

# LATERALIZATION OF LANGUAGE FUNCTIONS IN THE HUMAN BRAIN

## More symmetric than asymmetric

At first glance, the two cerebral hemispheres seem to be mirror images of each other. While certain parts of the left hemisphere control movement and sensations on the right side of the body, the corresponding parts of the right hemisphere are connected to the left side of the body.

But the hemispheres are not entirely symmetric. The most well-known asymmetry in humans concerns language (Springer & Deutsch, 1993).

## The left hemisphere - Wernicke and Broca

It has been known for a long time that people with damage to the left side of the brain frequently suffer from speech difficulties (e. g. aphasia), in addition to problems with the sensorymotor control of the right side of the body.

Broca's area and Wernicke's area, both discovered in the 19<sup>th</sup> century, are the most well-known speech centres. Both are usually located in the left hemisphere; (Springer & Deutsch, 1993).

Damage to Broca's Area primarily results in speech production impairment and loss of grammar and function words. Speech understanding usually remains quite good, but speech production becomes "telegraphic" and slow. Broca's aphasics may have problems with interpretation of semantically strange sentences such as "The man bit the dog". Since men rarely bite dogs, they tend to see the dog as the subject and the man as the object regardless of word order (handout 27/3, 2007).

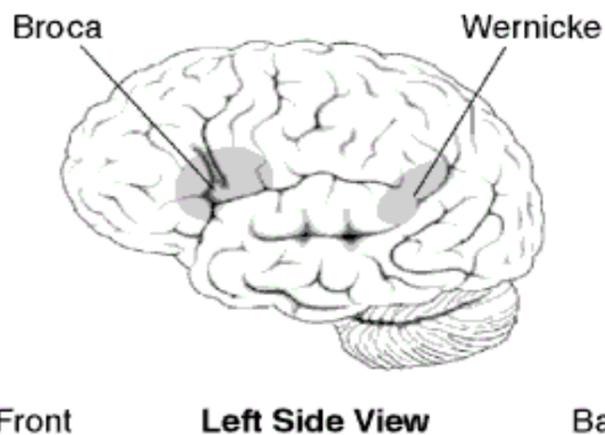


Fig 1: Broca's and Wernicke's area (Wikipedia, 2007)

Patients with damage to Wernicke's Area may speak fluently and use function words. Their problems mainly concern syntax and lexical words, which leads to difficulties with understanding language as well as with producing comprehensible sentences. In extreme cases, damage to Wernicke's area can lead to anomia – a loss of the ability to name things (Gazzaniga et al, 2002). More often, Wernicke's aphasics make paraphasias – that is, they substitute lexical words with words that somehow resemble them (handout 27/3, 2007)

## Speech functions and handedness

An interesting fact about the lateralization of speech areas is the way it corresponds to the handedness of the person. More than 95 % of right handed people have their speech centres in the left hemisphere. There is more variation among left-handers. 70 % of all left handed people also have their speech centres in the left hemisphere. According to Springer & Deutsch (1993) the majority of the remaining 30 % have their speech functions evenly distributed to both hemispheres. Other studies (handout 27/3) suggest that 15 % of those 30% have language functions in the right hemisphere while the other 15% have them in both hemispheres.

But since only 7-8% are left-handed, the vast majority of all people (~93 %) have left hemisphere language dominance (Gazzaniga et al, 2002; handout 27/3, 2007).

## Anatomical differences between the hemispheres

The planum temporale forms the upper part of the temporal lobe – the part of the cortex where Wernicke's Area is located. The planum temporale is larger in the left hemisphere in a majority (65 %) of right handed people (Springer & Deutsch, 1993). MRI studies of the brains of dyslexic children have shown that their planum temporales are the same size in both hemispheres. Maybe this means dyslexics have less specialized left hemispheres. What this theory doesn't explain is why 95% of right-handers have left-hemisphere language dominance even though only 65 % has a larger planum temporale (Gazzaniga et al, 2002).

Maybe the answer is to be found at a microscopical level. Today you can investigate the lateralization of brain functions from a cellular perspective. There are some known differences in cellular organisation.

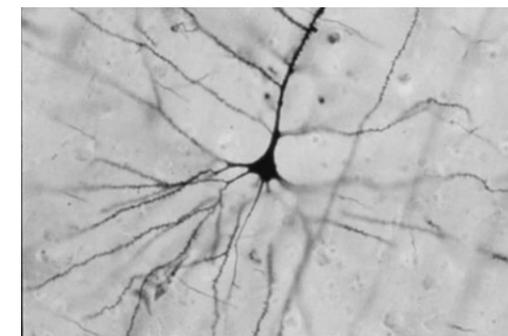


Fig 2: Pyramidal cell (Wikipedia, 2007)

The nerve cells of the cerebral cortex are arranged in columns. These columns of cells are wider and more distinct in the left temporal lobe compared to the right. The space between them is greater, but they also have a greater dendritic spread. The total dendrite length of the left-hemisphere pyramidal cells therefore is greater. There may also be chemical differences between the hemispheres - for example the enzyme choline acetyltransferase is present in higher levels in the left hemisphere. But the knowledge of cellular and chemical differences between the hemispheres still is limited (Gazzaniga et al, 2002).

