurons, prune synaptic connections, and develop new connections throughout an individual's lifetime. The concept of **neural plasticity**, or changes in the brain, refers primarily to changes in synaptic connections rather than to the growth of new neurons. When long-term memory encoding occurs, these memory traces form neural circuits. **Long-term potentiation** describes this phenomenon, in which memory traces create long-lasting excitatory circuits that increase synaptic activity when a memory trace is activated.

Encoding

Encoding is the process of taking external information and transforming it into a format that the brain can use. The first step is attention (controlled by the thalamus and frontal lobe). Then sensory information is formatted via the following four primary pathways that humans use to encode information.

- **Visual encoding** processes written or figure-based information, which is temporarily stored in **iconic memory**.
- **Acoustical encoding** processes verbal language and auditory information. It is often aided by the **phonological loop**, which repeats this information in a person's

echoic memory for improved storage and retrieval. Repetition may also include self-vocalizations to enhance auditory encoding (such as repeating a phone number out loud).

- **Tactile encoding** encodes touch-based information via the somatosensory cortex.
- The **semantic pathway** encodes sensory information that is associated with a particular meaning or context rather than strictly a sensory input.

Enhancing Encoding

There are a number of common methods that people use to enhance encoding and improve memory.

- **Chunking** or combining information, is a useful tool to aid in encoding information in short-term memory. Short-term memory is known to have a limited amount of storage (7 ± 2 items), as shown by the work of psychologist George A. Miller. However, chunking allows for more information storage (e.g., recalling the numbers 177614921812 is difficult, but chunking the same information into the more familiar formats of 1776-1492-1812 turns the same numbers into much easier-to-remember chunks).
- **Mnemonics** are also frequently used to recall information. Acronyms (e.g., common medical acronyms such as *ABC* for airway, breathing, and circulation) and physical cues (e.g., using the knuckles on your hand to recall short versus long months) are two of the most popular.
- **State-dependent memory** is a unique encoding/recall process that uses environmental cues to enhance encoding and recall of information. Research into this type of memory shows that if you learn information in a specific environment and body state, you will better recall that information when you are in the same state (e.g., you will recall testing information better if you learn the information in the same type of situation and body state as when you take the test).
- **Elaborative** or **connective encoding** is a process that assists with memory by attaching novel information to information that is already known. Making connections to already known information enhances an individual's ability to encode new information and store it in long-term memory.

Memory Storage

There are three types of memory storage.

- **Sensory memory** is the first stage of memory consolidation. It is extremely brief, 0.5 seconds (visual) to 2–3 seconds (auditory), storage of the information people

take in from their senses. Only critical information from the vast amounts that people take in is passed on to short-term, or working, memory.

- **Short-term, or working, memory** was classically defined by the American psychologist George A. Miller. He found that the human brain can typically hold 7 ± 2 items at any one time, though that amount may be increased with "chunking." Short-term, or working, memory (what you hold actively in your mind at any one time) generally lasts about 30 seconds. Acoustic encoding is strongly associated with this form of memory (e.g., repeating someone's telephone number out loud until you can write it down). Biologically, this process involves making biochemical changes to create proteins that enhance already existent synaptic connections.
- In **long-term memory**, information is transmitted from short-term consciousness to longer-term storage. It is believed that long-term memory is essentially unlimited and can last a lifetime. Semantic/meaningful coding is primarily associated with this type of memory. Biologically, this type of memory is associated with the development of new synaptic connections called **long-term potentiation**. Development of these connections is associated with REM stage sleep. The hippocampus in the temporal lobe is thought to be critical in consolidating long-term memories. But this process also includes a number of areas called the **medial temporal lobe memory system.** The amygdala is critical to forming and retaining memories associated with fear, anxiety, and the development of phobias. And memory storage is scattered across multiple areas in the cortex.
- **Semantic networks** are the memory connections made by an individual's lived history and the individual's memory of events that occur during his or her lifetime. **Spreading activation** occurs when the recall of one meaningful piece of information triggers the recall of other pieces of information (e.g., the recall of a childhood memory leads to remembering other details of your childhood).

