Introduction

Brain and Language

> The functional asymmetry of the human brain is unequivocal, and so is its anatomical asymmetry. The structural differences between the left and the right hemispheres are visible not only under the microscope but to the naked eye. The most striking asymmetries occur in language-related cortices. It is tempting to assume that such anatomical differences are an index of the neurobiological underpinnings of language.
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Attempts to understand the complexities of human cognitive abilities and especially the acquisition and use of language are as old and as continuous as history itself. What is the nature of the brain? What is the nature of human language? And what is the relationship between the two? Philosophers and scientists have grappled with these questions and others over the centuries. The idea that the brain is the source of human language and cognition goes back more than two thousand years. The philosophers of ancient Greece speculated about the brain/mind relationship, but neither Plato nor Aristotle recognized the brain's crucial function in cognition or language. However, others of the same period showed great insight, as illustrated in the following quote from the Hippocratic Treatises on the Sacred Disease, written c. 377 B.C.E.:

> [The brain is] the messenger of the understanding [and the organ whereby] in an especial manner we acquire wisdom and knowledge.

The study of language has been crucial to understanding the brain/mind relationship. Conversely, research on the brain in humans and other primates is helping to answer questions concerning the neurological basis for language. The study of the biological and neural foundations of language is called **neurolinguistics**. Neurolinguistic research is often based on data from atypical or impaired language and uses such data to understand properties of human language in general.

The Human Brain

"Rabbit's clever," said Pooh thoughtfully.
"Yes," said Piglet, "Rabbit's clever."
"And he has Brain."
"Yes," said Piglet, "Rabbit has Brain."
There was a long silence.
"I suppose," said Pooh, "that that's why he never understands anything."

A. A. MILNE, *The House at Pooh Corner*, 1928

The brain is the most complex organ of the body. It lies under the skull and consists of approximately 100 billion nerve cells (neurons) and billions of fibers that interconnect them. The surface of the brain is the **cortex**, often called "gray matter," consisting of billions of neurons. The cortex is the decision-making organ of the body. It receives messages from all of the sensory organs, initiates all voluntary and involuntary actions, and is the storehouse of our memories. Somewhere in this gray matter resides the grammar that represents our knowledge of language.

The brain is composed of **cerebral hemispheres**, one on the right and one on the left, joined by the **corpus callosum**, a network of more than 200 million fibers (see Figure I.1). The corpus callosum allows the two hemispheres of the brain to communicate with each other. Without this system of connections, the

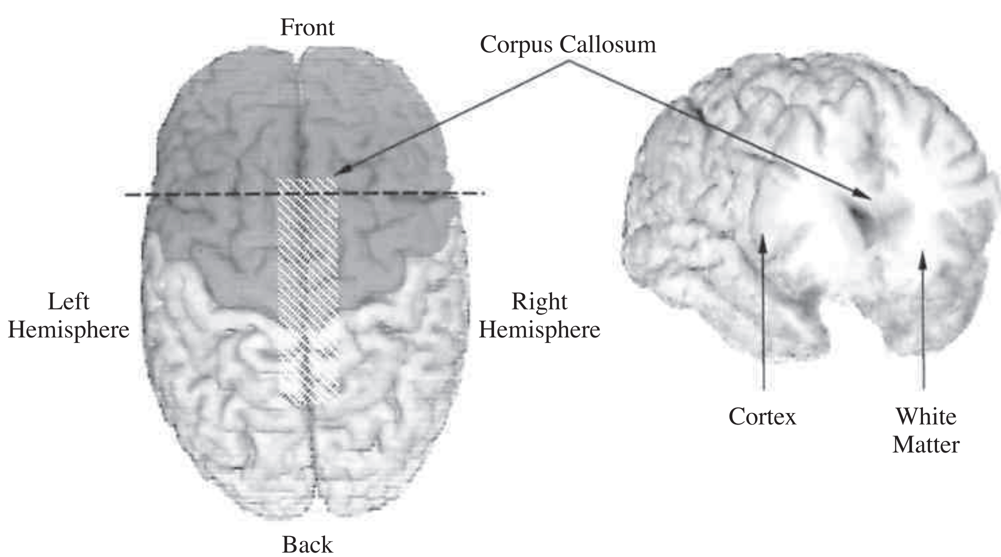
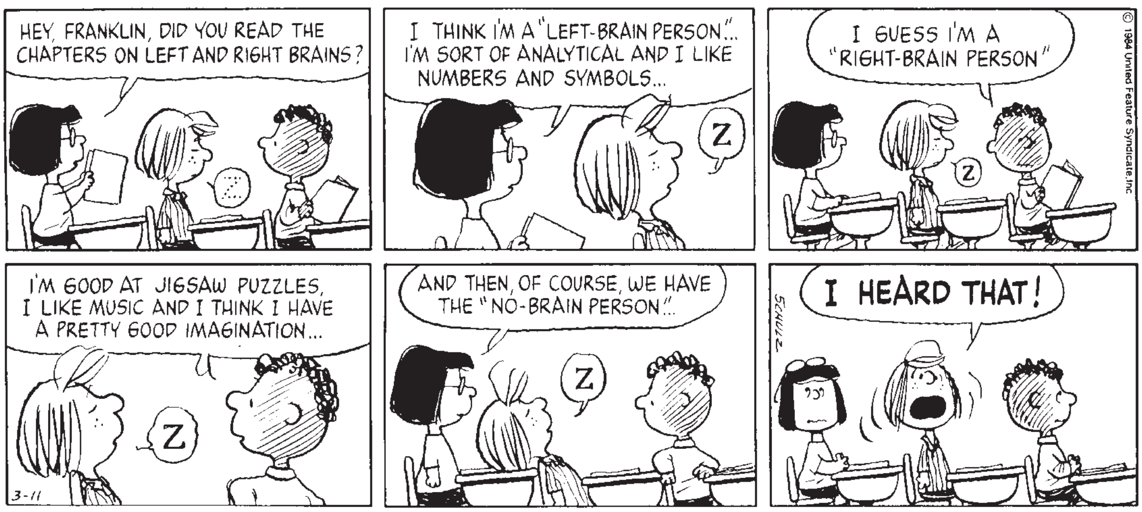


FIGURE I.1 | Three-dimensional reconstruction of the normal living human brain. The images were obtained from magnetic resonance data using the Brainvox technique. *Left panel* = view from top. *Right panel* = view from the front following virtual coronal section at the level of the dashed line.
Courtesy of Hanna Damásio.

two hemispheres would operate independently. In general, the left hemisphere controls the right side of the body, and the right hemisphere controls the left side. If you point with your right hand, the left hemisphere is responsible for your action. Similarly, sensory information from the right side of the body (e.g., right ear, right hand, right visual field) is received by the left hemisphere of the brain, and sensory input to the left side of the body is received by the right hemisphere. This is referred to as **contralateral** brain function.

The Localization of Language in the Brain



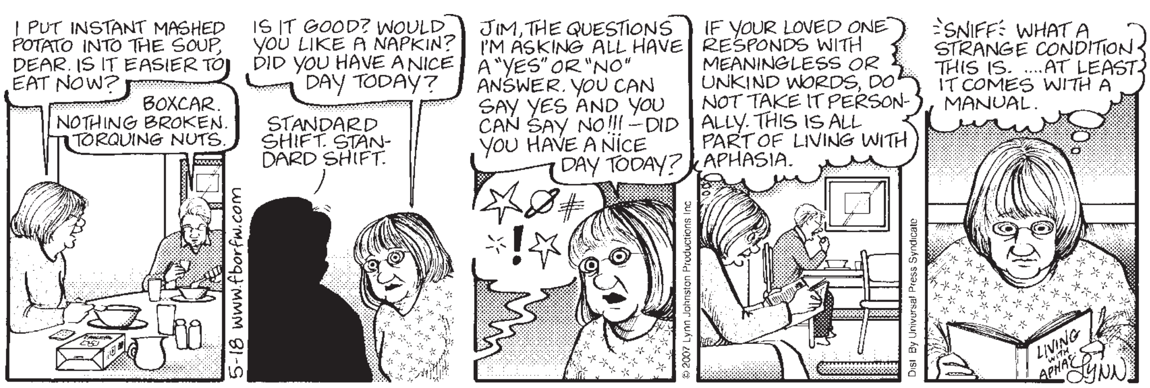
An issue of central concern has been to determine which parts of the brain are responsible for human linguistic abilities. In the early nineteenth century, Franz Joseph Gall proposed the theory of **localization**, which is the idea that different human cognitive abilities and behaviors are localized in specific parts of the brain. In light of our current knowledge about the brain, some of Gall's particular views are amusing. For example, he proposed that language is located in the frontal lobes of the brain because as a young man he had noticed that the most articulate and intelligent of his fellow students had protruding eyes, which he believed reflected overdeveloped brain material. He also put forth a pseudoscientific theory called "organology" that later came to be known as **phrenology**, which is the practice of determining personality traits, intellectual capacities, and other matters by examining the "bumps" on the skull. A disciple of Gall's, Johann Spurzheim, introduced phrenology to America, constructing elaborate maps and skull models such as the one shown in Figure I.2, in which language is located directly under the eye.

