Chapter 1

Learning the First Language(s)

One of the most extraordinary features of the human brain is its ability to acquire spoken language quickly and accurately. We are born with an innate capacity to distinguish the distinct sounds (phonemes) of all the languages on this planet, with no predisposition for one language over another. Eventually, we are able to associate those sounds with arbitrary written symbols to express our thoughts and emotions to others.

Other animals have developed sophisticated ways to communicate with members of their species. Birds and apes bow and wave appendages, honeybees dance to map out the location of food, and even one-celled animals can signal neighbors by emitting an array of various chemicals. The communicative systems of vervet monkeys, for instance, have been studied extensively. They are known to make up to ten different vocalizations. Amazingly, many of these are used to warn other members of the group about *specific* approaching predators. A "snake call" will trigger a different defensive strategy than a "leopard call" or an "eagle call." Apes in captivity show similar communicative abilities, having been taught rudimentary sign language and the use of lexigrams—symbols that do not graphically resemble their corresponding words—and computer keyboards. Some apes, such as the famous Kanzi, have been able to learn and use hundreds of lexigrams (Savage-Rumbaugh & Lewin, 1994). However, although these apes can learn a basic syntactic and referential system, their communications certainly lack the complexity of a full language.

By contrast, human beings have developed an elaborate and complex means of spoken communication that many say is largely responsible for our place as the dominant species on this planet. To accomplish this required both the development of the anatomical apparatus for precise speech (i.e., the larynx and vocal cords) along with the necessary neurological changes in the brain to support language itself. The enlargement of the larynx probably occurred as our ancestors began to walk upright. Meanwhile, as brain development became more complex, regions emerged that specialized in sound processing as well as musical and arithmetic notations (Vandervert, 2009). Somewhere along the way, too, a gene variation known as *FOXP2* appeared. Geneticists believe it contributed significantly to our ability to create precise speech. Evolutionary anthropologists are still debating whether language evolved slowly as these physical and cerebral capabilities were acquired, resulting in a period of semilanguage, or whether it emerged suddenly once all these capabilities were available.

SPOKEN LANGUAGE COMES NATURALLY

Spoken language is truly a marvelous accomplishment for many reasons. At the very least, it gives form to our memories and words to express our thoughts. A single human voice can pronounce all the hundreds of vowel and consonant sounds that allow it to speak any of the estimated 6,500 languages that exist today. (Scholars believe there were once about 10,000 languages, but many have since died out.) With practice, the voice becomes so fine-tuned that it makes only about one sound error per million sounds and one word error per million words (Pinker, 1994). Figure 1.1 presents a general timeline for spoken language development during the first three years of growth. The chart is a rough approximation. Some children will progress faster or slower than the chart indicates. Nonetheless, it is a useful guide to show the progression of skills acquired during the process of learning any language.

Before the advent of scanning technologies, we explained how the brain produced spoken language on the basis of evidence from injured brains. In 1861, French physician Paul Broca noticed that patients with brain damage to an area near the left temple understood language but had difficulty speaking, a condition known as aphasia. About the size of a quarter, this region of the brain is commonly referred to as Broca's area (Figure 1.2).

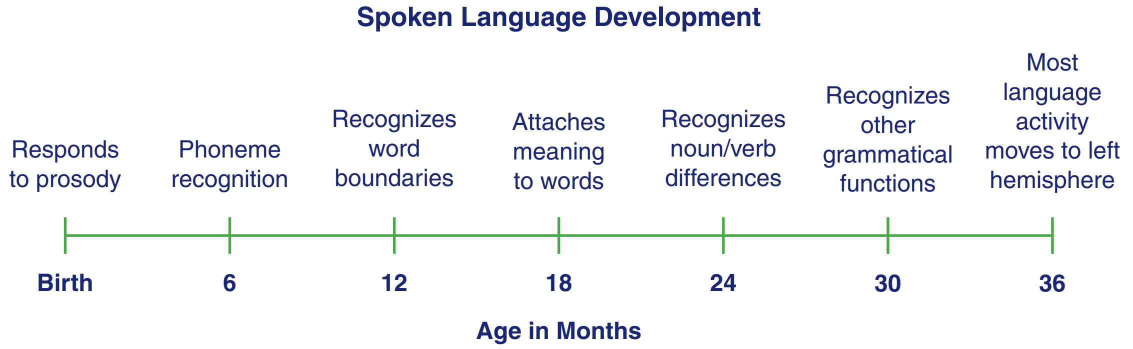

Figure 1.1 An average timeline of spoken language development during the child's first three years. There is considerable variation among individual children as visual and auditory processing develop at different rates.

In 1881, German neurologist Carl Wernicke described a different type of aphasia—one in which patients could not make sense out of words they spoke or heard. These patients had damage in the left temporal lobe. Now called Wernicke's area, it is located above the left ear and is about the size of a silver dollar. Those with damage to Wernicke's area could speak fluently, but what they said was quite meaningless. Ever since Broca discovered that the left hemisphere of the brain was specialized for language, researchers have attempted to understand the way in which normal human beings acquire and process their native language.

Processing Spoken Language

Recent research studies using imaging scanners reveal that spoken language production is a far more complex process than previously thought. When preparing to produce a spoken sentence, the brain uses not only Broca's and Wernicke's areas but also calls on several other neural networks scattered throughout the left hemisphere. Nouns are processed through one set of patterns; verbs are processed by separate neural networks. The more complex the sentence structure, the more areas that are activated, including some in the right hemisphere.

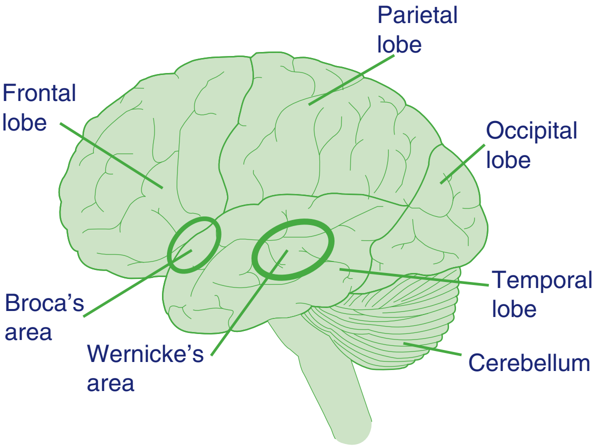

Figure 1.2 The language system in the left hemisphere is comprised mainly of Broca's area and Wernicke's area. The four lobes of the brain and the cerebellum are also identified.

In most people, the left hemisphere is home to the major components of the language processing system. Broca's area is a region of the left frontal lobe that is believed to be responsible for processing vocabulary, syntax (how word order affects meaning), and rules of grammar. Wernicke's area is part of the left temporal lobe and is thought to process the sense and meaning of language. However, the emotional content of language is governed by areas in the right hemisphere. More recent imaging studies have unexpectedly found that the cerebellum—long thought to be involved mainly in the planning and control of movement—also seems to be involved in language processing (Booth, Wood, Lu, Houk, & Bitan, 2007; Ghosh, Tourville, & Guenther, 2008). Four decades ago, researchers discovered that infants responded to speech patterns (Eimas, Siqueland, Jusczyk, & Vigorito, 1971). More recently, brain imaging studies of infants as young as 4 months of age confirm that the brain possesses neural networks that specialize in responding to the auditory components of language. Dehaene-Lambertz (2000) used electroencephalograph (EEG) recordings to measure the brain activity of 16 four-month-old infants as they listened to language syllables and acoustic tones. After numerous trials, the data showed that syllables and tones were processed primarily in different areas of the left hemisphere, although there was also some right-hemisphere activity. For language input, various features, such as the voice and the phonetic category of a syllable, were encoded by separate neural networks into sensory memory.