Retrieval

Retrieval is the process of getting stored information back into conscious memory. There are two types of retrieval processes. **Recognition** is the more basic retrieval process; it requires only that the individual identify that he or she has learned this information in the past (e.g., the answers to multiple-choice test questions). This process is simple and requires little cognitive load. The more complex version of retrieval is **free recall**; this requires more cognitive load. **Recall** is the ability to access the information directly from the memory (e.g., fill-in-the-blank test questions).

Humans use a number of **retrieval cues** to help with the recall of information and to relearn information. Examples are context cues (where the information was learned) or activating the semantic network of that information. When you cannot freely recall a piece of information, retrieval cues can assist by activating other neurons associated

with that information (e.g., you cannot recall someone's name, but you begin to think about other people in that social network and the name pops back into your mind). Because of the spreading activation that occurs via semantic networks, retrieval can also take the form of "relearning." **Relearning** happens when a person learns the same information a second time. There is a more rapid gain of information when it is relearned than when it is learned initially. It is always easier to relearn a piece of information than to learn a new piece, because it is only a matter of reactivating dormant connections in the brain.

Strong emotions may enhance the encoding and retrieval of **emotion-congruent** information. This is known as "flashbulb memory," in which powerful emotions create a vivid recollection (e.g., "Where were you during the 9/11 attacks?"). These memories degrade at the same rate as other memories, but humans often (incorrectly) continue to believe that the flashbulb memories are accurate. This can create difficulties with eyewitness testimony that occurs years after the event, as cognitive psychologist Elizabeth Loftus has found in her research. Emotions can also create difficulties with the recall of emotional-discongruent information (e.g., it can be more difficult to recall information learned during a happy experience when you are sad).

Forgetting

Memory dysfunctions can occur naturally. A retrieval failure may occur due to failure of the encoding specificity principle, in which the retrieval cue does not correspond well to the encoded memory. It could also be due to ineffective coding and low attention levels during learning. Either of these could result in the "tip of the tongue" phenomenon in which the individual cannot recall needed information. Memory dysfunctions can also occur due to brain injury, stroke, or disease. Two of the major disease processes associated with memory loss include Pick's and Alzheimer's diseases, in which beta-amyloid plaques interfere with synapse transmission allowing recall of information, and Wernicke-Korsakoff syndrome, in which prolonged alcohol use results in difficulty encoding new information and recalling previously learned information. Encoding and retrieval begin to decline after the age of 60. Aging individuals who maintain their cognitive activity show significantly less decline than those who do not. The effectiveness of working memory and episodic memory do show age-related declines. However, crystallized memory and procedural memory do not appear to be significantly affected in normal aging.

Measures of **retention** assess how humans hold onto information and how quickly they forget learned information. **Decay theory** states that forgetting occurs when the memory synapses degrade with disuse over the passage of time. The German psychologist Hermann Ebbinghaus was famous for establishing the empirical **forgetting curve** to show how quickly information degrades in the human memory (see Figure 2-2). He showed that recall degrades more rapidly than recognition memory.

