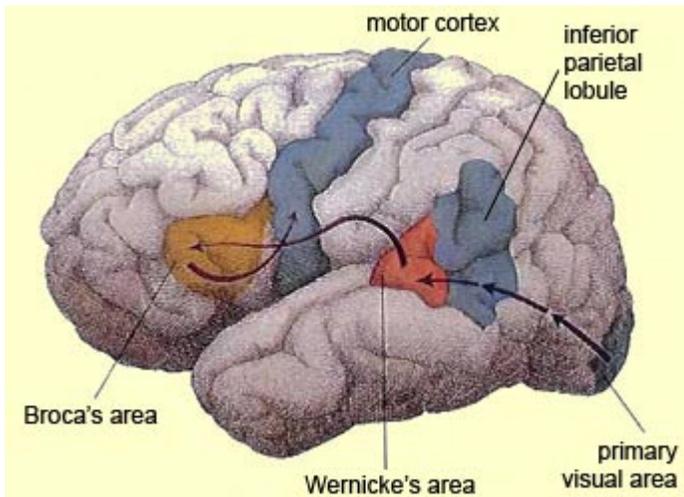


Taken From “The Brain From Top to Bottom” // http://thebrain.mcgill.ca/flash/i/i_10/i_10_cr/i_10_cr_lan/i_10_cr_lan.html#2

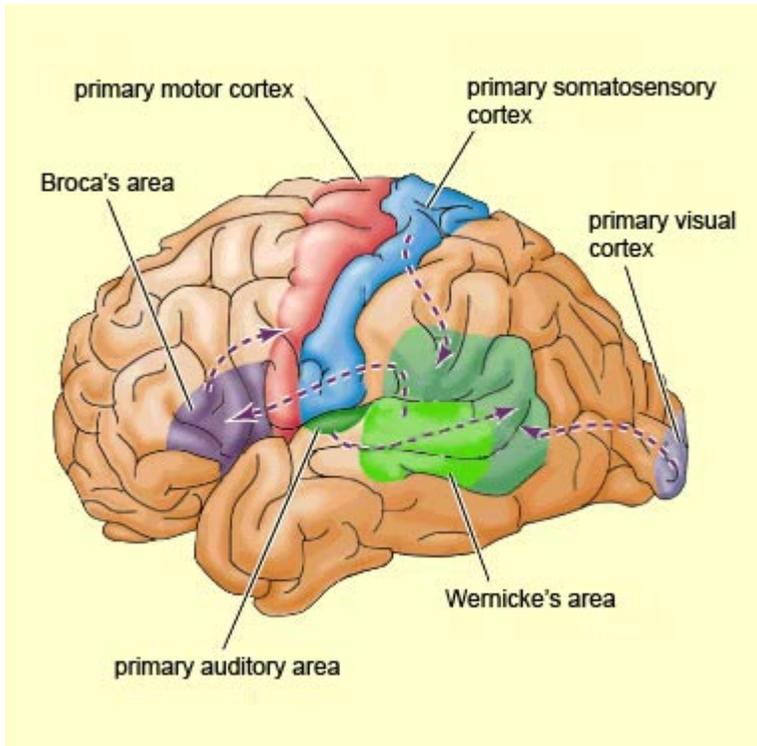
BROCA’S AREA , WERNICKE’S AREA, AND OTHER LANGUAGE-PROCESSING AREAS IN THE BRAIN // Brain Lateralization

For many years, scientists’ understanding of how the brain processes language was rather simple: they believed that Wernicke’s area interpreted the words that we hear or read, then relayed this information via a dense bundle of fibres to Broca’s area, which generated any words that we spoke in response. But subsequent experiments with brain imaging have revealed the existence of a **third region of the brain** that is also **indispensable for language**.

This region is the inferior parietal lobule, also known as “Geschwind’s territory”, in honor of the American neurologist Norman Geschwind, who foresaw its importance as early as the 1960s. Brain imaging studies have now shown that the inferior parietal lobule (angular gyrus and supramarginal gyrus) is **connected by large bundles of nerve fibres to both Broca’s area and Wernicke’s area**. Information might therefore travel between these last two areas either directly, via the arcuate fasciculus, or by a second, parallel route that passes through the inferior parietal lobule.