Gall was a pioneer and a courageous scientist in arguing against the prevailing view that the brain was an unstructured organ. Although phrenology has long been discarded as a scientific theory, Gall's view that the brain is not a uniform mass, and that linguistic and other cognitive capacities are functions of localized

FIGURE I.2 | Phrenology skull model.

brain areas, has been upheld by scientific investigation of brain disorders, and, over the past two decades, by numerous studies using sophisticated technologies.

Aphasia



The study of **aphasia** has been an important area of research in understanding the relationship between brain and language. Aphasia is the neurological term for any language disorder that results from brain damage caused by disease or trauma. In the second half of the nineteenth century, significant scientific advances were

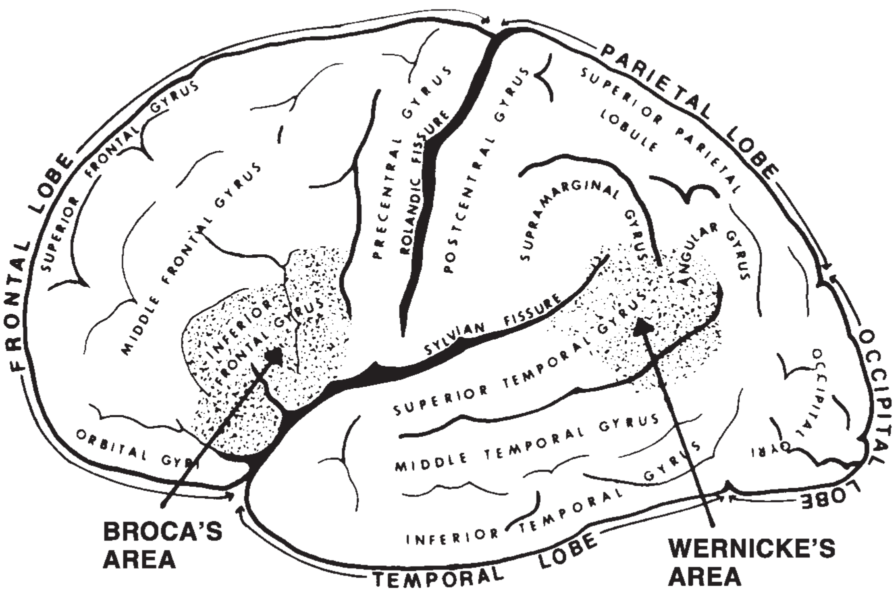


FIGURE I.3 | Lateral (*external*) view of the left hemisphere of the human brain, showing the position of Broca's and Wernicke's areas—two key areas of the cortex related to language processing.

made in localizing language in the brain based on the study of people with aphasia. In the 1860s the French surgeon Paul Broca proposed that language is localized to the left hemisphere of the brain, and more specifically to the front part of the left hemisphere (now called **Broca's area**). At a scientific meeting in Paris, he claimed that we speak with the left hemisphere. Broca's finding was based on a study of his patients who suffered language deficits after brain injury to the left frontal lobe. A decade later Carl Wernicke, a German neurologist, described another variety of aphasia that occurred in patients with lesions in areas of the left hemisphere temporal lobe, now known as **Wernicke's area**. Language, then, is lateralized to the left hemisphere, and the left hemisphere appears to be the language hemisphere from infancy on. **Lateralization** is the term used to refer to the localization of function to one hemisphere of the brain. Figure I.3 is a view of the left side of the brain that shows Broca's and Wernicke's areas.

The Linguistic Characterization of Aphasic Syndromes

Most aphasics do not show total language loss. Rather, different aspects of language are selectively impaired, and the kind of impairment is generally related to the location of the brain damage. Because of this damage-deficit correlation, research on patients with aphasia has provided a great deal of information about how language is organized in the brain.

Patients with injuries to Broca's area may have **Broca's aphasia**, as it is often called today. Broca's aphasia is characterized by labored speech and certain kinds of word-finding difficulties, but it is primarily a disorder that affects a person's ability to form sentences with the rules of syntax. One of the most notable characteristics of Broca's aphasia is that the language produced is often **agrammatic**, meaning that it frequently lacks articles, prepositions, pronouns, auxiliary verbs, and other grammatical elements that we will call "function words" for now. Broca's aphasics also typically omit inflections such as the past tense suffix *-ed* or the third person singular verb ending *-s*. Here is an excerpt of a conversation between a patient with Broca's aphasia and a doctor:

DOCTOR: Could you tell me what you have been doing in the hospital?
PATIENT: Yes, sure. Me go, er, uh, P.T. [physical therapy] none o'cot, speech . . . two times . . . read . . . r . . . ripe . . . rike . . . uh write . . . practice . . . get . . . ting . . . better.
DOCTOR: And have you been going home on weekends?
PATIENT: Why, yes . . . Thursday uh . . . uh . . . uh . . . no . . . Friday . . . Bar . . . ba . . . ra . . . wife . . . and oh car . . . drive . . . purpike . . . you know . . . rest . . . and TV.

Broca's aphasics (also often called **agrammatic aphasics**) may also have difficulty understanding complex sentences in which comprehension depends exclusively on syntactic structure and where they cannot rely on their real-world knowledge. For example, an agrammatic aphasic may have difficulty knowing who kissed whom in questions like:

Which girl did the boy kiss?

where it is equally plausible for the boy or the girl to have done the kissing; or might be confused as to who is chasing whom in passive sentences such as:

The cat was chased by the dog.

where it is plausible for either animal to chase the other. But they have less difficulty with:

Which book did the boy read?

or

The car was chased by the dog.

where the meaning can be determined by nonlinguistic knowledge. It is implausible for books to read boys or for cars to chase dogs, and aphasic people can use that knowledge to interpret the sentence.

Unlike Broca's patients, people with **Wernicke's aphasia** produce fluent speech with good intonation, and they may largely adhere to the rules of syntax. However, their language is often semantically incoherent. For example, one patient replied to a question about his health with:

I felt worse because I can no longer keep in mind from the mind of the minds to keep me from mind and up to the ear which can be to find among ourselves.

Another patient described a fork as "a need for a schedule" and another, when asked about his poor vision, replied, "My wires don't hire right."

People with damage to Wernicke's area have difficulty naming objects presented to them and also in choosing words in spontaneous speech. They may make numerous lexical errors (word substitutions), often producing **jargon** and **nonsense words**, as in the following example:

> The only thing that I can say again is madder or modder fish sudden fishing sewed into the accident to miss in the purdles.

Another example is from a patient who was a physician before his aphasia. When asked if he was a doctor, he replied:

> Me? Yes sir. I'm a male demaploze on my own. I still know my tubaboys what for I have that's gone hell and some of them go.

Severe Wernicke's aphasia is often referred to as **jargon aphasia**. The linguistic deficits exhibited by people with Broca's and Wernicke's aphasia point to a **modular** organization of language in the brain. We find that damage to different parts of the brain results in different kinds of linguistic impairment (e.g., syntactic versus semantic). This supports the hypothesis that the mental grammar, like the brain itself, is not an undifferentiated system, but rather consists of distinct components or modules with different functions.

The kind of word substitutions that aphasic patients produce also tell us about how words are organized in the mental lexicon. Sometimes the substituted words are similar to the intended words in their sounds. For example, *pool* might be substituted for *tool*, *sable* for *table*, or *crucial* for *crucible*. Sometimes they are similar in meaning (e.g., *table* for *chair* or *boy* for *girl*). These errors resemble the speech errors that anyone might make, but they occur far more frequently in people with aphasia. The substitution of semantically or phonetically related words tells us that neural connections exist among semantically related words and among words that sound alike. Words are not mentally represented in a simple list but rather in an organized network of connections.

Similar observations pertain to reading. The term dyslexia refers to reading disorders. Many word substitutions are made by people who become dyslexic after brain damage. They are called **acquired dyslexics** because before their brain lesions they were normal readers (unlike developmental dyslexics, who have difficulty learning to read). One group of these patients, when reading words printed on cards aloud, produced the kinds of substitutions shown in the following examples.

Stimulus	Response 1	Response 2
act	*play*	*play*
applaud	*laugh*	*cheers*
example	*answer*	*sum*
heal	*pain*	*medicine*
south	*west*	*east*

The omission of function words in the speech of agrammatic aphasics shows that this class of words is mentally distinct from content words like nouns. A similar phenomenon has been observed in acquired dyslexia. The patient who produced the semantic substitutions cited previously was also agrammatic and was not able to read function words at all. When presented with words like *which* or *would*, he just said, "No" or "I hate those little words." However, he could read homophonous nouns and verbs, though with many semantic mistakes, as shown in the following:

Stimulus	**Response**	**Stimulus**	**Response**
witch	*witch*	which	*no!*
hour	*time*	our	*no!*
eye	*eyes*	I	*no!*
hymn	*bible*	him	*no!*
wood	*wood*	would	*no!*

All these errors provide evidence that the mental dictionary has content words and function words in different compartments, and that these two classes of words are processed in different brain areas or by different neural mechanisms, further supporting the view that both the brain and language are structured in a complex, modular fashion.