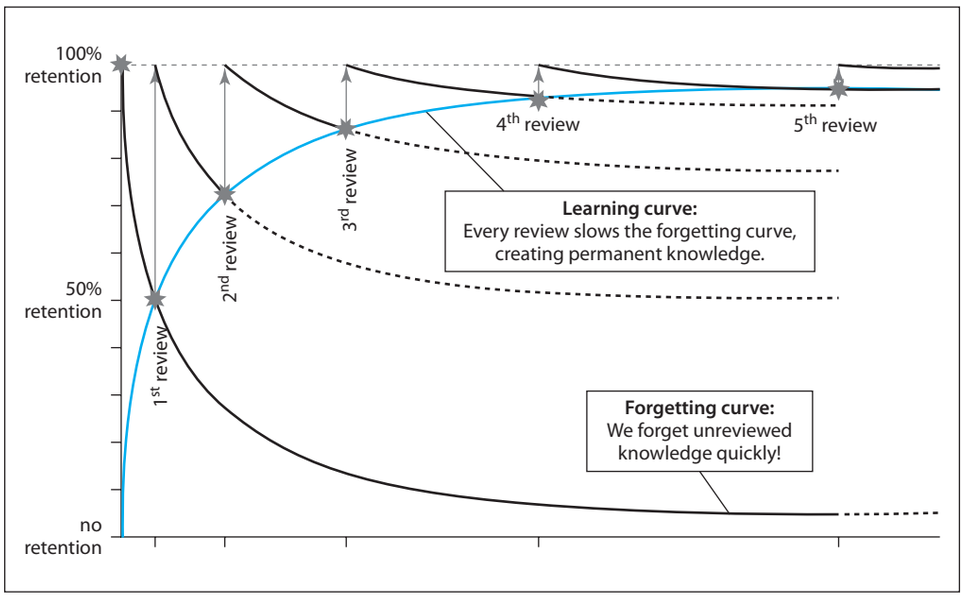

FIGURE 2-2 The learning curve and the forgetting curve.

Interference

Memory interference can also impact memory when the encoding of information is interfered with or prevented. **Retroactive interference** occurs when new information interferes with previously learned information. **Proactive interference** occurs when the old information prevents learning of new information. Both retroactive and proactive forms of interference can prevent encoding or retrieval of appropriate information (see Figure 2-3).

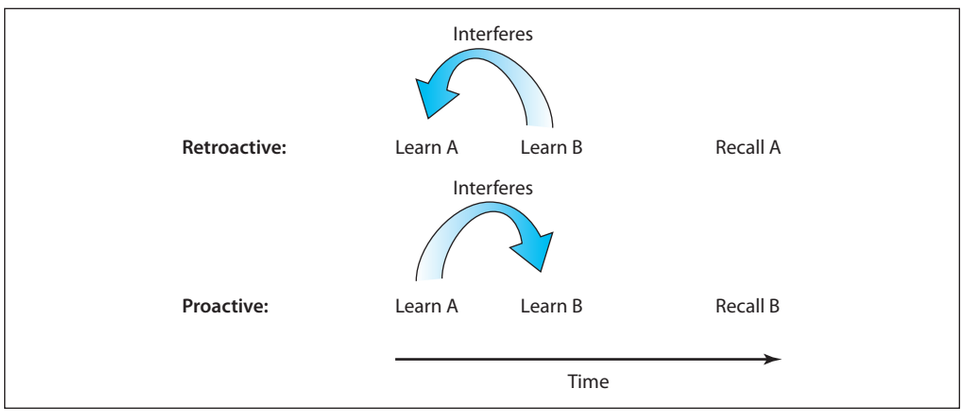

FIGURE 2-3 Retroactive and proactive interference.

LANGUAGE

There are three major theories of language development: learning/behaviorist, nativist, and interactionist. Each of these theories addresses the relative roles of nature versus nurture in language development.

- **Learning/behaviorist.** This theory was proposed by the American psychologist B. F. Skinner, who stated that children learn language in the same manner that they learn every other cultural norm, by observing and imitating those around them. Adults shape children's vocalizations by reinforcing with praise or providing the requested object. Children then learn to imitate the adults around them and develop language skills. Learning theory holds that brain structures may have emergent properties that grow as language vocalizations are shaped by external experiences.
- **Nativist.** The American linguist Noam Chomsky challenged the learning approach by claiming that children could not possibly learn every word combination and sentence before using it, and therefore language must have innate properties. Proponents point to research that shows that language acquisition in children occurs the same way across cultures. They argue that the basic structure and drive for language development is a function of the **language acquisition device (LAD)** in the brain. Chomsky has argued that language is unique to humans. When a research team taught a chimpanzee sign language, the animal was humorously named "Noam Chimpsky"; reportedly, Dr. Chomsky was not amused. The nativist-LAD approach is supported if an innate drive for language explains why children will often develop a means to communicate even when they do not speak the same language. A famous example is the development of the French Creole language in Louisiana by children placed in a nursery from different language cultures.
- **Interactionist.** Later researchers have combined these two earlier approaches and support the idea that some aspects of language are inherent to humans, while other aspects are learned. However, the specifics of which aspects are inherent and which are learned are still controversial.