The inferior parietal lobule of the left hemisphere lies at a key location in the brain, at the **junction of the auditory, visual, and somatosensory cortices**, with which it is massively connected. In addition, the neurons in this lobule have the particularity of being multimodal, which means that they can process different kinds of stimuli (auditory, visual, sensorimotor, etc.) simultaneously. This **combination of traits makes the inferior parietal lobule an ideal candidate for apprehending the multiple properties of spoken and written words: their sound, their appearance, their function, etc.** This lobule may thus help the brain to classify and label things, which is a prerequisite for forming concepts and thinking abstractly.



The **inferior parietal lobule** is one of the **last structures of the human brain to have developed in the course of evolution**. This structure appears to exist in rudimentary form in the brains of other primates, which indicates that language may have evolved through changes in existing neural networks, rather than through the emergence of completely new structures in the brain.

The **inferior parietal lobule** is also one of the **last structures to mature in human children**, and there are reasons to believe that it may play a key role in the acquisition of language. The **late maturation** of this structure would **explain**, among other things, why **children cannot begin to read and write until they are 5 or 6 years old**.

Over the years, and especially since the advent of brain-imaging technologies, scientists' beliefs regarding the anatomical and functional boundaries of Broca's area, Wernicke's area, and the inferior parietal lobule have changed a great deal. But it seems more and more likely that, as with other systems in the brain, these variations reflect the existence of several sub-regions with distinct functions.

In most people, the **right hemisphere** is **not the dominant hemisphere for language**. But even then, it is **still involved in understanding simple words, short phrases, metaphorical language, and prosody**.

When the left hemisphere is damaged, the right hemisphere can play an even more important role in language. One such case involves young children who suffer from frequent epileptic seizures that do not respond well to medication and that compromise their cognitive development.

If the focus of these seizures lies in only one hemisphere, but they affect both hemispheres, an operation called a **hemispherectomy** may be performed, in which removing a large portion of the diseased hemisphere successfully controls the seizures. If the hemisphere removed is the one that was dominant for language in this child (usually the left), and the child is very young, the right hemisphere will take over its language functions almost perfectly.

This phenomenon suggests that the right hemisphere has what it takes to handle the main functions of language. These operations have also demonstrated that the plasticity of the right hemisphere persists beyond what is generally considered the critical period for language acquisition.

MODELS OF SPOKEN AND WRITTEN LANGUAGE FUNCTIONS IN THE BRAIN

The earliest beginnings of spoken language in human beings go back perhaps 2 million years and were accompanied by changes in the brain that enabled it to process such language more effectively. This was not the case for **written language, which goes back scarcely 4000 years**. We may therefore say that humans are biologically designed to speak, but not to read and write.

As with so many other functions, the development of language in children follows the same pattern as the development of language in their species: **children learn to read and write several years after they have mastered spoken language**. The system of graphic language symbols is thus added onto the system of phonological language symbols that is already in place.

According to the **Geschwind-Wernicke model**, when one person hears another speak a word, it is **perceived first in the auditory cortex, then passed on to Wernicke's area**.

In contrast, according to this model, **when someone reads a word, it reaches the brain via the eyes rather than the ears**. Consequently, it is **perceived first, as a graphic pattern**, by the primary visual cortex, which passes it on to the angular gyrus. There, at the junction of the temporal, occipital, and parietal lobes, the spelling of the word is deciphered. The neurons of the angular gyrus are also especially well placed to categorize, conceptualize, and draw connections among various characteristics of an object. **The angular gyrus would thus be directly involved when you assign a name to an object or when you read its name**. The angular gyrus is also more active when you are retrieving the meaning of a word or holding it in memory for a short time.

From the angular gyrus, the information is then passed on to the adjacent region, Wernicke's area, where it is recognized as a word associated with its corresponding auditory form. From there, **regardless of whether the word has been heard or read, the message travels to Broca's area**, which adds a syntactic structure and an articulation plan. This rich, complex information is then transferred to the motor cortex, adjacent to Broca's area. **The pyramidal neurons of the motor cortex** then send their signals to the muscles of the mouth and larynx that produce the spoken word.

Recent studies have shown that **at least two distinct neural systems may be involved in reading**. According to this theory, the **brain reads mainly by translating written characters into the corresponding phonological elements of spoken language, but also by drawing connections between the complete images of written words and their meanings**. This latter recall process may thus in a sense short-circuit the process of drawing connections between words' phonological signatures and their meanings.