Additional evidence regarding hemispheric specialization is drawn from Japanese readers. The Japanese language has two main writing systems. One system, *kana*, is based on the sound system of the language; each symbol corresponds to a syllable. The other system, *kanji*, is ideographic; each symbol corresponds to a word. (More about this in chapter 11 on writing systems.) *Kanji* is not based on the sounds of the language. Japanese people with left-hemisphere damage are impaired in their ability to read *kana*, whereas people with right-hemisphere damage are impaired in their ability to read *kanji*. Also, experiments with unimpaired Japanese readers show that the right hemisphere is better and faster than the left hemisphere at reading *kanji*, and vice versa.

Most of us have experienced word-finding difficulties in speaking if not in reading, as Alice did in "Wonderland" when she said:

> "And now, who am I? I will remember, if I can. I'm determined to do it!" But being determined didn't help her much, and all she could say, after a great deal of puzzling, was "L, I know it begins with L."

This **tip-of-the-tongue phenomenon** (often referred to as **TOT**) is not uncommon. But if you could *rarely* find the word you wanted, imagine how frustrated you would be. This is the fate of many aphasics whose impairment involves severe **anomia—**the inability to find the word you wish to speak.

It is important to note that the language difficulties suffered by aphasics are not caused by any general cognitive or intellectual impairment or loss of motor or sensory controls of the nerves and muscles of the speech organs or hearing apparatus. Aphasics can produce and hear sounds. Whatever loss they suffer has to do only with the language faculty (or specific parts of it).

Deaf signers with damage to the left hemisphere show aphasia for sign language similar to the language breakdown in hearing aphasics, even though sign language is a visual-spatial language. Deaf patients with lesions in Broca's area show language deficits like those found in hearing patients, namely severely dysfluent, agrammatic sign production. Likewise, those with damage to Wernicke's area have fluent but often semantically incoherent sign language, filled with made-up signs. Although deaf aphasic patients show marked sign language deficits, they have no difficulty producing nonlinguistic gestures or sequences of nonlinguistic gestures, even though both nonlinguistic gestures and linguistic signs are produced by the same "articulators"—the hands and arms. Deaf aphasics also have no difficulty in processing nonlinguistic visual-spatial relationships, just as hearing aphasics have no problem with processing nonlinguistic auditory stimuli. These findings are important because they show that the left hemisphere is lateralized for language—an abstract system of symbols and rules—and not simply for hearing or speech. Language can be realized in different modalities, spoken or signed, but will be lateralized to the left hemisphere regardless of modality.

The kind of selective impairments that we find in people with aphasia has provided important information about the organization of different language and cognitive abilities, especially grammar and the lexicon. It tells us that language is a separate cognitive module—so aphasics can be otherwise cognitively normal—and also that within language, separate components can be differentially affected by damage to different regions of the brain.

Historical Descriptions of Aphasia

Interest in aphasia has a long history. Greek Hippocratic physicians reported that loss of speech often occurred simultaneously with paralysis of the right side of the body. Psalm 137 states: "If I forget thee, Oh Jerusalem, may my right hand lose its cunning and my tongue cleave to the roof of my mouth." This passage also shows that a link between loss of speech and paralysis of the right side was recognized.

Pliny the Elder (C.E. 23–79) refers to an Athenian who "with the stroke of a stone fell presently to forget his letters only, and could read no more; otherwise, his memory served him well enough." Numerous clinical descriptions of patients like the Athenian with language deficits, but intact nonlinguistic cognitive systems, were published between the fifteenth and eighteenth centuries. The language difficulties were not attributed to either general intellectual deficits or loss of memory, but to a specific impairment of language.

Carl Linnaeus in 1745 published a case study of a man suffering from jargon aphasia, who spoke "as if it were a foreign language, having his own names for all words." Another physician of that century reported on a patient's word substitution errors:

> After an illness, she was suddenly afflicted with a forgetting, or, rather, an incapacity or confusion of speech. . . . If she desired a *chair*, she would ask for a *table*. . . . Sometimes she herself perceived that she misnamed objects; at other times, she was annoyed when a *fan*, which she had asked for, was brought to her, instead of the *bonnet*, which she thought she had requested.

Physicians of the day described other kinds of linguistic breakdown in detail, such as a priest who, following brain damage, retained his ability to read Latin but lost the ability to read German.

The historical descriptions of language loss following brain damage foreshadow the later controlled scientific studies of aphasia that have provided substantial evidence that language is predominantly and most frequently a left-hemisphere function. In most cases lesions to the left hemisphere result in aphasia, but injuries to the right do not (although such lesions result in deficits in facial recognition, pattern recognition, and other cognitive abilities). Still, caution must be taken. The ability to understand intonation connected with various emotional states and also to understand metaphors (e.g., *The walls have ears*), jokes, puns, double entendres, and the like can be affected in patients with right hemisphere damage. If such understanding has a linguistic component, then we may have to attribute some language cognition to the right hemisphere.

Studies of aphasia have provided not only important information regarding where and how language is localized in the brain, but also data bearing on the properties and principles of grammar that have been hypothesized for non-brain-damaged adults. For example, the study of aphasia has provided empirical evidence concerning theories of word structure (chapter 1), sentence formation (chapter 2), meaning (chapter 3), and sound systems (chapters 4 and 5).

Brain Imaging Technology

The historical descriptions of aphasia illustrate that people have long been fascinated by the brain-language connection. Today we no longer need to rely on surgery or autopsy to locate brain lesions or to identify the language regions of the brain. Noninvasive brain recording technologies such as computer tomography (CT) scans and **magnetic resonance imaging (MRI)** can reveal lesions in the living brain shortly after the damage occurs. In addition, **positron emission tomography (PET)** scans, functional MRI (fMRI) scans, and single photon emission CT (SPECT) scans provide images of the brain in action. It is now possible to detect changes in brain activity and to relate these changes to localized brain damage and specific linguistic and nonlinguistic cognitive tasks.

Figures I.4 and I.5 show MRI scans of the brains of a Broca's aphasic patient and a Wernicke's aphasic patient. The black areas show the sites of the lesions. Each diagram represents a slice of the left side of the brain.

A variety of scanning techniques permit us to measure metabolic activity in particular areas of the brain. Areas of greater activity are those most involved in the mental processes at the moment of the scan. Supplemented by magnetic encephalography (MEG), which measures magnetic fields in the living brain, these techniques can show us how the healthy brain reacts to particular linguistic stimuli. For example, the brains of normal adults are observed when they are asked to listen to two or more sounds and determine if they are the same. Or they may be asked to listen to strings of sounds or read a string of letters and determine if they are real or possible words, or listen to or read sequences of words and say whether they form grammatical or ungrammatical sentences. The results of these studies reaffirm the earlier findings that language resides in specific areas of the left hemisphere.

Dramatic evidence for a differentiated and structured brain is also provided by studies of both normal individuals and patients with lesions in regions of the brain other than Broca's and Wernicke's areas. Some patients have difficulty speaking a person's name; others have problems naming animals; and still oth-

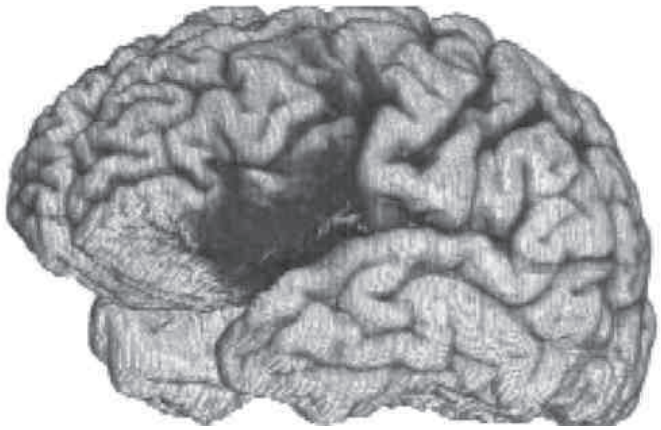


FIGURE I.4 | Three-dimensional reconstruction of the brain of a living patient with Broca's aphasia. Note area of damage in left frontal region (*dark gray*), which was caused by a stroke.
Courtesy of Hanna Damásio.

