The neurobiological foundations of language

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Završni rad

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Osijek, 2012.

Abstract

Language is a unique human cognitive ability that allows us to communicate ideas and thoughts, and in no other species do we find a communication system which is that complex. This complexity is represented in the arrangement of the brain's language-processing areas. Even though the left hemisphere, especially the two main centers called Broca's area and Wernicke's area, dominates when it comes to language comprehension and expression, many other regions of the brain contribute to the cognitive process that is language.

The last decades offered insight into the location and function of the language system thanks to the study of language disorders, which connected the data summoned from the examination of damaged brains to the specific linguistic functions of the affected areas in the normal brain.

When it comes to the organization of language in the brain, another interesting point would be language acquisition, a process that is known to be extremely prolific during early childhood, but stagnates after the onset of puberty. It is a crucial task of researchers to determine the reasons of this phenomenon in terms of brain plasticity.

This paper will give an overview of the brain's main language-processing regions and their respective functions. Another point will be the examination of the role of brain plasticity in the process of language acquisition. Finally, the most important language disorders will be introduced and explained.

Keywords: language processing, aphasia, language acquisition, Broca, Wernicke

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1. Introduction

Language is the remarkable system people use to communicate, and its research has been the central interest of many scientists for centuries. Not so long ago, researchers started dealing with the question of how language is represented in the brain and which areas of the brain perform language-related tasks. The key to this research was the study of the brains of people with language disorders. The comparison of the non-normal brain to a healthy one, in combination with the data about the expression of the brain defect in the person's linguistic abilities, offered insight into the language-related functions of certain parts of the brain. In the last few decades this research has made a great leap forward due to new imaging techniques and research models that have been developed in the neuroscientific field. This technological advance has made it possible to study the living brain, rather than to rely on conclusions drawn from autopsies.

Another point of the neuroscientific research of language is the matter of language acquisition. It is very well known that the young brain acquires language more easily and efficiently than the adult brain. For a long time, scientists have been curious about the reasons why language needs to be acquired until a certain age in order for it to be used proficiently, and why the adult brain cannot reach the same proficiency with a second language.

Finally, one of the most important subjects of language research are language disorders. The characteristics of the so-called aphasias are determined by the region of the brain that is damaged, as different aspects of language processing are placed in different locations.

This paper will give an overview of the most important areas of the brain that are involved in language processing, and examine their location and function. It will also deal with the issue of language acquisition, and the effect of brain plasticity, a phenomenon that may be described as the capability of the brain to change itself, on language acquisition in the young and in the adult brain. The final topic will be an overview of the most important language disorders that will give their main characteristics in terms of location and expression.

2. The Functional Anatomy of the Language System

A widely-believed fact about the location of the brain areas that are involved in the process of understanding and creating language is that one hemisphere is usually dominant – in most cases the left. This presumption has been proven right by a vast number of researches, especially those focusing on specific linguistic impairments caused by damage of one of the hemispheres of the brain.

The most important source for the discovery of language-related brain areas has been the study of aphasias, language disorders caused by brain lesions that are, in most cases, the results of strokes or head injuries. Early studies have discovered that about 96 per cent of people have a dominant left hemisphere when it comes to linguistic processing. This is also coincidental with the right-handedness of those individuals. Left-handed individuals on the other hand express left-hemisphere-domination in only 60 per cent of cases. American Sign Language has also been proven to depend mainly on the left hemisphere (Kandel, 2000:1175).

The two most important language-processing areas of the brain cortex are called Broca's area and Wernicke's area. An early model of language processing, the Wernicke-Geschwind model, assumes that those areas are responsible for processing the acoustic images of words and the articulation of speech. They are connected through a pathway, the arcuate fasciculus, which brings information from Wernicke's area to Broca's area. Furthermore, both areas interact with the so-called polymodal association areas in the frontal part of the brain cortex, which process different types of sensory information. Wernicke's area was considered to be responsible for determining the meaning of words, whereas Broca's area was thought to be crucial for converting acoustic images into words (Kandel, 2000:1175).

The development of new techniques, however, has, in later studies, led to the conclusion that the roles of both areas are not as clear as assumed in the Wernicke-Geschwind model (Kandel, 2000:1175). The communication between those areas has been found to be much more complex. New important language-processing areas have been found in the left cortex and subcortical regions (Kandel, 2000:1175), as well as in the right hemisphere, which also possesses linguistic functions, such as the phonological analysis of individual words and the identification of their concrete meanings (Openlearn).