Subsequent studies have supported these results (Bortfeld, Wruck, & Boas, 2007; Friederici, Friedrich, & Christophe, 2007). These remarkable findings suggest that even at this early age, the brain is already organized into functional networks that can distinguish between language fragments and other sounds. Other studies of families with severe speech and language disorders isolated a mutated gene—the *FOXP2* mentioned earlier—believed to be responsible for their deficits. This discovery lends further credence to the notion that the ability to acquire spoken language is encoded in our genes (Gibson & Gruen, 2008; Lai, Fisher, Hurst, Vargha-Khadem, & Monaco, 2001). The apparent genetic predisposition of the brain to the sounds of language explains why most young children respond to and acquire spoken language quickly. After the first year in a language environment, the child becomes increasingly able to differentiate those sounds heard in the native language and begins to lose the ability to perceive other sounds (Conboy, Sommerville, & Kuhl, 2008).

> *The ability to acquire language appears to be encoded in our genes.*

Gestures appear to have a significant impact on a young child's development of language, particularly vocabulary. Studies show that a child's gesturing is a significant predictor of vocabulary acquisition. The daily activities for children between the ages of 14 and 34 months were videotaped for 90 minutes every four months. At 42 months, children were given a picture vocabulary test. The researchers found that child gesture use at 14 months was a significant predictor of vocabulary size at 42 months, above and beyond the effects of parent and child word use at 14 months. These results held even when background factors such as socioeconomic status were controlled (Rowe, Özçaliskan, & Goldin-Meadow, 2008).

Brain Areas for Logographic and Tonal Languages

Functional magnetic resonance imaging (fMRI) and magnetoencephalography (MEG) studies have shown that native speakers of other languages, such as Chinese and Spanish, also use these same brain regions for language processing. Native Chinese speakers, however, showed additional activation in the right temporal and parietal lobe regions. This may be because Chinese is a logographic language and native speakers may be using the right hemisphere's visual processing areas to assist in processing language interpretation (Pu et al., 2001; Valaki et al., 2004). Additional evidence for this involvement of visual areas in the brain comes from imaging studies of Japanese participants reading both the older form of Japanese logographs (called *kanji*) and the simplified syllabic form (called *hiragana*). Kanji showed more activation than hiragana in the right-hemisphere visual processing areas, while hiragana showed more activation than kanji in the left-hemisphere areas responsible for phonological processing

(Buchweitz, Mason, Hasegawa, & Just, 2009). Another interesting finding among native Chinese speakers was that the brain area processing vowel sounds was separate from the areas processing variations of tone because Chinese is a tonal language (Green, Crinion, & Price, 2007; Liang & van Heuven, 2004).

Role of the Mirror Neuron System

To some degree language acquisition is dependent on imitation. Babies and toddlers listen closely to the sounds in their environment as their brain records those that are present more frequently than others. Eventually the toddler begins to repeat these sounds. Whatever response the toddlers get from adult listeners will affect their decision to repeat, modify, or perhaps discard the sounds they just uttered. This ongoing process of trying specific sounds and evaluating adult reactions is now believed to be orchestrated by the recently discovered *mirror neuron system.*

It seems the old saying “monkey see, monkey do” is truer than we would ever have believed. Scientists using brain imaging technology recently discovered clusters of neurons in the premotor cortex (the area in front of the motor cortex that plans movements) firing just before a person carried out a planned movement. Curiously, these neurons also fired when a person saw someone else perform the same movement. For example, the firing patterns of these neurons that preceded the subject grasping a pencil was identical to the pattern when the subject saw someone else do the same thing. Thus, similar brain areas process both the *production* and *perception* of movement (Fadiga, Craighero, & Olivier, 2005; Iacoboni et al., 2005). Neuroscientists believe these mirror neurons are responsible for helping babies and toddlers imitate the movements, facial expressions, emotions, and sounds of their caregivers. Subsequent studies suggest that the mirror neuron system also helps infants develop the neural networks that link the words they hear to actions of adults they see in their environment (Arbib, 2009).

Gender Differences in Language Processing

One of the earliest and most interesting discoveries neuroscientists made with functional imaging was that there were differences in the way male and female brains process language. Male brains tend to process language in the left hemisphere, while most female brains process language in both hemispheres. Figure 1.3 shows representational fMRIs with the solid white areas indicating areas of the brain that were activated during language processing

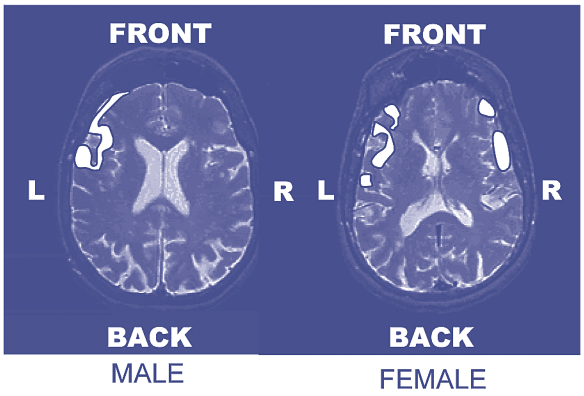

Figure 1.3 These are combined representational fMRIs showing the solid white areas of the male and female brains that were activated during language processing (Clements et al., 2006; Shaywitz et al., 1995).

(Burman, Bitan, & Booth, 2008; Clements et al., 2006; Shaywitz et al., 1995). A study of native Chinese speakers yielded similar findings (Hsiao & Shillcock, 2005).

Another interesting gender difference is the observation that the large bundle of neurons that connects the two hemispheres and allows them to communicate (called the *corpus callosum*) is proportionately larger and thicker in the female than in the male. Assuming function follows form, this difference implies that information travels between the two cerebral hemispheres more efficiently in females than in males. The combination of dual-hemisphere language processing and more efficient between-hemisphere communications may account for why most young girls generally acquire spoken language easier and more quickly than most young boys.

Nonetheless, the gender-difference debate continues. Some researchers suggest that these gender differences are minimal and of little importance as we age (e.g., Sommer, Aleman, Somers, Boks, & Kahn, 2008; Wallentin, 2009). But others maintain that these differences continue to affect the way each gender uses and interacts with language, even as adults (e.g., Guiller & Durndell, 2007; Jaušovec & Jaušovec, 2009).

STRUCTURE OF LANGUAGE

At first glance, the title of this section, “Structure of Language,” seems like an impossible task when one considers that there are more than 6,000 distinct languages—not counting dialects—spoken on this planet. Although the structures of these languages vary widely, there are some common elements. Obviously, all spoken language begins with sounds, so we will begin this discussion looking at sound patterns and how they are combined to make words. Our next step is to examine the rules that allow words to be combined into sentences that make sense and communicate information to others.