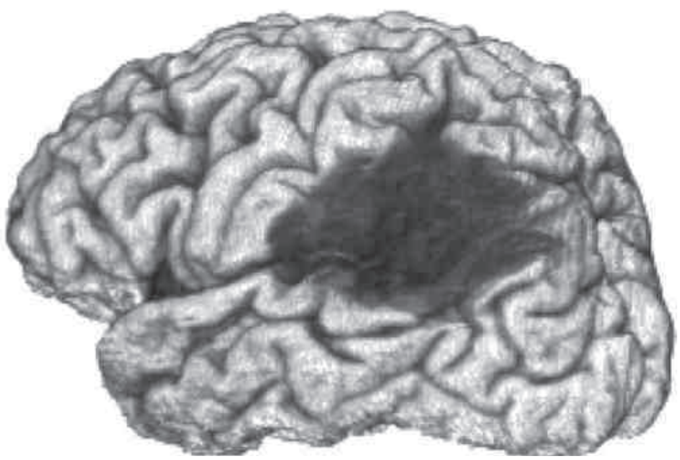


FIGURE I.5 | Three-dimensional reconstruction of the brain of a living patient with Wernicke's aphasia. Note area of damage in left posterior temporal and lower parietal region (*dark gray*), which was caused by a stroke.
Courtesy of Hanna Damásio.

ers cannot name tools. fMRI studies have revealed the shape and location of the brain lesions in each of these types of patients. The patients in each group had brain lesions in distinct, nonoverlapping regions of the left temporal lobe. In a follow-up PET scan study, normal subjects were asked to name persons, animals, or tools. Experimenters found that there was differential activation in the normal brains in just those sites that were damaged in the aphasics who were unable to name persons, animals, or tools.

Further evidence for the separation of cognitive systems is provided by the neurological and behavioral findings that follow brain damage. Some patients lose the ability to recognize sounds or colors or familiar faces while retaining all other functions. A patient may not be able to recognize his wife when she walks into the room until she starts to talk. This suggests the differentiation of many aspects of visual and auditory processing.

Brain Plasticity and Lateralization in Early Life

It takes only one hemisphere to have a mind.

A. L. WIGAN, *The Duality of the Mind*, 1844

Lateralization of language to the left hemisphere is a process that begins very early in life. Wernicke's area is visibly distinctive in the left hemisphere of the fetus by the twenty-sixth gestational week. Infants as young as one week old show a greater electrical response in the left hemisphere to language and in the right hemisphere to music. A recent study videotaped the mouths of babies between the ages of five and twelve months when they were smiling and when they were babbling in syllables (producing sequences like *mamama* or *gugugu*). The study found that during smiling, the babies had a greater opening of the left side of the mouth (the side controlled by the right hemisphere), whereas during babbling, they had a greater opening of the *right* side (controlled by the left hemisphere). This indicates more left hemisphere involvement even at this very early stage of productive language development (see chapter 7).

While the left hemisphere is innately predisposed to specialize for language, there is also evidence of considerable *plasticity* (i.e., flexibility) in the system during the early stages of language development. This means that under certain circumstances, the right hemisphere can take over many of the language functions that would normally reside in the left hemisphere. An impressive illustration of plasticity is provided by children who have undergone a procedure known as **hemispherectomy**, in which one hemisphere of the brain is surgically removed. This procedure is used to treat otherwise intractable cases of epilepsy. In cases of left hemispherectomy after language acquisition has begun, children experience an initial period of aphasia and then reacquire a linguistic system that is virtually indistinguishable from that of normal children. They also show many of the developmental patterns of normal language acquisition. UCLA professor Susan Curtiss and colleagues have studied many of these children. They hypothesize that the latent linguistic ability of the right hemisphere is "freed" by the removal of the diseased left hemisphere, which may have had a strong inhibitory effect before the surgery.

In adults, however, surgical removal of the left hemisphere inevitably results in severe loss of language function (and so is done only in life-threatening circumstances), whereas adults (and children who have already acquired language) who have had their right hemispheres removed retain their language abilities. Other cognitive losses may result, such as those typically lateralized to the right hemisphere. The plasticity of the brain decreases with age and with the increasing specialization of the different hemispheres and regions of the brain.

Despite strong evidence that the left hemisphere is predetermined to be the language hemisphere in most humans, some evidence suggests that the right hemisphere also plays a role in the earliest stages of language acquisition. Children with prenatal, perinatal, or childhood brain lesions in the right hemisphere can show delays and impairments in babbling and vocabulary learning, whereas children with early left hemisphere lesions demonstrate impairments in their ability to form phrases and sentences. Also, many children who undergo right hemispherectomy before two years of age do not develop language, even though they still have a left hemisphere.

Various findings converge to show that the human brain is essentially designed to specialize for language in the left hemisphere but that the right hemisphere is involved in early language development. They also show that, under the right circumstances, the brain is remarkably resilient and that if brain damage or surgery occurs early in life, normal left hemisphere functions can be taken over by the right hemisphere.

Split Brains

People suffering from intractable epilepsy may be treated by severing communication between their two hemispheres. Surgeons cut through the corpus callosum (see Figure I.1), the fibrous network that connects the two halves. When this pathway is severed, there is no communication between the “two brains.” Such **split-brain** patients also provide evidence for language lateralization and for understanding contralateral brain functions.

The psychologist Michael Gazzaniga states:

> With [the corpus callosum] intact, the two halves of the body have no secrets from one another. With it sectioned, the two halves become two different conscious mental spheres, each with its own experience base and

> control system for behavioral operations. . . . Unbelievable as this may seem, this is the flavor of a long series of experimental studies first carried out in the cat and monkey.[1]

When the brain is surgically split, certain information from the left side of the body is received only by the right side of the brain, and vice versa. To illustrate, suppose that a monkey is trained to respond with both its hands to a certain visual stimulus, such as a flashing light. After the training is complete, the brain is surgically split. The stimulus is then shown only to the left visual field (the right hemisphere). Because the right hemisphere controls the left side of the body, the monkey will perform only with the left hand.

In humans who have undergone split-brain operations, the two hemispheres appear to be independent, and messages sent to the brain result in different responses, depending on which side receives the message. For example if a pencil is placed in the left hand of a split-brain person whose eyes are closed, the person can use the pencil appropriately but cannot name it because only the left hemisphere can speak. The right brain senses the pencil but the information cannot be relayed to the left brain for linguistic naming because the connections between the two halves have been severed. By contrast, if the pencil is placed in the right hand, the subject is immediately able to name it as well as to describe it because the sensory information from the right hand goes directly to the left hemisphere, where the language areas are located.

Various experiments of this sort have provided information on the different capabilities of the two hemispheres. The right brain does better than the left in pattern-matching tasks, in recognizing faces, and in spatial tasks. The left hemisphere is superior for language, rhythmic perception, temporal-order judgments, and arithmetic calculations. According to Gazzaniga, "the right hemisphere as well as the left hemisphere can emote and while the left can tell you why, the right cannot."

Studies of human split-brain patients have also shown that when the interhemispheric visual connections are severed, visual information from the right and left visual fields becomes confined to the left and right hemispheres, respectively. Because of the crucial endowment of the left hemisphere for language, written material delivered to the right hemisphere cannot be read aloud if the brain is split, because the information cannot be transferred to the left hemisphere. An image or picture that is flashed to the right visual field of a split-brain patient (and therefore processed by the left hemisphere) can be named. However, when the picture is flashed in the left visual field and therefore "lands" in the right hemisphere, it cannot be named.

Other Experimental Evidence of Brain Organization

Dichotic listening is an experimental technique that uses auditory signals to observe the behavior of the individual hemispheres of the human brain. Subjects hear two different sound signals simultaneously through earphones. They may hear *curl* in one ear and *girl* in the other, or a cough in one ear and a laugh in the other. When asked to state what they heard in each ear, subjects are more fre-

[1]Gazzaniga, M. S. 1970. *The bisected brain*. New York: Appleton-Century-Crofts.

quently correct in reporting linguistic stimuli (words, nonsense syllables, and so on) delivered directly to the right ear, but are more frequently correct in reporting nonverbal stimuli (musical chords, environmental sounds, and so on) delivered to the left ear. Such experiments provide strong evidence of lateralization.

Both hemispheres receive signals from both ears, but the contralateral stimuli prevail over the **ipsilateral** (same-side) stimuli because they are processed more robustly. The contralateral pathways are anatomically thicker (think of a four-lane highway versus a two-lane road) and are not delayed by the need to cross the corpus callosum. The accuracy with which subjects report what they hear is evidence that the left hemisphere is superior for linguistic processing, and the right hemisphere is superior for nonverbal information.

These experiments are important because they show not only that language is lateralized, but also that the left hemisphere is not superior for processing all sounds; it is only better for those sounds that are linguistic. The left side of the brain is specialized for language, not sound, as we also noted in connection with sign language research discussed earlier.

Other experimental techniques are also being used to map the brain and to investigate the independence of different aspects of language and the extent of the independence of language from other cognitive systems. Even before the advances in imaging technology of the 1980s and more recently, researchers were taping electrodes to different areas of the skull and investigating the electrical activity of the brain related to perceptual and cognitive information. In such experiments scientists measure **event-related brain potentials (ERPs)**, which are the electrical signals emitted from the brain in response to different stimuli.