In the following chapters, we will examine the anatomy and functions of Broca's area and Wernicke's area, as well as some other brain areas that are important for language processing.

2.1. Broca's Area

In 1861, a French neurosurgeon, Paul Broca, studied patients with language disorders, who all had in common the inability to produce or understand language. On April 12, 1861, Leborgne, a 51-year-old hemiplegic man was admitted at the Bicêtre Hospital in Paris. He had been suffering from chronic epilepsy for more than thirty years. Leborgne was capable of understanding language, but he could produce only a single word – "tan", which intrigued Broca. Six days later Leborgne died of infection. Broca examined his brain and discovered a softening in the posterior part of the left frontal lobe. He concluded that this lesion had caused Leborgne's linguistic disability, and that this region was crucial for articulation of speech. (Franca, 2012:11) In his honor, this area has since been referred to as Broca's area.

Broca's area, also referred to as the anterior speech region or the motor speech region, is located in the inferior left frontal gyrus of the brain. Macroscopically, it consists of the opercular and triangular parts of the inferior frontal gyrus. In terms of brain cytoarchitectonics, the study of the cellular composition of the brain cortex, it can be divided into two sections – Brodmann areas 44 and 45. (Krmpotić-Nemanić, 2004:464) Both areas contribute to speech fluency, but they also function as two individual units (Thebrain.mcgill.ca). However, a large number of studies suggest that other cytoarchitectonic areas may also be part of Broca's area, such as Brodmann areas 6 and 47. (Franca, 2012:12)

Brodmann area 44 lies in the back part of Broca's area and right in front of the part of the brain cortex that guides body movements (Figure 1). For this reason Broca's area has been associated with motor articulatory aspects of speech creation. (Horwitz et al., 2003:1) Brodmann area 44 seems to be more involved in phonological and syntactic processing, and, according to recent studies, in the perception and processing of musical syntax. (Maess et al., 2001)

Brodmann area 45, in the front part of Broca's area, together with Brodmann area 44, are activated in processes dealing with semantic working memory, keeping semantic information temporarily in working memory in order to answer a particular semantic question. (Gabrieli et al., 1998). Recent studies using PET for functional brain imaging show that Broca's area participates in verbal short term memory required for sentence comprehension. Verbal short term memory is described as a phonological loop which consists of a temporary memory store for phonological information and a rehearsal process, which sends out commands to the vocal tract muscles, but does not carry them out. It seems that Broca's area is the crucial participant of the rehearsal component of the loop. (Kandel, 2000:1179)

The linguistic dysfunction studied by Broca, Broca's aphasia is described as the inability of creating grammatical utterances. Patients affected by this dysfunction usually have very slow and repetitive speech which lacks closed class words. (Franca, 2012:12) A more detailed description of Broca's aphasia will be given in later chapters.

2.2. Wernicke's Area

Wernicke's area is a region of the brain considered to be important for the recognition, perception, interpretation, and understanding of spoken language. (Tanner, 2007:1) It was first described by a young German neurologist, Carl Wernicke. In 1874, Wernicke was treating patients with hemiplegia of the right side. Unlike Broca's patients, their speech was profuse, but senseless, consisting mostly of grammatical markers, pronouns, prepositions, articles and auxiliaries. Those patients were also unable to understand what was said to them. (Franca, 2012:12) After Wernicke's patients died, he autopsied their brains and discovered a lesion in the left temporal lobe, right behind the primary auditory cortex. (Figure 1) His conclusion was that this lesion prevented the brain from storing *sound images* (*Klangbilder*) that are necessary for the understanding of spoken language. (Franca, 2012:12)

The location of Wernicke's area still causes a lot of controversy among scientists. For decades it was believed that it is located in the left posterior superior and middle temporal gyrus. (Musiek et al., 2011) The cytoarchitectonic regions most often associated with Wernicke's area are Brodmann area 22, 41, and 42, although some researchers claim that the so-called "receptive language center" consists of Brodmann area 22, 39, and 40. (Tanner, 2007:1) However, newer studies, based on scanning methods such as functional magnetic resonance imaging (fMRI) or positron emission tomography (PET), show that the language comprehension center is in fact located in the anterior portion of the superior temporal gyrus. (DeWitt, 2012:6) The inconsistencies between the old definition of Wernicke's area and the results of newer studies may not only be attributed to the improvement of brain scanning methods, but they can also be connected with the vague definition of "language understanding", which in itself is a rather complicated cognitive process consisting of many elements that may be executed in different regions of the brain. (Tanner, 2007:2)