## The right hemisphere's role in language

A rough division of the two hemispheres' abilities could be described as follows: The right hemisphere is thought to be better at visuospatial tasks and it seems to work in a more holistic way, in contrast to the more sequential, analytical left. Recognition of faces, as well as memory and orientation skills, are often impaired in patients with lesions on the right side. The left hemisphere is better at processing verbal stimuli, but in addition to language, some mathematical and musical skills also seem to be located to the left hemisphere (handout 17/4, 2007; ).

But this doesn't mean that the right hemisphere is unimportant to language. Damage to the right hemisphere can also result in language problems, though they are often more subtle.

The right hemisphere seems to be important for musicality. People who have lost their speech due to left hemisphere lesions frequently do not lose their ability to sing. Similarly, right hemisphere lesions can result in an impairment of musical skills although speech is unaffected. With the Wada Test you can anesthetize only one of the hemispheres by injecting amobarbital in the carotid artery that goes to it. When this test was performed on patients and they tried to sing with their right hemisphere asleep, the rhythm was still there, but the melody got monotone (Springer & Deutsch, 1993).

Patients with right hemisphere lesions sometimes have problems detecting the emotional information in speech signalled by prosody. Their own speech has less intonation as well. This could be because their ability to hear and produce the prosodic changes associated with emotion is impaired. Another possibility is that they have problems with processing the concept of emotions (Springer & Deutsch, 1993). Right-brain damage may also make the patient less skilled at realizing what is socially acceptable to say, and may cause him/her to mix different speech styles, e. g. formal and informal speech (handout 17/4, 2007).

The right hemisphere is important for pragmatics. Patients with right hemisphere damage tend to interpret expressions and metaphors literally and they cannot understand certain types of humour. In tests where right hemisphere patients are told to choose an ending for comic strips, they often pick the wrong ending (Springer & Deutsch, 1993).

Deason & Marsolek (2005) found a clear left hemisphere advantage for lowercase and UPPERCASE words, but not for AITeRnAtInG-cAsE words. When a visual prototype font (a very unfamiliar word format) was used, there was a right hemisphere advantage.

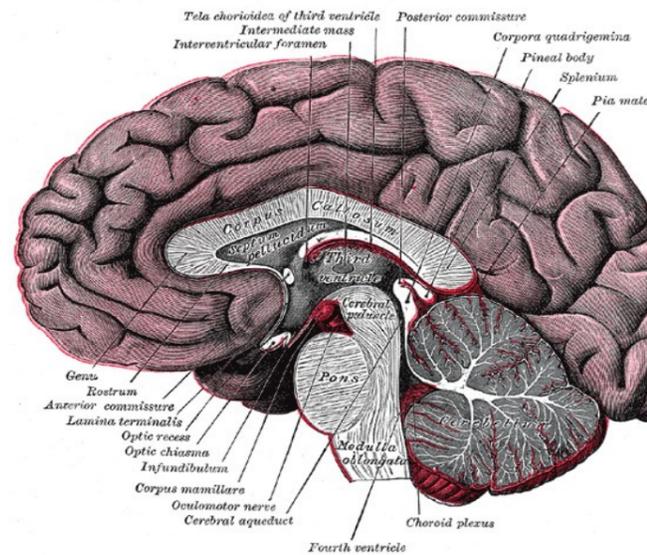


Fig 3: Cross section of the left hemisphere (Wikipedia, 2007)

## Language lateralization tests in split brain patients

The hemispheres are connected through the corpus callosum, a thick bundle of nerve fibers. In patients with severe epilepsy, the corpus callosum can be severed to prevent seizures from spreading through the brain. These so called split brain patients usually don't have any problems with language in everyday life, since visual and auditory information normally reaches both hemispheres. But in laboratory tests where they are restricted to using only one hand, ear or eye, some side effects do occur.

For example, a split brain patient who sees a picture of an object only in the left visual field knows what it is, but is unable to name it. This is because information from the left visual field only reaches the right hemisphere, which can't process words (Springer & Deutsch, 1993).

## Language lateralization tests in healthy subjects

There are ways to test lateralization of language in the normal brain as well. The dichotic listening test is based upon the fact that auditory information faster reaches the hemisphere contralateral to the ear it is presented to. Two different words are presented through headphones at the same time, one word to each ear. The word that reaches the hemisphere with the speech centre is processed slightly faster and is therefore the one that the subject hears better.