Despite the many different ways to write language, all beginning language speakers face the same task: making sense of sounds.

Many of the examples used will come from English to make it easier for the reader to follow the discussion. However, a few examples from other languages will also be used to explain deviations from English, particularly the Romance languages (these include French, Italian, Portuguese, Romanian, and Spanish). The main task here is to explain how *spoken* language is acquired because for most children, they speak their native tongue at least several years before they face having to learn to *read* it. This is an important point to remember because, although there are many different ways to write language—such as the Roman, Greek, Cyrillic, Arabic, and Hebrew alphabets as well as the logograms of Japanese and Chinese—all beginning language speakers face the same task: making sense of sounds.

Learning Phonemes

All languages consist of distinct units of sound called *phonemes*. Although each language has its own unique set of phonemes, only about 150 phonemes comprise all the world's languages. These phonemes consist of all the speech sounds that can be made by the human voice apparatus. Phonemes combine to form syllables. For example, in English, the consonant sound "t" and the vowel sound "o" are both phonemes that combine to form the syllable *to-*, as in *tomato.* Although the infant's brain can perceive the entire range of phonemes, only those that are repeated get attention, as the neural networks reacting to the unique sound patterns are continually stimulated and reinforced.

At birth, or some researchers say even before birth (Pocaro et al., 2006), babies respond first to the prosody—the rhythm, cadence, and pitch—of their mothers' voice, not to the words. Around the age of 6 months or so, infants start babbling, an early sign of language acquisition. The production of phonemes by infants is the result of genetically determined neural programs; however, language exposure is environmental. These two components interact to produce an individual's language system and, assuming no abnormal conditions, sufficient competence to communicate clearly with others. Their babbling consists of all those phonemes, even ones they have never heard. Within a few months, however, pruning of the phoneme networks begins, and by about one year of age, the surviving neural networks focus on the sounds of the language being spoken in the infant's environment (Beatty, 2001).

Learning Words and Morphemes

The next step for the brain is to detect words from the stream of sounds it is processing. This is not an easy task because people do not pause between words when speaking. Yet the brain has to recognize differences between, say, *green house* and *greenhouse*. Studies show that parents help this process along by slipping automatically into a different speech pattern when talking to their babies than when speaking to adults. Mothers tend to go into a teaching mode with the vowels elongated and emphasized. They speak to their babies in a higher pitch, with a special intonation, rhythm, and feeling. Researchers refer to this maternal speaking pattern as *motherese,* and suggest that mothers are instinctively attempting to help their babies recognize the sounds of language. Mothers use this pattern in other languages as well, such as Russian, Swedish, and Japanese (Burnham, Kitamura, & Vollmer-Conna, 2002).

Remarkably, babies begin to distinguish word boundaries by the age of 8 months even though they don't know what the words mean (Singh, 2008; Yeung & Werker, 2009). They now begin to acquire new vocabulary words at the rate of about 7 to 10 a day. By the age of 10 to 12 months, the toddler's brain has begun to distinguish and remember phonemes of the native language and to ignore foreign sounds. For example, one study showed that at the age of 6 months, American and

Japanese babies are equally good at discriminating between the "l" and "r" sounds, even though Japanese has no "l" sound. However, by age 10 months, Japanese babies have a tougher time making the distinction, while American babies have become much better at it. During this and subsequent periods of growth, one's ability to distinguish native sounds improves, while the ability to distinguish nonnative speech sounds diminishes (Cheour et al., 1998). Soon, *morphemes,* such as *-s, -ed,* and *-ing,* are added to their speaking vocabulary. At the same time, working memory and Wernicke's area are becoming fully functional so the child can now attach meaning to words. Of course, learning words is one skill; putting them together to make sense is another, more complex skill.

Vocabulary Gaps in Toddlers

In the early years, toddlers acquire most of their vocabulary words from their parents. Consequently, children who experience frequent adult-to-toddler conversations that contain a wide variety of words will build much larger vocabularies than those who experience infrequent conversations that contain fewer words. The incremental effect of this vocabulary difference grows exponentially and can lead to an enormous word gap during the child's first three years.

A particularly significant two-part longitudinal study (Hart & Risley, 2003) documented the vocabulary growth of 42 toddlers from the age of 7 to 9 months until they turned 3 years old. Because parental vocabulary is closely associated with their socioeconomic status (SES), part one of this study looked at toddlers in families from three different groups. On the basis of occupation, 13 of the families were upper SES, 23 were middle-lower SES, and 6 were on welfare. By the time the children were 3 years old, the researchers had recorded and analyzed over 1,300 hours of casual conversations between the children and their parents. To their surprise, the analysis showed a wide gap in the number of words present in the vocabularies of the children based on their SES. Children from the welfare families had an average recorded vocabulary size of just 525 words. Those from the middle-lower SES had 749 words, while the children in the upper SES had average vocabularies of 1,116 words (see Table 1.1). Furthermore, the children from welfare families were adding words to their vocabulary more slowly than the other children throughout the length of the study.

Table 1.1 English Vocabulary Size at Three Years of Age in Various Economic Groups

Socioeconomic Group	Average Number of Words in Vocabulary
Upper	1,116
Middle-Lower	749
Welfare	525

SOURCE: Hart & Risley, 2003

Part two of the study was conducted six years later. The researchers were able to test the language skills of 29 of these children who were then in third grade. Test results showed that the rate of early vocabulary growth was a strong predictor of scores at ages 9 to 10 on tests of vocabulary, listening, speaking, syntax, and semantics. This study points out how important the early years are in developing a child's literacy and how difficult it is to equalize children's preschool experiences with language.

In the United States, early literacy problems can be addressed successfully through the publically funded birth-to-school programs now available in several states. In these programs, school district personnel meet regularly with parents of infants in low SES households and provide them with inexpensive, age-appropriate resources to use with their children during the preschool years. The idea is to build the child's vocabulary and exposure to enriched language before entering school.

As for young children who speak languages other than English, the size of their mental lexicon will also be determined largely by the richness and breadth of the exposure they have had to vocabulary words in their native language. This in turn will have an impact on how well they learn English because their brain will usually attempt to match a new English word with its counterpart stored in the child's native language lexicon. Furthermore, one of the most reliable predictors of how well youngsters will learn to *read* is the size of their mental lexicons (Sousa, 2005).