2.3. The Arcuate Fasciculus

The arcuate fasciculus is a neuronal pathway that is thought to connect Broca's area and Wernicke's area. (Figure 1) Newer studies show that it actually connects Wernicke's area to premotor and motor areas, and not to Broca's area. (Hong, 2009) It is essential for normal speech and language function, because it connects receptive and expressive language areas. Damage to the arcuate fasciculus causes conduction aphasia, a language disorder characterized by fluent spontaneous speech, good comprehension, but poor repetition, naming impairments, and reading and writing difficulties. (Bernal and Ardila, 2010)

2.4. Other Language-related Brain Regions

Apart from Broca's and Wernicke's area, many other parts of the brain seem to be involved in the process of language understanding and production, such as certain parts of the insular cortex, and the basal ganglia. Those regions are part of the *language implementation system*, which analyzes heard speech and controls phonetics, syntax, and articulation. The *meditational system* consists of regions in the temporal, parietal, and frontal brain cortex, and connects the language implementation system with the *conceptual system* in the remaining higher-order association cortices, which is responsible for conceptual knowledge. (Kandel, 2000:1175)

Recent studies show that the anterior temporal and infratemporal cortices in the left hemisphere are important for word retrieval. If a certain part (Brodmann area 38) of that cortex is damaged, the person will have difficulty remembering the names of places and persons, but will still be able to name common things. Lesions of other parts of that region, such as Brodmann areas 21 and 20, cause difficulty with the retrieval of information of both unique and common names. A damage to the left posterior infra temporal region causes difficulty with remembering the names of particular items (tools, utensils, etc.). These findings may lead to the conclusion that those parts of the brain are responsible for the storage of words denoting categories of things. (Kandel, 2000:1182)

Another important area of the language system of the brain is the insula (Figure 2), which is located deep inside the brain's hemispheres. According to some studies, the insula might be important for the planning and coordination of speech movements. People with a damaged insula have trouble with the production of speech and tend to mix up the order of the phonemes in a word. (Kandel, 2000:1182)

There are two regions in the frontal cortex of the brain, the supplementary motor area and the anterior cingulated region, which are important for speech initiation and maintenance. If those areas are damaged, the person will be completely incapable to initiate speech. This state is called *mutism*. They also have an impaired initiation of other types of movements, which leaves them unable to communicate by words, gestures, and facial expressions. (Kandel, 2000:1182)

Although the left hemisphere of the brain is, in most cases, dominant when it comes to language, the right hemisphere also performs a number of language-related tasks. These abilities are often exhibited in people who have suffered certain types of brain injuries, or who have undergone special surgical procedures.

So-called “split-brain” people, whose corpus callosum, a part of the brain that enables communication between the right and the left hemisphere, has been cut in order to control epileptic seizures, sometimes, develop abilities of word comprehension and reading in the right hemisphere, but in most cases it has no lexical or grammatical abilities. (Kandel, 2000:1182)

In the healthy brain, the right hemisphere is important for communicative and emotional prosody (stress, timing, and intonation). If the frontal part of the right hemisphere is damaged, the person will not be capable of producing normal intonation in their speech. If the damage occurs in the back part of the right hemisphere, the person will not be able to identify emotional characteristics in somebody else’s speech. (Kandel, 2000:1182)

Another function of the right hemisphere is its contribution to understanding the pragmatic features of language. People with damage to the right hemisphere cannot incorporate sentences into a coherent narrative; they have trouble choosing appropriate language in social situations, and very often they are incapable of comprehending jokes. (Kandel, 2000:1183)

In some cases, due to severe neurological disease the entire left hemisphere of the brain needs to be removed. If this happens during infancy, the right hemisphere will be able to take over the tasks of the left hemisphere and the child will learn to speak fluently, even though they will be impaired in language if compared to children with only a left hemisphere. Adults on the other hand, permanently lose all of their language abilities after the removal of the right hemisphere. (Kandel, 2000:1183)

3. Language Acquisition and Brain Plasticity

Most children are exposed to language since birth, which is why language acquisition starts at a very early age and progresses rapidly. By about 10-12 months of age, the infant develops a “language-specific phonetic perception” which is characterized by sensitivity to phonetic contrasts in both native and non-native languages. (Lacerda and Nehme, 2001:1) By the age of three the child’s speech is already relatively grammatical, and it is capable of understanding complex syntax and grammar. Comparison of normal and abnormal language acquisition suggests that there must be some innate mechanisms that allow children to perceive phonemes, words, syntactic and semantic categories. (Stromswold, 2012:17)

The key to normal language acquisition lies in the timing of the first exposure to language. The period during which the child learns language is the period of the highest brain plasticity. During that time, the brain changes its pathways and synapses, and, if possible, corrects abnormalities or injuries.