For example, ERP differences result when the subject hears speech sounds versus nonspeech sounds, with a greater response from the left hemisphere to speech. ERP experiments also show variations in timing, pattern, amplitude, and hemisphere of response when subjects hear sentences that are meaningless, such as

The man admired Don's headache of the landscape.

as opposed to meaningful sentences such as

The man admired Don's sketch of the landscape.

Such experiments show that neuronal activity varies in location within the brain according to whether the stimulus is language or nonlanguage, with a left hemisphere preference for language. Even jabberwocky sentences—sentences that are grammatical but contain nonsense words, such as Lewis Carroll's *'Twas brillig, and the slithy toves*—elicit an asymmetrical left hemisphere ERP response, demonstrating that the left hemisphere is sensitive to grammatical structure even in the absence of meaning. Moreover, because ERPs also show the timing of neuronal activity as the brain processes language, they can provide insight into the mechanisms that allow the brain to process language quickly and efficiently, on the scale of milliseconds.

ERP and imaging studies of newborns and very young infants show that from birth onward, the left hemisphere differentiates between nonlinguistic acoustic processing and linguistic processing of sounds, and does so via the same neural pathways that adults use. These results indicate that at birth the left hemisphere is primed to process language, and to do so in terms of the specific localization of language functions we find in the adult brain.

What is more, these studies have shown that early stages of phonological and syntactic processing do not require attentional resources but are automatic, very much like reflexes. For example, even *sleeping* infants show the asymmetrical and distinct processing of phonological versus equally different but nonlinguistic acoustic signals; and adults are able to perform a completely unrelated task, one that takes up considerable attentional resources, at the same time they are listening to sentences, without affecting the nature or degree of the brain activity that is the neural reflex of automatic, mandatory early syntactic processing.

Experimental evidence from these various neurolinguistic techniques has provided empirical confirmation for theories of language structure. For example, ERP, fMRI, PET, and MEG studies provide measurable confirmation of discrete speech sounds and their phonetic properties. These studies also substantiate linguistic evidence that words have an internal structure consisting of *morphemes* (chapter 1) and belong to categories such as nouns and verbs. Neurolinguistic experiments also support the mental reality of many of the syntactic structures proposed by linguists. Thus neurolinguistic experimentation provides data for both aspects of neurolinguistics: for helping to determine where and how language is represented and processed in the brain, and for providing empirical support for concepts and hypotheses in linguistic theory.

The results of neurolinguistic studies, which use different techniques and different subject populations, both normal and brain damaged, are converging to provide the information we seek on the relationship between the brain and various language and nonlanguage cognitive systems. However, as pointed out by Professors Colin Phillips and Kuniyoshi Sakai,

> . . . knowing where language is supported in the human brain is just one step on the path to finding what are the special properties of those brain regions that make language possible. . . . An important challenge for coming years will be to find whether the brain areas implicated in language studies turn out to have distinctive properties at the neuronal level that allow them to explain the special properties of human language.[2]

The Autonomy of Language

In addition to brain-damaged individuals who have lost their language ability, there are children without brain lesions who nevertheless have difficulties in acquiring language or are much slower than the average child. They show no other cognitive deficits, they are not autistic or retarded, and they have no perceptual problems. Such children are suffering from **specific language impairment**

[2]Phillips, C., and K. L. Sakai. 2005. Language and the brain. *Yearbook of science and technology 2005*. Boston: McGraw-Hill Publishers.

(**SLI**). Only their linguistic ability is affected, and often only specific aspects of grammar are impaired.

Children with SLI have problems with the use of function words such as articles, prepositions, and auxiliary verbs. They also have difficulties with inflectional suffixes on nouns and verbs such as markers of tense and agreement. Several examples from a four-year-old boy with SLI illustrate this:

Meowmeow chase mice.
Show me knife.
It not long one.

An experimental study of several SLI children showed that they produced the past tense marker on the verb (as in *danced*) about 27 percent of the time, compared with 95 percent by the normal control group. Similarly, the SLI children produced the plural marker *-s* (as in *boys*) only 9 percent of the time, compared with 95 percent by the normal children.

Other studies of children with SLI reveal broader grammatical impairments, involving difficulties with many grammatical structures and operations. However, most investigations of SLI children show that they have particular problems with verbal inflection, especially with producing tensed verbs (*walks*, *walked*), and also with syntactic structures involving certain kinds of word reorderings such as *Mother is hard to please*, a rearrangement of *It is hard to please Mother.* In many respects these difficulties resemble the impairments demonstrated by aphasics. Recent work on SLI children also shows that the different components of language (phonology, syntax, lexicon) can be selectively impaired or spared. As is the case with aphasia, these studies of SLI provide important information about the nature of language and help linguists develop theories about the underlying properties of language and its development in children.

SLI children show that language may be impaired while general intelligence stays intact, supporting the view of a grammatical faculty that is separate from other cognitive systems. But is it possible for language to develop normally when general intelligence is impaired? If such individuals can be found, it argues strongly for the view that language does not derive from some general cognitive ability.

Other Dissociations of Language and Cognition

> [T]he human mind is not an unstructured entity but consists of components which can be distinguished by their functional properties.
>
> **NEIL SMITH AND IANTHI-MARIA TSIMPLI,** *The Mind of a Savant: Language, Learning, and Modularity*, 1995

There are numerous cases of intellectually handicapped individuals who, despite their disabilities in certain spheres, show remarkable talents in others. There are superb musicians and artists who lack the simple abilities required to take care of themselves. Such people are referred to as **savants**. Some of the most famous savants are human calculators who can perform arithmetic computations at phenomenal speed, or calendrical calculators who can tell you without pause on which day of the week any date in the last or next century falls.

Until recently, most such savants have been reported to be linguistically handicapped. They may be good mimics who can repeat speech like parrots, but they show meager creative language ability. Nevertheless, the literature reports cases of language savants who have acquired the highly complex grammar of their language (as well as other languages in some cases) but who lack nonlinguistic abilities of equal complexity. Laura and Christopher are two such cases.

Laura

Laura was a retarded young woman with a nonverbal IQ of 41 to 44. She lacked almost all number concepts, including basic counting principles, and could draw only at a preschool level. She had an auditory memory span limited to three units. Yet, when at the age of sixteen she was asked to name some fruits, she responded with *pears*, *apples*, and *pomegranates*. In this same period she produced syntactically complex sentences like *He was saying that I lost my battery-powered watch that I loved*, and *She does paintings, this really good friend of the kids who I went to school with and really loved*, and *I was like 15 or 19 when I started moving out of home . . .*

Laura could not add 2 + 2. She didn't know how old she was or how old she was when she moved away from home, nor whether 15 is before or after 19. Nevertheless, Laura produced complex sentences with multiple phrases and sentences with other sentences inside them. She used and understood passive sentences, and she was able to inflect verbs for number and person to agree with the subject of the sentence. She formed past tenses in accord with adverbs that referred to past time. She could do all this and more, but she could neither read nor write nor tell time. She did not know who the president of the United States was or what country she lived in. Her drawings of humans resembled potatoes with stick arms and legs. Yet, in a sentence imitation task, she both detected and corrected grammatical errors.

Laura is but one of many examples of children who display well-developed grammatical abilities, less-developed abilities to associate linguistic expressions with the objects they refer to, and severe deficits in nonlinguistic cognition.

In addition, any notion that linguistic competence results simply from communicative abilities, or develops to serve communicative functions, is belied by studies of children with good linguistic skills, but nearly no or severely limited communicative skills. The acquisition and use of language seem to depend on cognitive skills different from the ability to communicate in a social setting.

Christopher

Christopher has a nonverbal IQ between 60 and 70 and must live in an institution because he is unable to take care of himself. The tasks of buttoning a shirt, cutting his fingernails, or vacuuming the carpet are too difficult for him. However, his linguistic competence is as rich and as sophisticated as that of any native speaker. Furthermore, when given written texts in some fifteen to twenty languages, he translates them quickly, with few errors, into English. The languages include Germanic languages such as Danish, Dutch, and German; Romance languages such as French, Italian, Portuguese, and Spanish; as well as Polish, Finnish, Greek, Hindi, Turkish, and Welsh. He learned these languages from speakers who used them in his presence, or from grammar books. Christopher loves to study and learn languages. Little else is of interest to him. His situation strongly suggests that his linguistic ability is independent of his general intellectual ability.

The question as to whether the language faculty is a separate cognitive system or whether it is derivative of more general cognitive mechanisms is controversial and has received much attention and debate among linguists, psychologists, neuropsychologists, and cognitive scientists. Cases such as Laura and Christopher argue against the view that linguistic ability derives from general intelligence because these two individuals (and others like them) developed language despite other pervasive intellectual deficits. A growing body of evidence supports the view that the human animal is biologically equipped from birth with an autonomous language faculty that is highly specific and that does not derive from general human intellectual ability.