Be that as it may, reading is a very rapid process. The brain is estimated to have only a few tenths of a second to translate every symbol into sound. The speed of this processing is so crucial that even very slight disorders in processing the image, its color, or its contrast may suffice to make reading an arduous task.

Major lesions in the left parieto-occipital area can make someone unable to read and/or write while leaving their spoken-language abilities intact. In contrast, lesions in auditory associative areas such as Wernicke's area will prevent someone both from understanding spoken language and from reading.

Increasingly, however, results from brain-imaging studies are raising questions about the classic model of localized language functions as proposed by Geschwind. These findings argue instead for zones of convergence and a more distributed concept of language areas, one that implies parallel coding and processing of information.

The middle portion of the inferior temporal gyrus (Brodmann area 37) is another associative area of convergence for language. It is located between the visual cortex and the anterior temporal cortex and becomes more active during various language-related tasks, such as reading, or pronouncing the name of an object or a letter. As in the angular gyrus, a lesion in the middle portion of the inferior temporal gyrus can cause deficits in reading and in identifying objects.

The model **first proposed by Geschwind has undergone many modifications** since. For example, **we now know that when someone reads a word, their brain does not have to convert it into a pseudo-auditory response before they can pronounce it**. In fact, the **visual information from the printed word seems to be transmitted from the visual cortex to Broca's area without having to pass through the angular gyrus**.

Blind people use their fingers to read characters in the form of the raised dots of Braille. We now know that in people who are blind from birth, it is the **visual cortex that takes charge of the information received through the fingers when they are reading Braille**, despite the total absence of any visual input.

While **reading** requires the co-ordinated operation of the brain's visual system and its linguistic system, **writing** is based on co-ordination of its linguistic system and its motor system, which controls the precise gestures involved in writing.

The terms “alexia” and “agraphia” refer to the inability to read and to write, respectively. These two language disorders seem to depend on two specialized systems that are distinct and independent.

Another condition, called “anomia”, consists in a difficulty in retrieving the names of objects. It is often observed following damage to the angular gyrus.

HANDEDNESS, LANGUAGE, AND BRAIN LATERALIZATION

Brain lateralization is the phenomenon whereby a **given function is preferentially controlled by one side of the brain rather than the other**. The brain’s left and right hemispheres are thus the site of distinct cognitive functions whose complementarity is ensured by the corpus callosum, the main bundle of nerve fibres connecting the two hemispheres.

Lateralization seems to be an **ingenious strategy** that developed over the course of human evolution to **get the most out of the space available in the brain**. For instance, lateralization increases processing speed by avoiding the long pathways that would otherwise be needed to connect regions on opposite sides of the brain. Also, when two symmetrical areas on opposite sides of the brain perform two different functions, the brain’s cognitive capacities are in a sense doubled.

Handedness and language are two highly lateralized functions. Though there is no direct relationship between the two, the lateralization of the skilful hand does nevertheless influence the lateralization of language. Many studies, using tests such as **Wada’s test** (follow the Tool module link to the left), **have shown that in 92 to 96% of right-handed people, it is the left hemisphere that is specialized for language**.

For **left-handed people**, things are a bit more complicated, and the results of studies are less consistent. Some authors say that about **70% of left-handed people are left-lateralized for language, 15% are right-lateralized, and 15% are ambilateral (their language functions are more evenly distributed between their two hemispheres)**. But other studies have found that only 15% of left-handed people are left-lateralized for language while 15% are right-lateralized and 70% are ambilateral to varying extents.

The difference in the linguistic functioning of the two hemispheres raises the possibility of anatomical differences between the language areas on the left and right sides of the brain, because though the **two hemispheres** are similar in overall appearance, they are **not exact replicas of each other**. The first descriptions of asymmetries between language-related areas on the two sides of the brain date back to the 19th century, when brain autopsies **revealed that the lateral sulcus was longer and shallower in the left hemisphere than in the right**.

More recently, tools such as **magnetic resonance imaging (MRI)** have discovered other **left/right asymmetries in language-processing areas** of the brain. One of the most significant asymmetries is observed in the **temporal planum**, located on the superior surface of the temporal lobe. This triangular region, which penetrates deep into the lateral sulcus, **forms the heart of Wernicke's area**, one of the most important functional areas for language.