The earliest stages of language acquisition are characterized by the formation of a “perceptual map” of the infant's native language. After this point, the infant’s brain plasticity starts to fade, which is why the acquisition of another language at a later point becomes a much more complex task. (Zhang and Wang, 2007:3)

Speech perception abilities acquired in early infancy allow us to easily process our native language, in spite of the large acoustic variability in speaker, accent, speech rate, and emotional affect that it exhibits. For this reason, adult listeners experience great difficulty in distinguishing speech sounds of a foreign language, and they find it too fast and confusing. Even if the adult person acquires a high proficiency in the second language, the native language will still dominate in speech perception. (Zhang and Wang, 2007:5)

The most important hypothesis about language acquisition is that, if a child is not exposed to language during the period of great neural plasticity, it will never be able to acquire language properly. This period is thought to end shortly before the beginning of puberty. There are several documented cases of so-called “wild children”, who were isolated from speaking population and therefore had not developed language. After they were discovered, only those whose brain was still capable of synaptic *pruning*, a process that involves the reorganization of synapses, could successfully acquire language. The younger the child was, the higher was the chance that its brain was still plastic enough to reorganize itself. Most of the older children remained language-impaired. (Bates, 2012:31)

Puberty also seems to be the turning point for second language acquisition. Studies have shown that native speakers of Korean and Chinese who started learning English at an early age acquired high proficiency with English morphology and syntax, while those who started learning English after puberty never achieved such high proficiency levels. (Stromswold, 2012:7)

Just like the brain's capability to learn a second language diminishes with age, so does the possibility of language recovery after it is destroyed by lesions in the left hemisphere. If the lesion occurs before the age of five, full language recovery is possible. After puberty this possibility is significantly reduced. If brain damage to the right or the left hemisphere occurs during infancy, the period of the highest brain plasticity, in many cases the children develop normal or nearly normal language abilities. Adults with the same type of brain damage, develop irreversible aphasia, because their brains cannot reorganize neural pathways. (Bates, 2012:3)

Even the study of the development of the brain's language regions supports the theory of puberty as the end of the period of language acquisition. Before birth, the language-related areas in the brain seem to be functionally asymmetrical. The part that later develops into the left hemisphere is larger, but appears about a week after the same part on the right, which means that the left hemisphere and its language areas lag behind the development of the right hemisphere. After birth, during infancy, the rate at which connections are made between neural cell bodies in the language-related areas of the left hemisphere, especially those around Broca's area, is slower than the same process on the right side of the brain. This means that at this point, fine tuning in the brain occurs as response to the exposure to the frequencies of the native language. The ability of the brain to perform these processes shrinks with time up until puberty, when, by measuring the electrical brain activity of a brain exposed to language, we get approximately the same results as in the adult brain. (Stromswold, 2012:7)

Some studies, however, claim that there is a certain level of language-related fine tuning even in the adult rain. For example, it has been documented that intensive language training increases the possibility of recovery from aphasia even years after the brain damage. This suggests, that the adult brain is still capable of reorganizing of the language-related parts in the brain. (Meinzer, 2004:6)

4. Language disorders

Human language is a unique communication system which hugely differs from the natural communication systems of animals. This is the reason why language-related brain regions cannot be studied through animal homologs. Instead, various language disorders have made it possible to determine which parts of the brain are involved in the process of creating and understanding language.

The early study of aphasias led to important conclusions on how language is processed in the brain. If a certain language disorder is present, it can be related to a physiological problem in that particular part of the brain. (Lee, 2012) Both Broca and Wernicke, the two pioneers in brain research, came to their revolutionary conclusions by examining the brains of patients with language impairments.

Today, many brain scanning methods used to explore the brains of patients with aphasias provide essential information for the investigation of the neural basis of language processing. (Kandel, 2000:1175)

This chapter will give an overview of the most important language disorders and describe their most common features. Also, disorders such as alexia, agraphia, and developmental dyslexia, which are attributed to disorders of other systems of the brain and not the language system in itself, will be briefly introduced.