Genetic Basis of Language

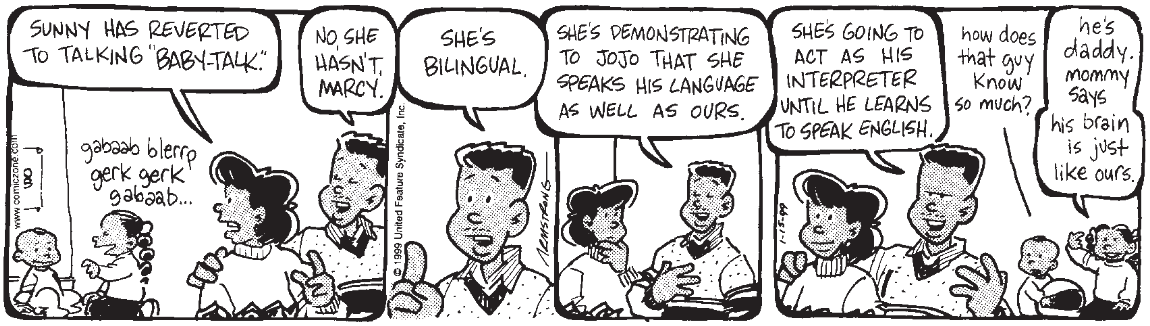
Studies of genetic disorders also reveal that one cognitive domain can develop normally along with abnormal development in other domains, and they also underscore the strong biological basis of language. Children with Turner syndrome (a chromosomal anomaly) have normal language and advanced reading skills along with serious nonlinguistic (visual and spatial) cognitive deficits. Similarly, studies of the language of children and adolescents with Williams syndrome reveal a unique behavioral profile in which certain linguistic functions seem to be relatively preserved in the face of visual and spatial cognitive deficits and moderate retardation. In addition, developmental dyslexia and SLI also appear to have a genetic basis. And recent studies of Klinefelter syndrome (another chromosomal anomaly) show quite selective syntactic and semantic deficits alongside intact intelligence.

Epidemiological and familial aggregation studies show that SLI runs in families. One such study is of a large multigenerational family, half of whom are language impaired. The impaired members of this family have a very specific grammatical problem: They do not reliably use word-endings or "irregular" verbs correctly. In particular, they often fail to indicate the tense of the verb. They routinely produce sentences such as the following:

She remembered when she hurts herself the other day.
He did it then he fall.
The boy climb up the tree and frightened the bird away.

These and similar results show that a large proportion of SLI children have language-impaired family members, pointing to SLI as a heritable disorder. Studies also show that monozygotic (identical) twins are more likely to both suffer from SLI than dizygotic (fraternal) twins. Thus evidence from SLI and other genetic disorders, along with the asymmetry of abilities in linguistic savants, strongly supports the view that the language faculty is an autonomous, genetically determined module of the brain.

Language and Brain Development



Language and the brain are intimately connected. Specific areas of the brain are devoted to language, and injury to these areas disrupts language. In the young child, injury to or removal of the left hemisphere has severe consequences for language development. Conversely, increasing evidence shows that normal brain development depends on early and regular exposure to language. (See chapter 7.)

The Critical Period

Under normal circumstances, a child is introduced to language virtually at the moment of birth. Adults talk to him and to each other in his presence. Children do not require explicit language instruction, but they do need exposure to language in order to develop normally. Children who do not receive linguistic input during their formative years do not achieve nativelike grammatical competence. Moreover, behavioral tests and brain imaging studies show that late exposure to language alters the fundamental organization of the brain for language.

The **critical-age hypothesis** assumes that language is biologically based and that the ability to learn a native language develops within a fixed period, from birth to middle childhood. During this **critical period**, language acquisition proceeds easily, swiftly, and without external intervention. After this period, the acquisition of grammar is difficult and, for most individuals, never fully achieved. Children deprived of language during this critical period show atypical patterns of brain lateralization.

The notion of a critical period is true of many species and seems to pertain to species-specific, biologically triggered behaviors. Ducklings, for example, during the period from nine to twenty-one hours after hatching, will follow the first moving object they see, whether or not it looks or waddles like a duck. Such behavior is not the result of conscious decision, external teaching, or intensive practice. It unfolds according to what appears to be a maturationally determined schedule that is universal across the species. Similarly, as discussed in a later section, certain species of birds develop their bird song during a biologically determined window of time.

Instances of children reared in environments of extreme social isolation constitute "experiments in nature" for testing the critical-age hypothesis. The most dramatic cases are those described as "wild" or "feral" children. A celebrated case, documented in François Truffaut's film *The Wild Child*, is that of Victor, "the wild boy of Aveyron," who was found in 1798. It was ascertained that he had been left in the woods when very young and had somehow survived. In 1920 two children, Amala and Kamala, were found in India, supposedly having been reared by wolves.

Other children have been isolated because of deliberate efforts to keep them from normal social intercourse. In 1970, a child called Genie in the scientific reports was discovered. She had been confined to a small room under conditions of physical restraint and had received only minimal human contact from the age of eighteen months until nearly fourteen years.

None of these children, regardless of the cause of isolation, was able to speak or knew any language at the time they were reintroduced into society. This linguistic inability could simply be caused by the fact that these children received no linguistic input, showing that language acquisition, though an innate, neurologically based ability, must be triggered by input from the environment. In the documented cases of Victor and Genie, however, these children were unable to acquire grammar even after years of exposure, and despite the ability to learn many words.

Genie was able to learn a large vocabulary, including colors, shapes, objects, natural categories, and abstract as well as concrete terms, but her grammatical skills never fully developed. The UCLA linguist Susan Curtiss, who worked with Genie for several years, reported that Genie's utterances were, for the most part, "the stringing together of content words, often with rich and clear meaning, but with little grammatical structure." Many utterances produced by Genie at the age of fifteen and older, several years after her emergence from isolation, are like those of two-year-old children, and not unlike utterances of Broca's aphasia patients and people with SLI, such as the following:

Man motorcycle have.
Genie full stomach.
Genie bad cold live father house.
Want Curtiss play piano.
Open door key.

Genie's utterances lacked articles, auxiliary verbs like *will* or *can*, the third-person singular agreement marker *-s*, the past-tense marker *-ed*, question words like *who*, *what*, and *where*, and pronouns. She had no ability to form more complex types of sentences such as questions (e.g., *Are you feeling hungry?*). Genie started learning language after the critical period and was therefore never able to fully acquire the grammatical rules of English.

Tests of lateralization (dichotic listening and ERP experiments) showed that Genie's language was lateralized to the *right* hemisphere. Her test performance was similar to that found in split-brain and left hemispherectomy patients, yet Genie was not brain damaged. Curtiss speculates that after the critical period, the usual language areas functionally atrophy because of inadequate linguistic stimulation. Genie's case also demonstrates that language is not the same as communication, because Genie was a powerful nonverbal communicator, despite her limited ability to acquire language.

Chelsea, another case of linguistic isolation, is a woman whose situation also supports the critical-age hypothesis. She was born deaf but was wrongly diagnosed as retarded. When she was thirty-one, her deafness was finally diagnosed, and she was fitted with hearing aids. For years she has received extensive language training and therapy and has acquired a large vocabulary. However, like Genie, Chelsea has not been able to develop a grammar. ERP studies of the localization of language in Chelsea's brain have revealed an equal response to language in both hemispheres. In other words, Chelsea also does not show the normal asymmetric organization for language.

More than 90 percent of children who are born deaf or become deaf before they have acquired language are born to hearing parents. These children have also provided information about the critical age for language acquisition. Because most of their parents do not know sign language at the time these children are born, most receive delayed language exposure. Several studies have investigated the acquisition of American Sign Language (ASL) among deaf signers exposed to the language at different ages. Early learners who received ASL input from birth and up to six years of age did much better in the production and comprehension of complex signs and sign sentences than late learners who were not exposed to ASL until after the age of twelve, even though all of the subjects in these studies had used sign for more than twenty years. There was little difference, however, in vocabulary or knowledge of word order.

Another study compared patterns of lateralization in the brains of adult native speakers of English, adult native signers, and deaf adults who had not been exposed to sign language. The nonsigning deaf adults did not show the same cerebral asymmetries as either the hearing adults or the deaf signers. In recent years there have been numerous studies of late learners of sign language, all with similar results.

The cases of Genie and other isolated children, as well as deaf late learners of ASL, show that children cannot fully acquire language unless they are exposed to it within the critical period—a biologically determined window of opportunity during which time the brain is prepared to develop language. Moreover, the critical period is linked to brain lateralization. The human brain is primed to develop language in specific areas of the left hemisphere, but the normal process of brain specialization depends on early and systematic experience with language. Language acquisition plays a critical role in, and may even be *the* trigger for, the realization of normal cerebral lateralization for higher cognitive functions in general, not just for language.