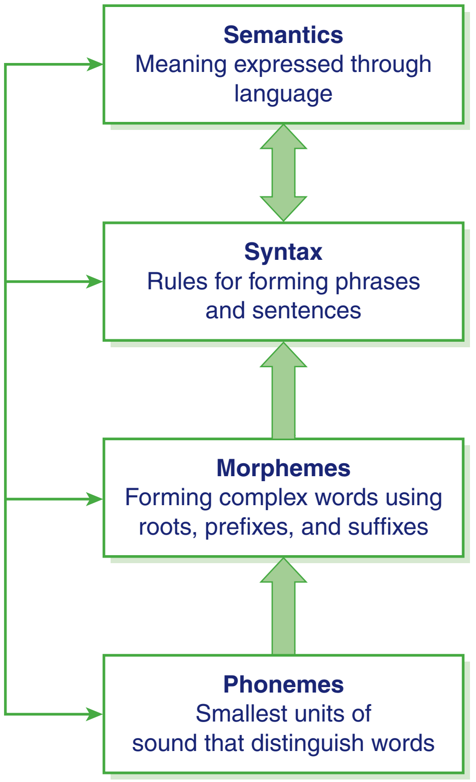

Figure 1.4 The diagram represents the levels of hierarchy in language and in language acquisition. In early language learning, the process usually flows from the bottom to the top, as indicated by the white arrows. But as the learner becomes more fluent in language, recycling from the top to lower levels also occurs, as indicated by the arrows to the left.

Syntax and Semantics

Language Hierarchy

With more exposure to speech, the brain begins to recognize the beginnings of a hierarchy of language (Figure 1.4). Phonemes, the basic sounds, can be combined into morphemes, which are the smallest units of a language that have meaning. Through a set of conventions, morphemes are combined into words. These words may accept prefixes, suffixes, and infixes (insertions), and may undergo a change of consonants or vowels. A part may be repeated as, for example, in Malay where the plural of *orang* ("person") becomes *orang-orang.*

In many languages words are modified for person, number, tense, definiteness (as in English, the difference between *a* and *the*), and mood (e.g., indicative, imperative, subjunctive). Word inflection can be relatively easy, as in Turkish, or it can be a combinational nightmare, as in Russian. Yet some languages, for instance, Chinese, do not inflect words at all because their morphology consists of compounding and a few derivations. Many languages sort verbs into categories, usually "regular" and "irregular." Words can be put together according to the rules of syntax (word order) to form phrases and sentences with meaning. In English, the difference in meaning (semantics) between the sentences "The woman chased the dog" and "The dog chased the woman" results from a different word order, or syntax. Toddlers show evidence of their progression through the syntactic and semantic levels in English when simple statements, such as *Candy,* evolve to more complex ones, *Give me candy.* They also begin to recognize that shifting the words in sentences can change their meaning.

The Syntactic Network

Syntax refers to the rules and conventions that govern the *order* of words in phrases, clauses, and sentences. Each language has its own rules of syntax. This chapter presents a few differences in syntax found among common world languages. Chapter 2 describes how English syntax can pose problems for non-English-speaking individuals who are attempting to learn English.

SVO, SOV, and VSO Strings. One of the rules of sentence word order common to many languages involves the placement of the subject, verb, and object. In some languages, such as English, German, and the Romance languages, the common word order is subject-verb-object—or SVO. An example in English, German, French, and Spanish, respectively: *I see the train, Ich sehe den Zug, Je vois le train,* and *Veo el tren.* Other languages, such as Japanese, use a subject-object-verb order—or SOV (*I the train see*). Actually, until a few centuries ago, English also allowed the SOV sequence in certain formal settings. This can be recognized in archaic expressions that still exist today, such as *With this ring I thee wed* and *Till death do us part.* Still other languages, such as Modern Irish (Gaelic), use the VSO string (*See I the train*).

Some languages, such as Latin and Finnish, avoid the word order problem by adding prefixes and suffixes to verbs and nouns to identify the subject and object. For example, in Latin, the verb forms *amo* (I love), *amas* (you love), and *amat* (he/she loves) use the suffixes *-o, -as, -at* to identify the subject of the sentence. In Finnish, the English word *school* when used as the subject of a sentence is *koulu,* but when used as the object as in *to school,* it becomes *kouluun,* while *in school* becomes *koulussa.*

Adjective-Noun Order. In English and German, the adjective precedes the noun it modifies; in Romance languages, the adjective generally follows the noun. The English phrase *white hat* becomes *weißer Hut* in German, but *chapeau blanc* in French, *cappello bianco* in Italian, and *sombrero blanco* in Spanish. However, there are infrequent occasions when the adjective will be placed before the noun for special emphasis as in French, *Oh, le pauve homme* (Oh, the poor man!).

Subject-Prominent and Topic-Prominent Languages. Some languages, like the Romance languages and English, are subject prominent in that every sentence must have a subject in the initial position, even if the subject plays no role, as in *It is snowing* or *It is possible that the sun will shine today.* Other languages, like Japanese, Mandarin, and Korean, are topic prominent in which the topic holds the initial position and there may or may not be a subject. For example, *It is cold in here* becomes in Mandarin *Here very cold.* In Korean, *The 747 is a big airplane* becomes *Airplanes* (topic) *the 747 is big.* As for Japanese, *Red snapper is my favorite fish* translates to *Fish* (topic) *red snapper favorite it is* (note the SOV string). Topic-prominent languages also downplay the role of the passive voice and avoid "dummy subjects," such as the *It* in *It is snowing.*

Grammatical Gender. Nouns in English are gender neutral, except for the few personal pronouns *he, him, his* and *she, her, hers.* But in languages with grammatical gender, nouns can be masculine, feminine, or neuter. In French, Italian, Portuguese, and Spanish, for example, nouns are either masculine or feminine; German adds neuter as well. Moreover, in the Romance languages, personal pronouns agree in gender with the *noun* they modify, not with the *subject.* In English, however, the personal pronoun agrees with the gender of the subject. English speakers say, *John forgot* <u>*his*</u> *pen,* but the French say, *John a oublié* <u>*sa*</u> *plume.* The personal pronoun *sa* is feminine because the word for pen, *plume,* is feminine.

The gender of the noun can be different from the gender of the individual the noun describes. In German, a young girl is neuter, *das Mädchen.* In his essay, "That Awful German Language," Mark Twain (1876) observed: ". . . a tree is male, its buds are female, its leaves are neuter; horses are sexless, dogs are male, cats are female—tomcats included, of course." He also noted that foreigners "would rather decline two drinks than one German adjective." Although this may seem bizarre, young children learning German or other gender languages acquire gender marking quickly with few errors. Further, they do not associate the nouns' gender markings with human maleness or femaleness. Their brains just form the needed neural networks in the language processing areas, that then become more robust as the children continue to learn and practice their native tongue.

The Semantic Network

As phonemes combine into morphemes, and morphemes into words, and words into phrases, the mind needs to arrange and compose these pieces into sentences that express what the speaker wants to say. Meanwhile, the listener's language areas must recognize speech sounds from other background noise and interpret the speaker's meaning. This interaction between the components of language and the mind in search of meaning is referred to as *semantics.* Meaning occurs at three different levels of language: the morphology level, the vocabulary level, and the sentence level.

Morphology-Level Semantics. Meaning can come through word parts, or morphology. The word *biggest* has two morphemes, *big* and *-est.* When children can successfully examine the morphology of words, their mental lexicons are greatly enriched. They learn that words with common roots often have common meaning, such as *nation* and *national,* and that prefixes and suffixes alter the meaning of words in certain ways. Morphology also helps children learn and create new words, and can help them spell and pronounce words correctly.

Vocabulary-Level Semantics. A listener who does not understand many of the vocabulary words in a conversation will have trouble comprehending meaning. Of course, the listener may infer meaning based on context, but this is unreliable unless the listener understands most of the vocabulary. Children face this dilemma every day as adults around them use words they do not understand.