4.1. Broca's Aphasia

Broca's aphasia, also referred to as verbal aphasia, motor aphasia, and efferent motor aphasia, is the most common non-fluent aphastic syndrome. (McCaffrey ch. 7) It is caused by damage to a large part of the frontal lobe including Broca's area, the surrounding frontal fields, the underlying white matter, insula, and basal ganglia, and a small part of the anterior superior temporal gyrus. (Kandel, 2000:1175)

People with Broca's aphasia tend to speak labored and slow, and have problems with articulation and intonation. Their speech sounds rather monotonic. (Kandel, 2000:1175) The length of their sentences is short and they usually consist of two utterances, in extreme cases only one. Their verbal communication, however, is in most cases successful due to the fact that the selection of words, especially nouns, is correct. Utterances usually consist of noun-verb combinations. Adjectives and adverbs are also occasionally used, while articles, conjunctions, prepositions, auxiliary verbs, pronouns and grammatical markers are omitted. (McCaffrey ch.7)

People with Broca's aphasia have difficulty repeating complex sentences. Although they seem to understand words and sentences they hear, this is only partially true. New studies have shown that they understand sentences whose meaning can be guessed from the individual meaning of the words they consist of or by using common knowledge of how the world works. They cannot understand sentences in which complex grammar is used. For example the sentence *The boy who kissed the girl is young.* is understandable to them, because they assume that the agent comes before and the object after the verb, but *The boy who the girl kissed is young.* is not, because it requires the usage of more complex syntax. Nevertheless, they are still capable of forming grammatically correct structures. They can identify that a sentence needs a certain morpheme in order to be grammatically well formed. When confronted with the following sentences, *The boy was kissed by the girl.* and *The boy was kissed girl.*, they will recognize that the morpheme *by* is missing in the second sentence in order for it to be grammatically correct. This phenomenon is called the *"syntax-there-but-not-there" paradox*. (Kandel, 2000:1177)

People who have Broca's aphasia seem to be incapable of linking two elements, such as antecedent to a pronoun, because they cannot keep the first element in their working memory until they come across the second one and the two can be joined. This indicates that Broca's area participates in verbal short-term memory necessary for sentence comprehension. (Kandel, 2000:1179)

Other signs of Broca's aphasia are right hemiparesis, which is usually the result of a stroke or seizure and mostly affects the face and arm, as well as depression caused by the fact that the Person is very well aware of their disability and reacts dramatically to their errors. (Kandel, 2000:1176)

4.2. Wernicke's Aphasia

Wernicke's aphasia, also known as semantic or receptive aphasia, is usually caused by damage to the posterior part of the left auditory association cortex (Brodmann area 22). In severe cases the middle temporal gyrus and deep white matter are also damaged. (Kandel, 2000:1179)

People with this disorder tend to speak effortlessly and fluently. There are no no *ums* and *ers* or long pauses in their speech. (Ingram, 2007:50) Unlike people with Broca's aphasia, their speech is melodic and produced at a normal rate. Their main problem is a severe semantic impairment, which makes the content of their speech incomprehensible. (Kandel, 2000:1179) They have great difficulty with the choice of words and phonemes, which is why their speech is sometimes called *cocktail hour speech.* Apart from the semantic impairment, people with Wernicke's aphasia usually have difficulty with auditory comprehension. (McCaffrey ch. 8) Sometimes, the ability to understand other people's speech is completely missing, but usually they get the main points of a conversation, although they miss the details. The damaged Wernicke's area is considered to be part of a processor of speech sounds that associates the sounds with concepts. (Kandel, 2000:1180) They are also completely unaware of the errors in their speech.

People suffering from Wernicke's aphasia are often affected by the so-called *phonemic paraphrasias,* which means that wrong phonemes or words substitute the intended, correct ones. This results in completely unintelligible words or even neologisms. For example, instead of *trying* they say *tying*, or instead of *recuperation*, *repuceration.* Sometimes it is impossible to determine their intended word. (Ingram, 2007:50) They also have difficulty selecting the right words for what they intend to say. The phenomenon *press of speech* is also present in Wernicke's aphasics, where they speak very rapidly, interrupting other people's speech. (McCaffrey ch.8) Another characteristic of Wernicke's aphasia is *logorrhea,* or diarrhea of the mouth, where they speak in long sentences with a large number of unnecessary words. (Msu.edu)