The left temporal planum appears to be more developed in 65% of all individuals, and the right temporal planum in only 10%. **In some people's brains, the temporal planum is more than five times larger on the left than on the right, making it the most asymmetrical structure in the brain.**

This greater size of the left temporal planum compared with the right is **already present in the fetus**, where it can be observed starting from the 31st week of gestation. This observation strengthens the hypothesis of a genetic predisposition for brain asymmetry.

Because such an overwhelming majority of people are right-handed, left-handed people quickly come to realize that they are living in a world where the **objects are designed for right-handed people**. From coffee pots to power tools to guitars, any items that are not perfectly symmetrical are designed for "righties". The results may range from minor inconvenience to serious injuries and even death—statistics show, for instance, that the frequency of highway and workplace accidents is higher among left-handed people than among right-handed ones.

But being left-handed can also have some advantages. For instance, in the sport of fencing, the majority of the opponents that any contestant faces are right-handed. Hence, left-handed fencers will have far more experience in parrying attacks from their right-handed opponents than these opponents will have in repelling their left-handed attacks.

THE RIGHT HEMISPHERE'S CONTRIBUTION TO LANGUAGE

Our social interactions are based largely on our developing social intelligence regarding other people—what some authors call a "theory of mind". The reason we need such intelligence is that in addition to understanding the information conveyed explicitly by people's words, we **must also constantly decipher their beliefs, intentions, knowledge, and affective states** if we are going to interact with these people effectively.

Consequently, if we want to really understand a conversation with someone else, we need more than a simple mastery of the basic elements of spoken human language, because that person **will also be expressing information non-verbally that alters the meaning of what he or she is saying.**

The **phonological, syntactic, and lexical** aspects of this discourse are controlled by the left hemisphere, which is **why it was long considered the dominant hemisphere for language.**

The **contributions of the right hemisphere to language behavior** are more subtle and nuanced and were not recognized until much later on. The **right hemisphere provides the ability to go beyond the literal meanings** of words and employs multiple processes to do so. The new science of communication from the perspective of the “minor hemisphere” for language is called **pragmatics**.

The pragmatic function is the **ability to understand things that are implicitly signified in discourse**—for example, the meanings of metaphors, or of questions like “Do you have a light?” When right-handed people suffer damage to the right hemisphere of the brain, this pragmatic function is affected, and they tend to interpret such metaphors and questions literally. In fact, these people react exactly as if they were dealing with idioms in a foreign language: **their grammar and phonology may be correct, but they do not understand the verbal humour or metaphors that native speakers of that language use every day**. Thus, by contributing to the emotional and tonal components of language, the right hemisphere infuses verbal communication with additional meanings.

Where does the pragmatic function reside in the brains of left-handed people? Researchers are not sure. There are many possibilities, depending on where the person’s other, conventional language abilities are located: in the left hemisphere, the right hemisphere, or both. More **generally speaking, the right hemisphere** seems to show a **predilection for spatial tasks and for recognizing faces and music**, while the **left hemisphere appears more active in dealing with language and with computational and logical tasks**. But these are, of course, only generalizations: in normal individuals, the two hemispheres work together, exchanging information via the corpus callosum.

This interaction between the two hemispheres is the basis for all the extensive co-operation that takes place within the central nervous system and shows just how much the two hemispheres complement each other for most functions, including language.

In attempting to compare the size of certain homologous cortical areas in the left and right hemispheres, researchers face two major obstacles. First, the variations among individuals are often greater than the variations between hemispheres. Second, the parts of the brain that display activity in functional brain images do not necessarily coincide with precise cytoarchitectural regions of the brain.

Certain stimuli that seem similar can preferentially activate one hemisphere or the other, **depending on the life experiences** of the individual concerned. For instance, **for the average person, recognizing the position of the pieces on a chessboard is a spatial task and hence is performed chiefly by the right hemisphere. But for a chess master, it is more like interpreting a language that has its own grammar and hence tends to be performed by the left hemisphere instead.**

Music can also activate the left hemisphere more than the right, depending on whether the individual has musical training or not. This finding contradicts the earliest hypotheses, which held that the musical functions of the brain were located exclusively in the right hemisphere.

A greater overall contribution by the right hemisphere among left-handed people might explain why the proportion of left-handers is higher among mathematicians and musicians than among the general population. Both of these professions apply visualization functions that are normally located in this hemisphere.