Sentence-Level Semantics. The sentence "Boiling cool dreams walk quickly to the goodness" illustrates that morphology and syntax can be preserved even in a sentence that lacks semantics. The words are all correct English words in the proper syntactic sequence, but the sentence does not make sense. Adults recognize this lack of sense immediately. But children often encounter spoken language that does not make sense to them. To understand language, the listener has to detect meaning at several different levels. Because adults do not normally speak sentences that have no meaning, a child's difficulty in finding meaning may result from a sentence having meaning for one person but not another. At this level, too, the listener's background knowledge or experience with the topic being discussed will influence meaning.

The cerebral processes involved in producing and interpreting meaning must occur at incredible speed during the flow of ordinary conversation. How it is that we can access words from our enormous storehouse (the mental lexicon) and interpret the meaning of conversation so quickly? What types of neural networks can allow for such speed and accuracy? Although linguistic researchers differ on the exact nature of these networks, most agree that the mental lexicon is organized according to meaningful relationships between words. Experimental evidence for this notion comes from numerous studies that involve word priming. In these studies, the subjects are presented with pairs of words. The first word is called the prime and the second word is the target. The target can be a real word or a nonword (like *spretz*). A real-word target may or may not be related in meaning to the prime. After being shown the prime, the subject must decide as quickly as possible if the target is a word. The results invariably show that subjects are faster and more accurate in making decisions about target words that are related in meaning to the prime (e.g., *swan–goose*) than to an unrelated prime (e.g., *tulip–goose*). Researchers suspect that the reduced time for identifying related pairs results from these words being physically closer to each other among the neurons that make up the semantic network, and that related words may be stored together in specific cerebral regions (Gazzaniga, Ivry, & Mangun, 2002; Lavigne & Darmon, 2008).

Additional evidence for this idea that the brain stores related words together has come from imaging studies using PET scans. Subjects in PET scanners were asked to name persons, animals, and tools. The results (Figure 1.5) showed that naming items in the same category activated the same area of the brain (Chouinard & Goodale, in press; Damasio, Grabowski, Tranel, Hichwa, & Damasio, 1996). It seems that the brain stores clusters of closely associated words in a tightly packed network so that words *within* the network can activate each other in minimal time. Activating words *between* networks, however, takes longer.

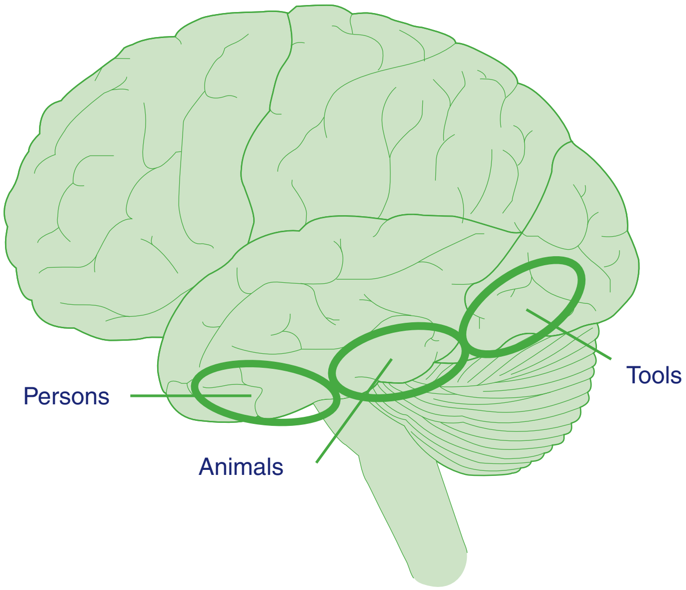

Figure 1.5 This diagram is a representation of the combined PET scan results showing that naming persons, animals, and tools mostly activated different parts of the brain (Chouinard & Goodale, in press; Damasio et al., 1996).

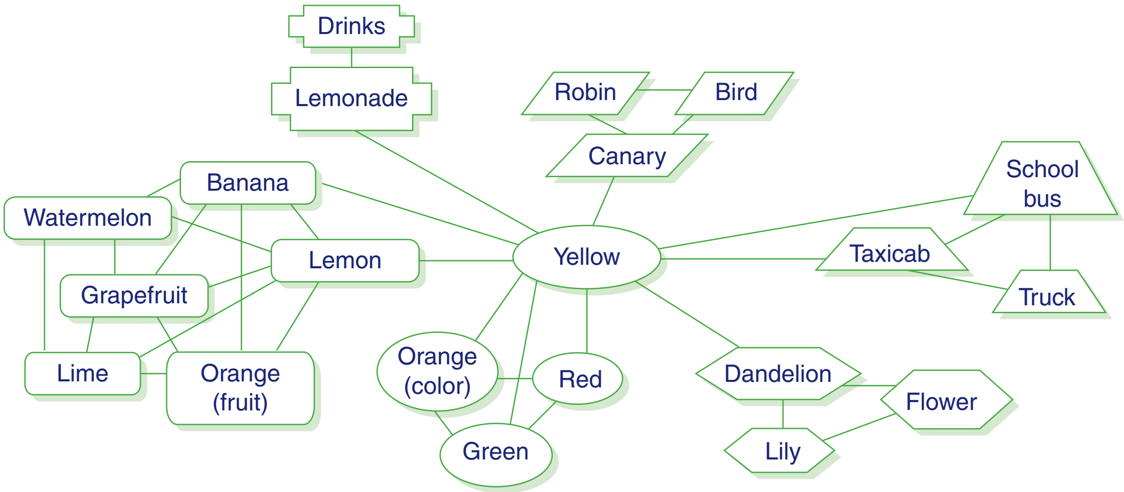

Figure 1.6 This is a representation of a semantic network. Words that are semantically related are closer together in the network, such as *lemon–yellow,* than words that have no close relationship, such as *lemon–bird.* Similar geometric figures identify semantically related words.The lines connect words from different networks that are associated, such as *lemon–yellow.*

How can we best represent these networks? Several different models have been proposed. One that seems to garner substantial support from contemporary neuroscientists is based on an earlier model first proposed by Collins and Loftus (1975) in the mid-1970s. In this model, words that are related are connected to each other. The distance between the connection is determined by the semantic relationship between the words. Figure 1.6 is an example of a semantic network. Note that the word *lemon* is close to—and would have a strong connection to—the word *grapefruit,* but is distant from the word *bird.* If we hear the word *lemon,* then the neural area that represents *lemon* will be activated in the semantic network. Other words in the network such as *lime* and *grapefruit* would also be activated and, therefore, accessed very quickly. The word *bird* would not come to mind.

From Words to Sentences

We have just discussed how the brain acquires, stores, and recognizes words. But to communicate effectively, the words must be arranged in a sequence that makes sense. Languages have developed certain rules—called grammar—that govern the order of words so that speakers of the language can understand each other. In some languages, such as English, different arrangements of words in a sentence can result in the same meaning. *The girl ate the candy* has the same meaning as *The candy was eaten by the girl.* Of course, different word arrangements (syntax) can lead to different meanings, as in *The boat is in the water* and *The water is in the boat.*

As a child's syntactic and semantic networks develop, context plays an important role in determining meaning. When hearing the sentence *The man bought a hot dog at the fair,* the youngster is very likely to picture the man eating a frankfurter rather than a steaming, furry animal that barks. That is because the rest of the sentence establishes a context that is compatible with the first interpretation but not the second.