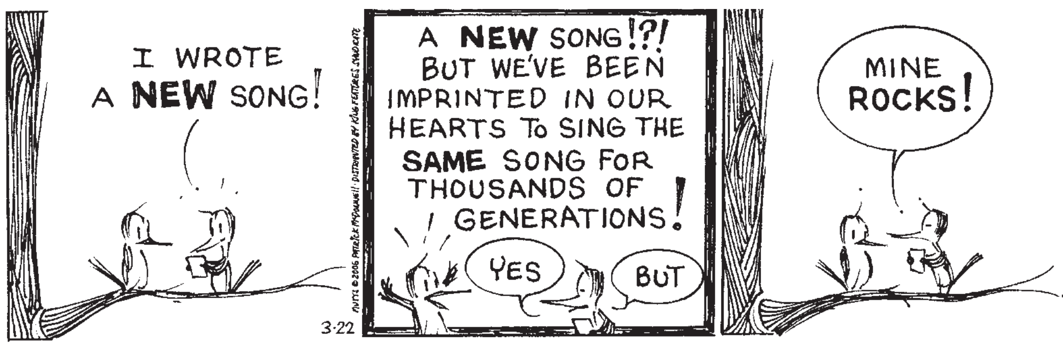
Beyond the critical period, the human brain seems unable to acquire the grammatical aspects of language, even with substantial linguistic training or many years of exposure. However, it is possible to acquire words and various conversational skills after this point. This evidence suggests that the critical period holds for the acquisition of grammatical abilities, but not necessarily for all aspects of language.

The selective acquisition of certain components of language that occurs beyond the critical period is reminiscent of the selective impairment that occurs in various language disorders, where specific linguistic abilities are disrupted. This selectivity in both acquisition and impairment points to a strongly modularized language faculty. Language is separate from other cognitive systems and autonomous, and is itself a complex system with various components. In the chapters that follow, we will explore these different language components.

A Critical Period for Bird Song

That's the wise thrush; he sings each song twice over
Lest you should think he never could recapture
The first fine careless rapture!

ROBERT BROWNING, "Home-thoughts, from Abroad," 1845



Mutts © Patrick McDonnell, King Features Syndicate

Bird song lacks certain fundamental characteristics of human language, such as discrete sounds and creativity. However, certain species of birds show a critical period for acquiring their "language" similar to the critical period for human language acquisition.

Calls and songs of the chaffinch vary depending on the geographic area that the bird inhabits. The message is the same, but the form or "pronunciation" is different. Usually, a young bird sings a simplified version of the song shortly after hatching. Later, it undergoes further learning in acquiring the fully complex version. Because birds from the same brood acquire different chaffinch songs depending on the area in which they finally settle, part of the song must be learned. On the other hand, because the fledging chaffinch sings the song of its species in a simple degraded form, even if it has never heard it sung, some aspect of it is biologically determined, that is, innate.

The chaffinch acquires its fully developed song in several stages, just as human children acquire language. There is also a critical period in the song learning of chaffinches as well as white-crowned sparrows, zebra finches, and many other species. If these birds are not exposed to the songs of their species during certain fixed periods after their birth—the period differs from species to species—song acquisition does not occur. The chaffinch is unable to learn new song elements after ten months of age. If it is isolated from other birds before attaining the full complexity of its song and is then exposed again after ten months, its song will not develop further. If white-crowned sparrows lose their hearing during a critical period after they have learned to sing, they produce a song that differs from other white crowns. They need to hear themselves sing in order to produce particular whistles and other song features. If, however, the deafness occurs after the critical period, their songs are normal. Similarly, baby nightingales in captivity may be trained to sing melodiously by another nightingale, a "teaching bird," but only before their tail feathers are grown. After that period, they know only the less melodious calls of their parents, and nothing more can be done to further their musical development.

On the other hand, some bird species show no critical period. The cuckoo sings a fully developed song even if it never hears another cuckoo sing. These communicative messages are entirely innate. For other species, songs appear to be at least partially learned, and the learning may occur throughout the bird's lifetime. The bullfinch, for example, will learn elements of songs it is exposed to, even those of another species, and incorporate those elements into its own quiet warble. In a more recent example of unconstrained song learning, Danish ornithologists report that birds have begun to copy the ring tones of cellular phones.

From the point of view of human language research, the relationship between the innate and learned aspects of bird song is significant. Apparently, the basic nature of the songs of some species is present from birth, which means that it is biologically and genetically determined. The same holds true for human language: Its basic nature is innate. The details of bird song and of human language are both acquired through experience that must occur within a critical period.

The Development of Language in the Species

> As the voice was used more and more, the vocal organs would have been strengthened and perfected through the principle of the inherited effects of use; and this would have reacted on the power of speech. But the relation between the continued use of language and the development of the brain has no doubt been far more important. The mental powers in some early progenitor of man must have been more highly developed than in any existing ape, before even the most imperfect form of speech could have come into use.
>
> **CHARLES DARWIN,** *The Descent of Man,* 1871

There is much interest today among biologists as well as linguists in the relationship between the development of language and the evolutionary development of the human species. Some view language as species specific; some do not. Some view language ability as a difference in degree between humans and other primates—a continuity view; others see the onset of language ability as a qualitative leap—the discontinuity view.

In trying to understand the development of language, scholars past and present have debated the role played by the vocal tract and the ear. For example, it has been suggested that speech could not have developed in nonhuman primates because their vocal tracts were anatomically incapable of producing a large enough inventory of speech sounds. According to this hypothesis, the development of language is linked to the evolutionary development of the speech production and perception apparatus. This, of course, would be accompanied by changes in the brain and the nervous system toward greater complexity. Such a view implies that the languages of our human ancestors of millions of years ago may have been syntactically and phonologically simpler than any language known to us today. The notion "simpler" is left undefined, although it has been suggested that this primeval language had a smaller inventory of sounds.

One evolutionary step must have resulted in the development of a vocal tract capable of producing the wide variety of sounds of human language, as well as the mechanism for perceiving and distinguishing them. However, the existence of mynah birds and parrots is evidence that this step is insufficient to explain the origin of language, because these creatures have the ability to imitate human speech, but not the ability to acquire language.

More important, we know from the study of humans who are born deaf and learn sign languages that are used around them that the ability to hear speech sounds is not a necessary condition for the acquisition and use of language. In addition, the lateralization evidence from ERP and imaging studies of people using sign language, as well as evidence from sign language aphasia, show that sign language is organized in the brain like spoken language. Certain auditory locations within the cortex are activated during signing even though no sound is involved, supporting the contention that the brain is neurologically equipped for language rather than speech. The ability to produce and hear a wide variety of sounds therefore appears to be neither necessary nor sufficient for the development of language in the human species.

A major step in the development of language most probably relates to evolutionary changes in the brain. The linguist Noam Chomsky expresses this view:

> It could be that when the brain reached a certain level of complexity it simply automatically had certain properties because that's what happens when you pack 10^{10} neurons into something the size of a basketball.[3]

The biologist Stephen Jay Gould expresses a similar view:

> The Darwinist model would say that language, like other complex organic systems, evolved step by step, each step being an adaptive solution. Yet language is such an integrated "all or none" system, it is hard to imagine it evolving that way. Perhaps the brain grew in size and became capable of all kinds of things which were not part of the original properties.[4]

Other linguists, however, support a more Darwinian natural selection development of what is sometimes called "the language instinct":

> All the evidence suggests that it is the precise wiring of the brain's microcircuitry that makes language happen, not gross size, shape, or neuron packing.[5]

The attempt to resolve this controversy clearly requires more research. Another point that is not yet clear is what role, if any, hemispheric lateralization

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[3]Chomsky, N., in Searchinger, G. 1994. The human language series, program 3. Video. New York: Equinox Film/Ways of Knowing, Inc.

[4]Gould, S. J., in Searchinger, G. 1994. The human language series, program 3. Video. New York: Equinox Film/Ways of Knowing, Inc.

[5]Pinker, S. 1995. *The language instinct*. New York: William Morrow.

played in language evolution. Lateralization certainly makes greater specialization possible. Research conducted with birds and monkeys, however, shows that lateralization is not unique to the human brain. Thus, while it may constitute a necessary step in the evolution of language, it is not a sufficient one.

We do not yet have definitive answers to the origin of language in the human brain. The search for these answers goes on and provides new insights into the nature of language and the nature of the human brain.

Summary

The attempt to understand what makes the acquisition and use of language possible has led to research on the brain-mind-language relationship. **Neurolinguistics** is the study of the brain mechanisms and anatomical structures that underlie linguistic competence and performance. Much neurolinguistic research is centered on experimental and behavioral data from people with impaired or atypical language. These results greatly enhance our understanding of language structure and acquisition.

The brain is the most complex organ of the body, controlling motor and sensory activities and thought processes. Research conducted for more than a century has shown that different parts of the brain control different body functions. The nerve cells that form the surface of the brain are called the **cortex**, which serves as the intellectual decision maker, receiving messages from the sensory organs and initiating all voluntary actions. The brain of all higher animals is divided into two parts called the **cerebral hemispheres**, which are connected by the **corpus callosum**, a network that permits the left and right hemispheres to communicate.