You can test language lateralization visually with a tachistoscope. Visual stimuli is flashed rapidly on a screen while the subject is focusing on a point in the middle of the screen. If the stimuli is a word, it is perceived slightly faster with the right eye, while a picture will be seen faster with the left (handout 27/3, 2007; Springer & Deutsch, 1993).

## Why lateralization?

There are different theories about why speech is lateralized, and why the same hemisphere often controls speech as well as the dominant hand. The part of the motor cortex which controls the hand is close to the part which controls the mouth. Fine motor control and a well-developed neural network is necessary for using the main hand as well as for speaking (Ellegård, 1982). Maybe the reason why speech functions developed in the left hemisphere is that it already had structures involved in complex motor activity (Springer & Deutsch, 1993).

Not all animals have lateralized brain functions. The lateralization we see in humans today may have begun with mutations that lead to changes in the structure of the left hemisphere.

These structural changes made it possible to develop new abilities on the left side while the old abilities were still present in the right hemisphere. Since the two hemispheres are connected through the corpus callosum, keeping the original structure and function in one hemisphere was enough, making lateralization a win-win situation (Ellegård, 1982).

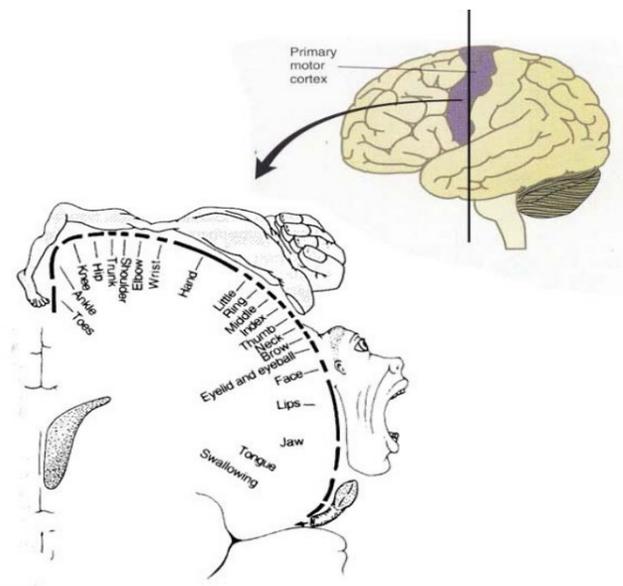


Fig 4: Motor homunculus (Uppsala universitet, 2007)

Some studies suggest brain asymmetries in non-human primates, but more evidence is needed. Song production in some species of songbirds (e. g. canaries) is lateralized – exactly how isn't clear although lesions of the left hemisphere seem to impair their singing more than lesions of the right hemisphere (Springer & Deutsch, 1993).

There is fossil evidence that homo erectus individuals were right-handed more often than left-handed, while monkeys are as likely to prefer the left hand as the right. Based on skull findings, the homo erectus brain seems to have been bigger on the left side (Zlatev, 2007).

### Left, right or somewhere in between?

It can be tempting to draw too wide conclusions based on the fact that the hemispheres are different. Springer & Deutsch (1993) and Gazzaniga (2002) describe this as "dichomania"; one example is the popular view of the right hemisphere as the imaginative, artistic hemisphere and the left hemisphere as the analytical, rational one. Even though there might be a grain of truth in this, the brain is far more complex and there still are many grey areas of the grey matter.



Fig 5: fMRI brain scan (Wikipedia, 2007)

### Some lateralization trivia

- Autists have a smaller corpus callosum (Gazzaniga et al, 2002)
- Real life rain man Kim Peek was born without corpus callosum (Wisconsin medical society, 2007).
- People who are born without a corpus callosum usually have normal IQ and language skills, but may have some problems with phonological processing, e. g. rhymes (Springer & Deutsch, 1993)
- Most people open the right side of the mouth more than the left during speech (Hausmann et al, 1998).
- If hemispherectomy (removal of one hemisphere) is performed at a very young age, there are no signs of impairment in higher mental functions (Springer & Deutsch, 1993)

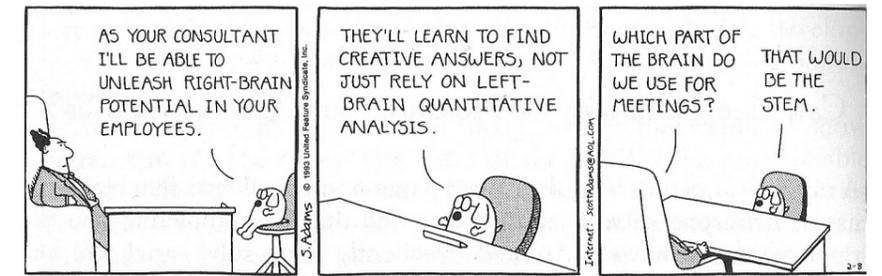


Fig 6: Dilbert (Springer & Deutsch, 1993)

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