4.3. Conduction Aphasia

Conduction aphasia is a rather rare type of aphasia. It is caused by damage to the arcuate fasciculus which connects Broca's and Wernicke's areas, and the left perisylvian area of the cortex. In some cases the superior temporal gyrus, the insula, the primary auditory cortex, auditory association areas, and the supramarginal gyrus are damaged, while Broca's and Wernicke's area remain intact. (McCaffrey ch.8)

People with conduction aphasia usually produce fluent speech and are capable of understanding simple sentences. Like people with Wernicke's aphasia, they have problems with the assembly of phonemes in a correct way, which usually occurs when they try to repeat what was said to them. Polysyllabic words or more complex utterances cannot be repeated. Interestingly, their ability to repeat numbers is usually not impaired. (McCaffrey ch.8)

Conduction aphasia seems to be caused by damage to connectional system that is part of the network required for the combination of phonemes into words. Often, a person with conduction aphasia will try to produce utterances similar to the intended word, trying to correct themselves repeatedly, because they are well aware of their impairment. The words and utterances they produce sound distorted, because they add unnecessary syllables and sounds. (McCaffrey ch.8)

People affected by conduction aphasia usually have unimpaired auditory understanding. They understand nouns and verbs in sentences, but they cannot comprehend grammatical morphemes, such as prepositions and conjunctions, because of the lacking communication between Broca's and Wernicke's area. (McCaffrey ch.7)

4.4. Transcortical Motor and Sensory Aphasias

Transcortical aphasias are caused by damage to areas near Broca's and Wernicke's area, which means that the communication between the main language-related areas and the rest of the brain is made impossible. The damage is usually located on the left side of the brain. (Kandel, 2000:1180)

Transcortical motor aphasia is the result from injuries to the left dorsolateral frontal area and a part of the association cortex in front of Broca's area that are most typically caused by stroke. People affected by this aphasia lack fluency in their speech, but they usually have unimpaired comprehension, since Wernicke's area is, in most cases, not damaged. The dorsolateral frontal cortex is involved in the process of selection of words, which makes those people capable of producing ordinary conversation, but incapable of associating names of actions with particular objects. For example, a person with transcortical motor aphasia would not be able to connect the word *kick* with the word *ball.* If caused by damage to the left supplementary motor area the initiation of speech and its control are impaired. (Kandel, 2000:1180)

People with transcortical motor aphasia are capable of repeating very long sentences, even if their speech is effortful and with many pauses. The utterances are usually very short and consist of only one or two words. (Atlantaaphasia.org)

Transcortical sensory aphasia is extremely rare. It is caused by vascular insufficiency which damages the temporal-occipital-parietal junction, located behind Wernicke's area, that connects the main language areas with parts of the brain important for word meaning. People with this aphasia have difficulty with understanding, but their speech is fluent and grammatically correct. They are capable of repetition, and even of grammatical corrections to sentences that are incomprehensible to them. Their semantic retrieval is impaired, which is why they will often choose a word of similar content instead of the correct word. (Kandel, 2000:1181)

Mixed transcortical and sensory aphasia is the least common of the transcortical aphasias. Damage to the areas around Broca's and Wernicke's area and the arcuate fasciculus, most often caused by narrowing of the internal carotid artery, isolates those regions from the rest of the brain. Sufferers are incapable of understanding others and have a sever speaking difficulty. They are, however, capable of repetition of words, sentences and even songs. (Atlantaaphasia.org)

4.5. Global Aphasia

Global aphasia is, after Broca's and Wernicke's aphasia, the third most common aphastic disorder. It is caused by damage to Broca's area, the basal ganglia, the insula, the superior temporal gyrus, and Wernicke's area. The damage is caused by a large infarct of the middle cerebral artery, and accompanied by right facial paralysis and paralysis the right arm and leg.

People with this type of aphasia have lost all basic language functions. They are no longer capable of understanding or producing speech, which usually consists of only a few words or very short phrases. The repetition of words or sentences is lost. In order to express a thought, they may use the same word repeatedly. Routines such as counting or naming the days of the week, and singing of melodies learned previous to the brain damage, are still preserved. (Kandel, 2000:1181)

4.6. Anomic Aphasia

Anomic aphasia, also referred to as amnesic aphasia, is most often caused by a lesion in the temporal parietal area and the angular gyrus, which leads to a breakdown of many pathways of the brain's language system. The main problem of people with this disorder is that they have difficulty with choosing the right expressions for what they want to say. It is hard for them to remember names they should know well, which is why they use circumlocutions, ambiguous and roundabout speech, for the words they cannot remember. In some cases, the person knows the required word, but is incapable of expressing it. Their speech is otherwise fluent, grammatically correct, and they are capable of repeating words and sentences.