Influence of Language on Cognition

Cross-culturally, children usually speak their first words at the age of 10 to 12 months. The first 10 to 15 words are slow in developing, but then between 1 and 2 years of age, children go through a vocabulary spurt. Research shows that bilingual children do not develop language more slowly. They may initially have a smaller vocabulary in each language, but they have a greater total vocabulary across both. By around 8 years old, bilingual children have approximately the same vocabulary level as their monolanguage peers. When socioeconomic status is controlled, research shows that bilingual

children tend to have greater analytical ability, selective attention, and cognitive flexibility, but slower language-processing speed than their monolanguage peers.

The form and structure of the language you use shapes how you view the world. Language can change your attitudes, worldviews, and self-identity. In a study by American sociolinguist Susan Ervin-Tripp, bilingual Japanese women were asked to complete a set of sentences. When responding in English, the women communicated more North American-European values in relation to a woman's role in society and the economy. When responding in Japanese and using the same statements, the women communicated more traditional Japanese views on women's self-identity and cultural roles. So even the language used moment-to-moment can alter how someone interacts with the world.

Different Brain Areas Control Language and Speech

The neurons involved in language are generally located in the left hemisphere of the brain. Broca's area in the left frontal lobe is predominantly responsible for the production of speech (see Figure 2-4). Someone with damage in this area would understand language but would have difficulty producing the words to respond. In contrast, Wernicke's area in the left temporal lobe is responsible for the understanding of language.

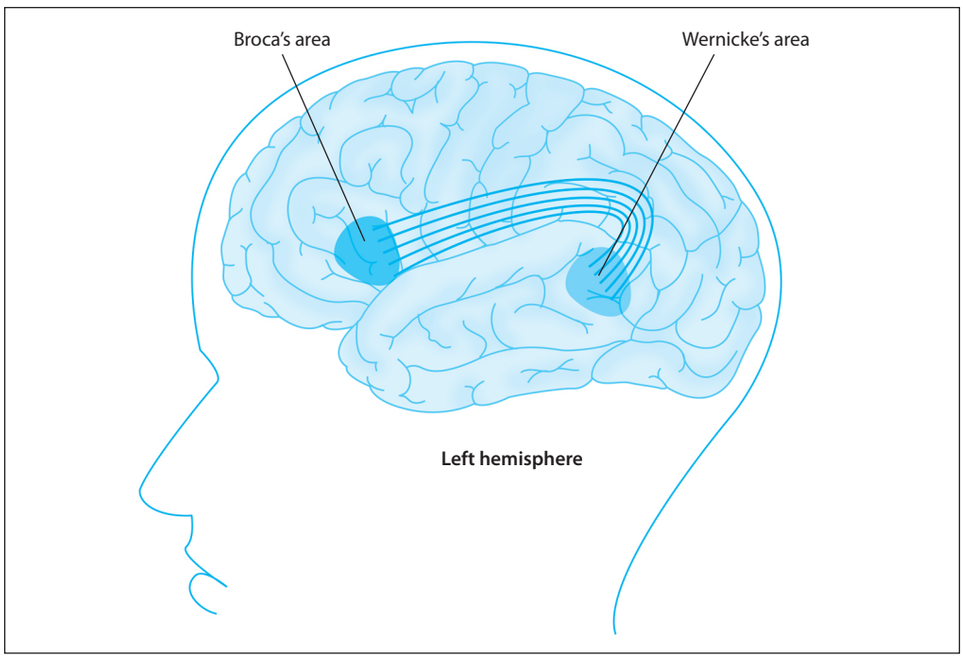

FIGURE 2-4 Broca's area (speech) and Wernicke's area (language).

A person with damage in the Wernicke's area could produce words, but it would be "word salad," or a string of words that do not make sense together. That person would also have difficulty understanding statements made to him or her.

However, do not confuse Wernicke's area (anatomical location) with Wernicke's encephalopathy or **Wernicke-Korsakoff syndrome**, which is the result of prolonged thiamine (Vitamin B_1) deficiency, usually in the context of alcohol addiction. Wernicke's encephalopathy does not primarily affect Wernicke's area. Karl Wernicke was a very prolific German neurologist who put his name on many of his discoveries. His work was great for science, but confusing for students.