Each hemisphere exhibits **contralateral** control of functions. The left hemisphere controls the right side of the body, and the right hemisphere controls the left side. Despite the general symmetry of the human body, much evidence suggests that the brain is asymmetric, with the left and right hemispheres **lateralized** for different functions.

Neurolinguists have many tools for studying the brain, among them **dichotic listening** experiments and many types of scans and electrical measurements. These techniques permit the study of the living brain as it processes language. By studying **split-brain** patients and **aphasics,** localized areas of the brain can be associated with particular language functions. For example, lesions in the part of the brain called **Broca's area** may suffer from **Broca's aphasia**, which results in impaired syntax and **agrammatism**. Damage to **Wernicke's area** may result in **Wernicke's aphasia**, in which fluent speakers produce semantically anomalous utterances, or even worse, **jargon aphasia**, in which speakers produce nonsense forms that make their utterance uninterpretable. Damage to yet different areas can produce **anomia**, a form of aphasia in which the patient has word-finding difficulties.

Deaf signers with damage to the left hemisphere show aphasia for sign language similar to the language breakdown in hearing aphasics, even though sign language is a visual-spatial language.

Other evidence supports the lateralization of language. Children who undergo a left **hemispherectomy** show specific linguistic deficits, whereas other cognitive abilities remain intact. If the right brain is damaged or removed after the first two or three years, however, language is unimpaired, but other cognitive disorders may result.

The language faculty is **modular**. It is independent of other cognitive systems with which it interacts. Evidence for modularity is found in studies of aphasia, of children with **specific language impairment** (**SLI**), of linguistic **savants**, and of children who learn language past the **critical period**. The genetic basis for an independent language module is supported by studies of SLI in families and twins and by studies of genetic anomalies associated with language disorders.

The **critical-age hypothesis** states that there is a window of opportunity between birth and middle childhood for learning a first language. The imperfect language learning of persons exposed to language after this period supports the hypothesis. Some songbirds also appear to have a critical period for the acquisition of their calls and songs.

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Exercises

1. The Nobel Prize laureate Roger Sperry has argued that split-brain patients have two minds:

    > Everything we have seen so far indicates that the surgery has left these people with two separate minds, that is, two separate spheres of consciousness. What is experienced in the right hemisphere seems to lie entirely outside the realm of experience of the left hemisphere.

    Another Nobel Prize winner in physiology, Sir John Eccles, disagrees. He does not think the right hemisphere can think; he distinguishes between "mere consciousness," which animals possess as well as humans, and language, thought, and other purely human cognitive abilities. In fact, according to him, human nature is all in the left hemisphere.

    Write a short essay discussing these two opposing points of view, stating your opinion on how to define "the mind."

2. **A.** Some aphasic patients, when asked to read a list of words, substitute other words for those printed. In many cases, the printed words and the substituted words are similar. The following data are from actual aphasic patients. In each case, state what the two words have in common and how they differ:

	Printed Word	Word Spoken by Aphasic
i.	liberty	freedom
	canary	parrot
	abroad	overseas
	large	long
	short	small
	tall	long
ii.	decide	decision
	conceal	concealment
	portray	portrait
	bathe	bath
	speak	discussion
	remember	memory

    B. What do the words in groups (i) and (ii) reveal about how words are likely to be stored in the brain?

3. The following sentences spoken by aphasic patients were collected and analyzed by Dr. Harry Whitaker. In each case, state how the sentence deviates from normal nonaphasic language.

    a. There is under a horse a new sidesaddle.
    b. In girls we see many happy days.
    c. I'll challenge a new bike.
    d. I surprise no new glamour.
    e. Is there three chairs in this room?

- **f.** Mike and Peter is happy.
- **g.** Bill and John likes hot dogs.
- **h.** Proliferate is a complete time about a word that is correct.
- **i.** Went came in better than it did before.

4. The investigation of individuals with brain damage has been a major source of information regarding the neural basis of language and other cognitive systems. One might suggest that this is like trying to understand how an automobile engine works by looking at a damaged engine. Is this a good analogy? If so, why? If not, why not? In your answer, discuss how a damaged system can or cannot provide information about the normal system.

5. What are the arguments and evidence that have been put forth to support the notion that there are two separate parts of the brain?

6. Discuss the statement: *It only takes one hemisphere to have a mind*.

7. In this chapter, dichotic listening tests in which subjects hear different kinds of stimuli in each ear were discussed. These tests showed that there were fewer errors made in reporting linguistic stimuli such as the syllables *pa*, *ta*, and *ka* when heard through an earphone on the right ear; other nonlinguistic sounds such as a police car siren were processed with fewer mistakes if heard by the left ear. This is a result of the contralateral control of the brain. There is also a technique that permits visual stimuli to be received either by the right visual field, that is, the right eye alone (going directly to the left hemisphere), or by the left visual field (going directly to the right hemisphere). What are some visual stimuli that could be used in an experiment to further test the lateralization of language?

8. The following utterances were made either by Broca's aphasics or Wernicke's aphasics. Indicate which is which by writing a "B" or "W" next to the utterance.

- **a.** Goodnight and in the pansy I can't say but into a flipdoor you can see it.
- **b.** Well . . . sunset . . . uh . . . horses nine, no, uh, two, tails want swish.
- **c.** Oh, . . . if I could I would, and a sick old man disflined a sinter, minter.
- **d.** Words . . . words . . . words . . . two, four, six, eight, . . . blaze am he.

9. Shakespeare's Hamlet surely had problems. Some say he was obsessed with being overweight, because the first lines he speaks in the play when alone on the stage in Act II, Scene 2, are:

> O! that this too too solid flesh would melt,
>
> Thaw, and resolve itself into a dew;

Others argue that he may have had Wernicke's aphasia, as evidenced by the following passage from Act II, Scene 2:

> Slanders, sir: for the satirical rogue says here
>
> that old men have grey beards, that their faces are

wrinkled, their eyes purging thick amber and
plum-tree gum and that they have a plentiful lack of
wit, together with most weak hams: all which, sir,
though I most powerfully and potently believe, yet
I hold it not honesty to have it thus set down, for you
yourself, sir, should be old as I am, if like a crab
you could go backward.

Take up the argument. Is Hamlet aphasic? Argue either case.

10. **Research projects:**
    - **a.** Recently, it's been said that persons born with "perfect pitch" nonetheless need to exercise that ability at a young age or it goes away by adulthood. Find out what you can about this topic and write a one-page (or longer) paper describing your investigation. Begin with defining "perfect pitch." Relate your discoveries to the *critical-age hypothesis* discussed in this chapter.
    - **b.** Consider some of the high-tech methodologies used to investigate the brain discussed in this chapter, such as PET scans and MRIs. What are the upsides and downsides of the use of these technologies on healthy patients? Consider the cost, the intrusiveness, and the ethics of exploring a person's brain weighed against the knowledge obtained from such studies.
    - **c.** Investigate claims that PET scans show that reading silently and reading aloud involve different parts of the left hemisphere.

11. **Article review project:** Read, summarize, and critically review the article that appeared in *Science*, Volume 298, November 22, 2002, by Marc D. Hauser, Noam Chomsky, and W. Tecumseh Fitch, entitled "The Faculty of Language: What Is It, Who Has It, and How Did It Evolve?"

12. As discussed in the chapter, agrammatic aphasics may have difficulty reading function words, which are words that have little descriptive content, but they can read more contentful words such as nouns, verbs, and adjectives.
    - **a.** Which of the following words would you predict to be difficult for such a person?

ore	bee	can (be able to)	but
not	knot	may	be
may	can (metal container)	butt	or
will (future)	might (possibility)	will (willingness)	might (strength)

    - **b.** Discuss three sources of evidence that function words and content words are stored or processed differently in the brain.

13. The traditional writing system of the Chinese languages (e.g., Mandarin, Cantonese) is ideographic (each concept or word is represented by a distinct

character). More recently, the Chinese government has adopted a spelling system called *pinyin*, which is based on the Roman alphabet, and in which each symbol represents a sound. Following are several Chinese words in their character and *pinyin* forms. (The digit following the Roman letters in *pinyin* is a tone indicator and may be ignored.)

木	mu4	tree
花	hua1	flower
人	ren2	man
家	jia1	home
狗	gou3	dog

Based on the information provided in this chapter, would the location of neural activity be the same or different when Chinese speakers read in these two systems? Explain.

14. **Research project:** Dame Margaret Thatcher, a former prime minister of the United Kingdom, has been (famously) quoted as saying: "If you want something said, ask a man . . . if you want something done, ask a woman." This suggests, perhaps, that men and women process information differently. This exercise asks you to take up the controversial question: *Are there gender differences in the brain having to do with how men and women process and use language?* You might begin your research by seeking answers (try the Internet) to questions about the incidence of SLI, dyslexia, and language development differences in boys versus girls.

15. **Research project:** Discuss the concept of *emergence* and its relevance to the quoted material of footnotes 3 and 4, as opposed to footnote 5, on page 27.