Two subtypes of anomic aphasia are *averbia*, caused by damage near Broca's area, where the person is incapable of remembering verbs, and *color anomia*, where the person cannot name colors despite the intact capability of recognizing them. (Atlantaaphasia.org)

4.7. Alexia, Agraphia, and Developmental Dyslexia

Alexia, also known as word blindness, is the loss of the ability to read. It is accompanied by aphasia since the disorder is attributed to a disconnection between the visual system and the language centers of the brain. The affected part of the visual system that causes alexia is on the left side of the brain, because the language areas are, in most cases, on the left hemisphere. *Agraphia*, the loss of the ability to write, often accompanies alexia, depending on the location of the damage. (Kandel, 2000:1183)

Alexia can be classified into two subtypes: *peripheral alexia*, where the affected person has difficulty with the perceptual processing of letters, and *central alexia*, where the person's impairment lies within the translating of perceptual data into meaning and speech. (Sheldon, Malcolm, and Barton, 2008:616)

Developmental dyslexia, a reading disorder that affects 10 to 30 per cent of the population, is characterized by the difficulty in learning to read and spell. The affected people, mostly children, have normal eyesight and hearing and normal IQ.

Children with developmental dyslexia have difficulty with associating phonemes with letters. They do, however, understand other types of communicative symbols such as traffic signs. This leads to the conclusion that the disorder may be caused by visual processing defects which result in an impaired communication between the visual and the language system.

Studies show that developmental dyslexia might be caused by an abnormal development of the visual pathway cells, which are smaller than the cells of a healthy individual. The cells of the visual cortex of those people also show cytoarchitectonic abnormalities and inappropriate connections. (Kandel, 2000:1185)

5. Conclusion

The language system of the brain is located mostly in the left hemisphere in the majority of the population. According to this principle, the main language-processing areas, Broca's area and Wernicke's area, are placed on the left side of the brain, whereas the right side possesses fewer abilities involved in language perception and comprehension.

One of the earliest models of the language system in the brain involves Broca's area, Wernicke's area, and the arcuate fasciculus. Broca's area is up until today thought to be the brain's main center for language expression, as it is placed right in front of the motoric part of the cortex, which is responsible for body movements. Wernicke's region on the other hand is important for language understanding, even though scientists argue that this definition is not precise enough, and that the process of understanding language can be divided into many components that may be executed in different parts of the brain, and not just in Wernicke's area. Even the exact location of this region remains controversial, though recent studies offer neuroimaging data that suggest, that it is actually placed closer to the front part of the temporal lobe than previously believed. The arcuate fasciculus is the third main element of the early and simplified model of the language system. Its location has also not yet been entirely detected, but it is now clear that it does not only send information from Wernicke's area to Broca's area, but also the other way round. Parts that are not included in this basic model perform other, perhaps more subtle, language-processing tasks, the main being the right hemisphere, which seems to be important for prosody and pragmatics, while previously thought to be uninvolved in language processing.

Language acquisition, which is sometimes described as a human instinct, is a process that starts in infancy, when the infant is first exposed to phonetic features of language. The reason why learning language is easier if it occurs during the early years of the child's development is brain plasticity, which allows the human brain to establish new connections, or recuperate from damage. An adult person's brain plasticity is much lower that a child's, which is why the adult brain will have much more difficulty learning a second language or language at all.

The study of language disorders has been the main focus of the research of the brain's language system. It offers crucial discoveries that lead to a better understanding of linguistic processes in the brain. First conclusions about how language is represented in the brain have been made precisely by examination of aphasic brains. Broca and Wernicke discovered the main language-processing areas by performing autopsies of patients who were unable to communicate properly, either because they could not express language, or because they were unable to understand it.

By now, various language disorders have been described and localized in the brain, and their further study, which is facilitated by the huge technological advance in brain imaging techniques, will lead to new and detailed knowledge of how language works in the brain.