How does the young brain learn to process the structure of sentences? One prominent model suggests that words in a sentence are assigned syntactic roles and grouped into syntactic phrases (Pinker, 1999). For example, the sentence *The horse eats the hay* consists of a noun phrase (*the horse*), a verb (*eats*), and another noun phrase (*the hay*). A rule of grammar is that a verb (V) can be combined with its direct object to form a verb phrase (VP). In the preceding example, the verb phase would be *eats the hay.* The combination of the noun phrase (NP) and the verb phrase comprises the sentence (S), which can be represented by the syntactic model shown in Figure 1.7.

As sentences become more complicated, each module can contain another module within it. For example, the sentence *The parent told the principal her son is ill* contains a verb phrase that is also a sentence (*her son is ill*). To ensure rapid processing and accurate comprehension, the brain groups the phrases into the hierarchy as represented by the diagram shown in Figure 1.8.

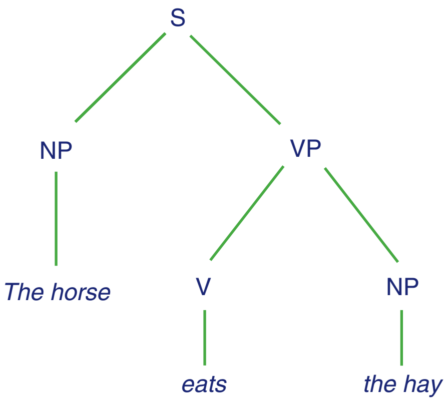

Figure 1.7 This model illustrates how the brain may process sentences to establish meaning. By grouping, or chunking, individual words into phrases, processing time is increased.

How Can We Speak So Rapidly?

This module-within-a-module pattern (Figure 1.8) has two major advantages. First, by rearranging and including different phrase packets, the brain can generate and understand an enormous number of sentences without having to memorize every imaginable sentence verbatim. Second, this pattern allows the brain to process syntactic information quickly so that it can meet the demanding comprehension time required for normal conversation. The efficiency of the system is amazing! The young adult brain can determine the meaning of a spoken word in about one-fifth of a second. The brain needs just one-fourth of a second to name an object and about the same amount of time to pronounce it. For readers, the meaning of a printed word is registered in an astounding one-eighth of a second (Pinker, 1999).

Recognizing Meaning

The brain's ability to recognize different meanings in sentence structure is possible because Broca's and Wernicke's areas establish linked networks that can understand the difference between *The dog chased the cat* and *The cat chased the dog*. In an fMRI study, Dapretto and Bookheimer (1999) found that Broca's and Wernicke's areas work together to determine whether changes in syntax or semantics result in changes in meaning. For example, *The policeman arrested the thief* and *The thief was arrested by the policeman* have different syntax but the same meaning. The fMRI

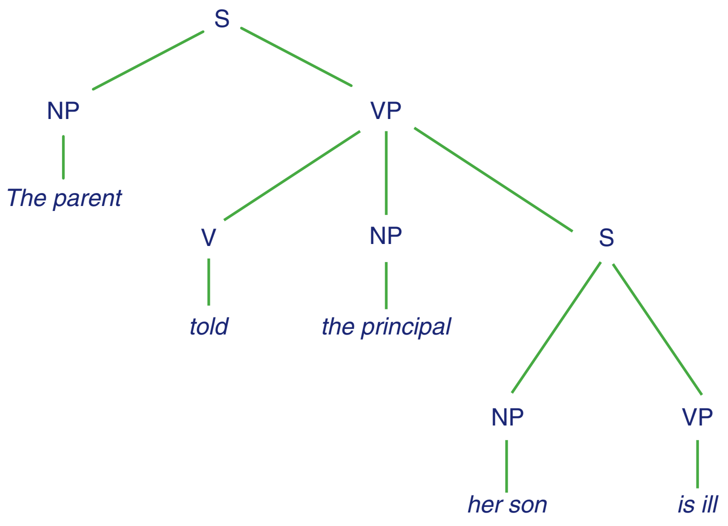

Figure 1.8 This illustrates how the brain proceeds to make additional chunks into phrases to ensure rapid processing and accurate interpretation.

showed that Broca's area was highly activated when subjects were processing these two sentences. Wernicke's area, on the other hand, was more activated when processing sentences that were semantically—but not syntactically—different, such as *The car is in the garage* and *The automobile is in the garage.*

How is it that Wernicke's area can so quickly and accurately decide that two semantically different sentences have the same meaning? The answer may lie in two other recently discovered characteristics of Wernicke's area. One is that the neurons in Wernicke's area are spaced about 20 percent farther apart and are cabled together with longer interconnecting fibers (called *axons*) than the corresponding area in the right hemisphere of the brain (Galuske, Schlote, Bratzke, & Singer, 2000). The implication is that the practice of language during early human development results in longer and more intricately connected neurons in the Wernicke region, allowing for greater sensitivity to meaning.

The second discovery regarding Wernicke's area is its ability to recognize predictable events. An MRI study found that Wernicke's area was activated when subjects were shown differently colored symbols in various patterns, whether the individuals were aware of the pattern sequence or not (Bischoff-Grethe, Proper, Mao, Daniels, & Berns, 2000). This capacity of Wernicke's area to detect predictability suggests that our ability to make sense of language is rooted in our ability to recognize syntax. The researchers noted that language itself is very predicable because it is constrained by the rules of grammar and syntax. And these findings are presumably true for any language.

The Components of Speaking and Understanding Language

Any model for speaking and understanding any language has to address the various stages of sound interpretation, beginning with the auditory input and ending with the formation of a mental concept represented by the word or words. Figure 1.9 shows the various neural components that linguistic researchers and neuroscientists believe are required for spoken language comprehension. It is a complex process, but the efficient organization of the linguistic networks that was built up through practice allows it to occur very quickly.

To understand the different components, let's take the word *dog* through the model. After the spoken word *dog* enters the ear canal, the listener has to decode the sound pattern. In the word form area of the brain, acoustic analysis separates the relevant word sounds from background noise, decodes the phonemes of the word (*duh-awh-guh*), and translates them into a phonological code that can be recognized by the mental lexicon. The lexicon selects the best representation it has in store and then activates the syntactic and semantic networks, which work together to form the mental image of a furry animal that barks (concept formation). All this occurs in just a fraction of a second thanks to the extensive network of neural pathways that were established during the early years of speaking and listening.

Notice that the flow of information in this model is from the bottom up and, thus, appears linear. However, feedback from higher to lower levels is possible. For example, if the lexicon does not recognize the first set of signals, it could reactivate the phonological coding component to produce another set before they decay. It is important to understand how this spoken language processing works because the process of *reading* words shares several steps with this model of spoken language processing.