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Figures

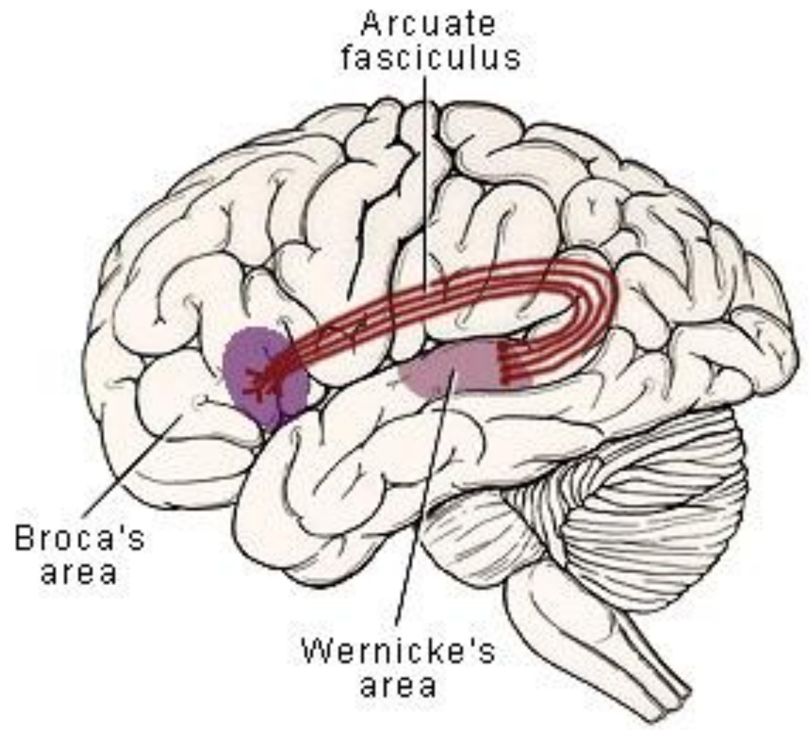

Figure 1. Broca’s area, Wernicke’s area, and the arcuate fasciculus (Abovetopsecret.com)

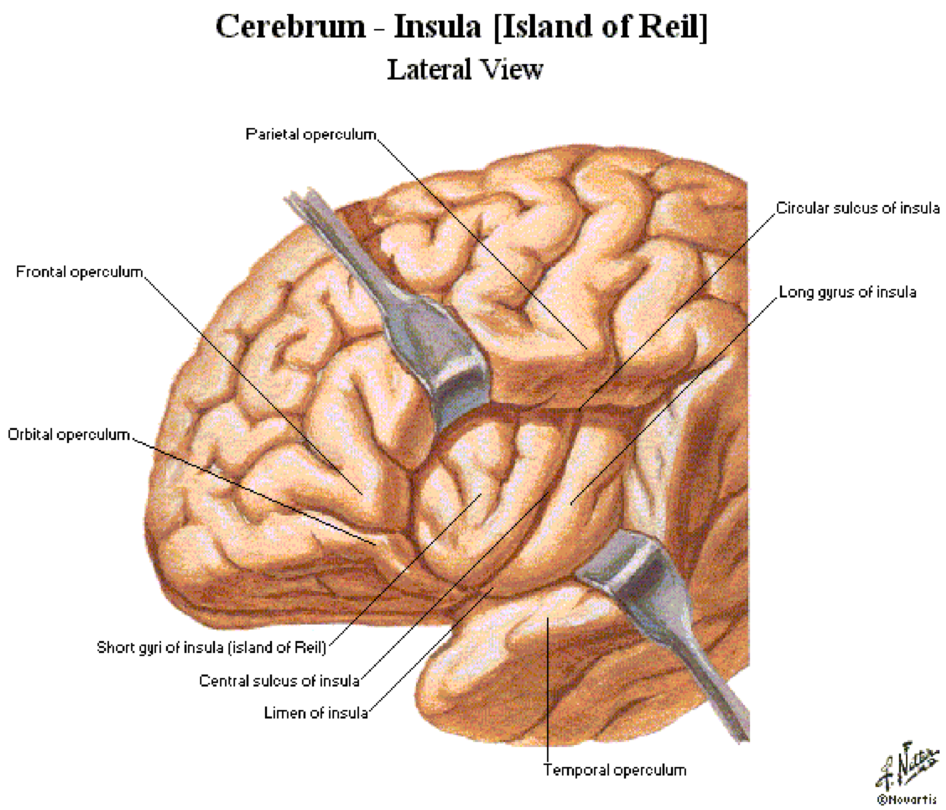

Figure 2. Insula (Alfin2100.blogspot.com)