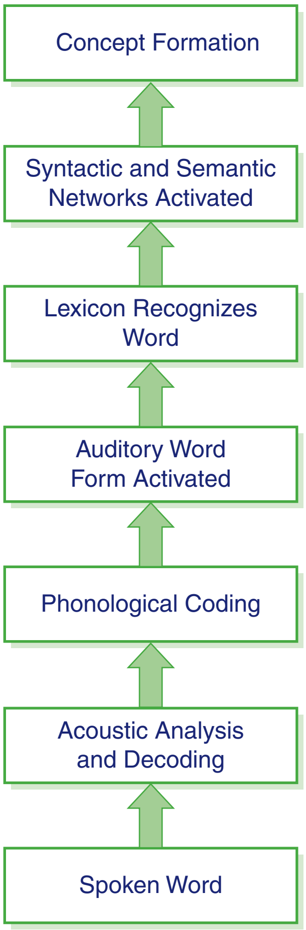

Figure 1.9 This schematic representation shows the major neural components required for spoken language processing. Feedback from higher to lower levels is possible. (Adapted from Gazzaniga et al., 2002.)

LEVELS OF LANGUAGE COMPREHENSION

Parents speak differently to their children than to other adults. Elementary teachers use different language with their students than with their principal. Speech can be formal, as in the classroom, or informal, as around the dinner table. When young children use informal language, it is often context dependent; that is, the conversation focuses on the immediate situation or activities at hand. On the other hand, formal speech may be more context independent or abstract in that the child may be relating different possible endings to a story. Sometimes people say one thing but really mean something else, and they hope that the listener will catch on to the subtler meaning. These different language forms are a recognition that there are several types and levels of spoken language and of language comprehension.

Explicit Comprehension

The most basic type of language comprehension is explicit comprehension—the sentence is clear and unambiguous. When someone says *I need a haircut,* the interpretation is unmistakable. The listener knows exactly what the speaker means and does not need to draw any inferences or elaborate further. Adults tend to use explicit sentences with children to avoid ambiguity. *Eat your vegetables* and *Please be quiet* are clear statements. Whether the child complies, of course, is another story.

Inferred Comprehension

A more sophisticated form of language comprehension requires the listener to make inferences about meanings that go beyond what the speaker explicitly said. A principal who says to a tardy teacher, *Our school really gets off to a great start in the morning when all the staff is here by 8:15,* is really saying, *Be on time.* The teacher has to infer the statement's real intent by reading between the lines of what the principal explicitly said.

Young children have difficulty with inferred comprehension. If the parent says, *Vegetables are good for you,* the child may not pick up on the underlying intent of this statement—eat your vegetables. Consequently, the child may not finish the vegetables and the parent may mistake this behavior as disobedience when it was really a lack of inferred comprehension.

Teachers sometimes use language requiring inferred comprehension when explicit comprehension would be much easier. A teacher who says, for example, *Do you think I should speak if someone else is talking?* may provoke a variety of responses in the minds of the students. One could think absolutely not, while another might hope she would just speak louder than everyone else so the lesson could move along. A few might get the real intent—oh, she wants us to be quiet.

> *Teachers sometimes use language requiring inferred comprehension when explicit comprehension would be much easier.*

Context Clues. We discussed earlier how context can be an important clue for determining the meaning of vocabulary words in a sentence. Context can also help with inferred comprehension. A first-grade teacher who is telling her spouse over dinner how crowded her classroom is and that there are too many students who need special help may just be seeking sympathy. But in having the same conversation with her principal, she is really saying she needs an instructional aide. She never says that explicitly; the principal must infer the teacher's intent from her statement and the context.

Children need to develop an awareness that language comprehension exists on several levels. It involves different styles of speech that reflect the formality of the conversation, the context in which it occurs, and the explicit as well as underlying intent of the speaker. When children gain a good understanding of these patterns in speech, they will be better able to comprehend what they read.

LEARNING TWO FIRST LANGUAGES

Some young children have the good fortune to be raised in a home where two languages are spoken, so they acquire both simultaneously. They are referred to as simultaneous bilinguals. It is already a wonder that the young brain can learn spoken language so quickly and with little effort. But the fact that it can learn two languages at the same time and in such a manner that the speaker can easily switch from one to the other is truly amazing. The very nature of this fascinating ability has been the object of research interest to neuroscientists seeking answers to questions such as the following:

- Are the brain of bilinguals different from those of monolinguals?
- Are the two languages processed by the same regions of the brain, or does each have its own networks?
- How do the processing areas interact when the person speaking is shifting from one language to the other?
- Can exposing a child to a second language too soon delay the development of the brain networks that are processing the first language?

Here is what studies have found.

Are Monolingual and Bilingual Brains Different?

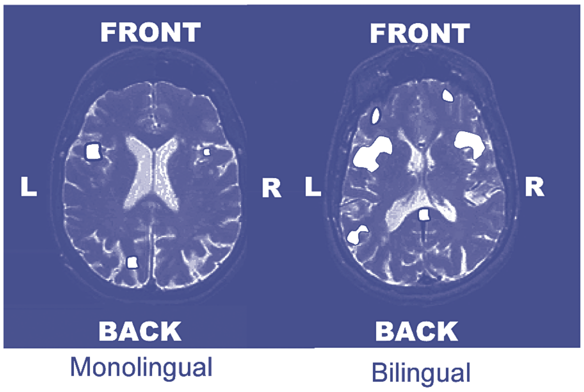

Figure 1.10 This composite fMRI image shows that the brain's language areas in the left hemisphere are activated when both the monolingual and bilingual subjects spoke language. But the bilinguals also activated the region on the right side corresponding to Broca's area when they shifted between two languages. (Adapted from Kovelman et al., 2009.)

Linguists have wondered for decades whether the brains of bilingual individuals are different from monolinguals. In a significant study, Kovelman and her colleagues used imaging technology (fMRI) to examine the brains of 21 young adults, 10 monolinguals who spoke only English and 11 bilinguals who spoke both English and Spanish since birth (Kovelman, Baker, & Petitto, 2008). The researchers found that the brains of bilinguals and monolinguals are similar, and that both process their individual languages in fundamentally similar ways. That is, there was similar increased brain activity across both monolinguals and bilinguals in the brain's classic left-hemisphere language regions, such as Broca's area (see Figure 1.2), when they were speaking in only one language (monolingual mode). However, when the bilinguals were simultaneously processing each of their two languages and rapidly switching between them (bilingual mode), they showed an increase in brain activity in both the left and the right hemisphere, with greater activation in the right hemisphere's equivalent of Broca's area, as shown in Figure 1.10.

The researchers suggest that this finding is a key indicator of the brain's bilingual signature. The results were so promising that Kovelman carried out a similar study using an optical imaging system and got similar results (Kovelman, Shalinsky, Berens, & Petitto, 2008). However, several studies have shown that this right-hemisphere involvement in language processing in bilinguals who learned both languages as toddlers is not found in individuals who learned the second language (L2) at a later time, despite their degree of fluency in the L2 (Hull & Vaid, 2007).

Building the Bilingual Brain

The Kovelman teams (Kovelman, Baker, & Petitto, 2008; Kovelman, Shalinsky et al., 2008) also proposed that bilingual language processing provides a new window into the extent of what an individual's neural architecture for language processing could be, if only we used it. It may be, the researchers continue, that the monolingual is not taking full advantage of the neural landscape for language and cognitive processing that nature has provided us. In other words, we are not born with monolingual, bilingual, or multilingual brains. Rather, the bilingual "signature" that appears is most likely the result of *environmental exposure* to several languages during the child's early years.

Exposing young children to other languages helps build the neural networks that will make it easier to learn a third language later in life.

Another feature of structural differences in the brains of monolinguals and bilinguals is the thick cable of nerves that connects the two hemispheres—the *corpus callosum*—that was discussed earlier. It seems to be larger and more densely populated with neurons in bilinguals than in monolinguals, most likely to accommodate the multilanguage capacity (Coggins, Kennedy, & Armstrong, 2004). The implication here is that exposing very young children to other languages helps build the neural networks that will consolidate and process them. Furthermore, it seems that these networks will make it easier for these individuals to learn a third language later in life (Bloch et al., 2009).

Do the Two Languages Use the Same or Different Brain Regions?

Numerous studies have looked at whether each language is represented by distinct or overlapping cerebral areas. Research using neuroimaging techniques, cortical stimulation, and clinical findings seems to indicate that most bilinguals possess three different types of neural sites:

1. Multiuse sites where both languages perform multiple tasks. These are located in the frontal, temporal, and parietal areas.

2. Single-task sites that carry out one specific task for both languages. These are found in the postcentral and parietal areas.
3. Single-use sites that perform one specific task for one language. There are located in the frontal, temporal, and parietal areas.

These results support the notion that bilinguals have distinct brain regions representing both languages and different language tasks, in addition to overlapping or shared sites that support both languages and multiple tasks (Lucas, McKhann, & Ojemann, 2004; Roux et al., 2004; Serafini, Gururangan, Friedman, & Haglund, 2008). At the very least, these findings should encourage parents and educators to ensure that bilingual students receive continued support in developing both of their languages, thereby strengthening and consolidating the language processing networks.

How Do the Two Languages Interact During Speech?

When a bilingual is speaking in the first language (L1), are elements of the second language (L2) activated as well? If so, how does the bilingual brain deal with it? The answer to the first question is that considerable research evidence exists showing that both languages are active in the brain, even when only one language is spoken (Guo & Peng, 2006; Thierry & Wu, 2007). Answering the second question is a bit more involved. Two different models have emerged to explain the interaction between L1 and L2 when a bilingual is speaking in only one (target) language. In the first group of language-specific selection models, it is thought that both languages may be active but bilinguals develop the ability to selectively focus solely on word candidates in the intended language. In the alternative model, word candidates from both languages compete for selection, requiring that cross-language activity be modulated so that the speaker can select the correct word. In this model, the selection mechanism may require the speaker to inhibit word candidates in the nontarget language. Researchers have conducted a number of studies seeking behavioral and neuroimaging data to support one model or the other. As of this writing, the research evidence seems to favor the inhibiting model (Kroll, Bobb, Misra, & Guo, 2008; Rodriguez-Fornells et al., 2005; van Heuven, Schriefers, Dijkstra, & Hagoort, 2008).

Figure 1.11 illustrates how the inhibiting model is thought to work. Assume that a Spanish-English bilingual speaker has the image of a chair in mind. Instantly, vocabulary words for the object in both Spanish and English are activated in the mental lexicons and ready to be spoken. But because the speaker is using English (target language), the Spanish (nontarget language) word candidates of *silla* and *asiento* (and any others that the speaker may know) must be inhibited so that the speaker can select from the English candidates, *chair* and *seat.* In this example, the speaker chooses *chair.*

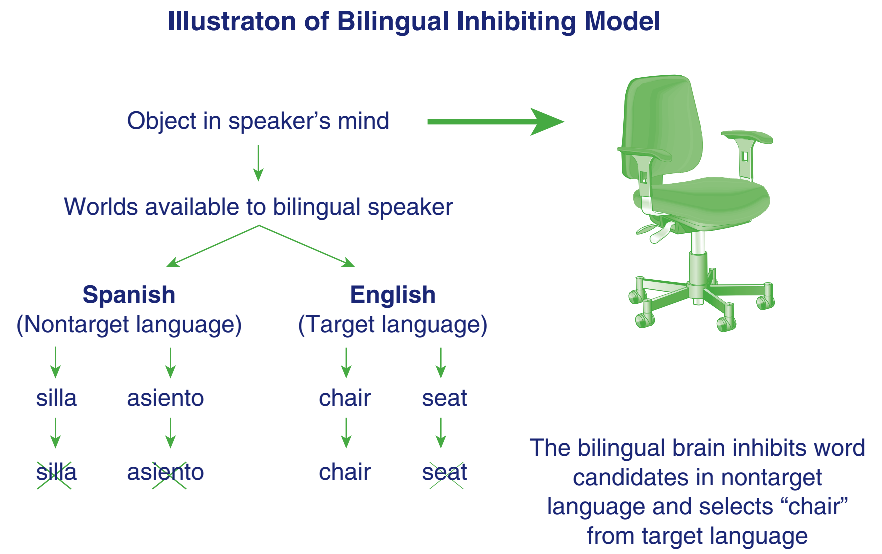

Figure 1.11 In this example, the Spanish-English bilingual speaker, who is using English (target language) on this occasion, must inhibit the two Spanish word candidates and select from the English candidates—the selection here being *chair.*

Despite the time and neural effort involved in the inhibiting mechanism, bilinguals rarely make random errors of language when they speak. This is surprising if we assume that candidate words in both languages are simultaneously available and in competition for selection. Some researchers suggest that as a result of their exposure to two languages simultaneously, bilinguals possess a formidable mechanism of cognitive control that develops as they become more competent in the L1 and the L2. If so, that capability should generally enhance other executive control processes that are already evident in bilingual infants (Kovács & Mehler, 2009) and continue as the individual ages (Abutalebi & Green, 2007; Bialystok, Craik, Klein, & Viswanathan, 2004).

Can Learning the Second Language Too Soon Delay the First Language?

We have already seen that the infant human brain can begin to develop cerebral regions that manage the acquisition of more than one language simultaneously. We have also noted that some of these regions do not appear in the monolingual brain, giving the bilingual toddler distinct advantages for current and future language processing. As long as both languages are learned simultaneously from or soon after birth, the brain seems able to acquire them with little or no impact on the development of either language. However, if the second language is acquired around the age of 5 years or later, then problems may arise, as we shall discuss in Chapter 2.

WHAT'S COMING

The child's brain has now acquired the fundamentals of its native language(s). Neural networks are developing rapidly in Broca's and Wernicke's areas, and every day brings new vocabulary and understanding to the expanding mental lexicon. How will these acquired native language skills and knowledge help the child accomplish the next major cognitive task: learning another language later? All the steps the brain must go through to progress from the native language to another language at a later age—in this case, English—are unveiled in the next chapter.

CHAPTER 1

Key Points to Ponder

Jot down on this page key points, ideas, strategies, and resources you want to consider later. This sheet is your personal journal summary and will help to jog your memory.