A dive into the human mind – From perception to emotions

https://doi.org/10.56238/sevened2024.001-005

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ABSTRACT

Perception is the ability to associate sensory information with memory and cognition in order to form concepts about the world, ourselves and guide our behavior. From this concept, we understand that perception is a factor that depends on the senses, memory, cognition and behavior. Understanding the location of an object requires the coordination of sensory and motor information. Knowledge of auditory perception is less extensive than that of visual perception. This is due to the ease of studying visual perception and the difficulty in studying auditory perception, given that it doesn't exactly reflect the reality of sound from a physical point of view, i.e. there is a variation between the sound emitted by the sound source, the individual's perception and also the variation between different people. Attention is the process of focusing consciousness, concentrating mental processes on a single main task and leaving others in the background. This process is only possible through our ability to selectively sensitize a set of neurons in certain brain regions responsible for carrying out the main task, inhibiting the others. In order to understand the study of emotions and reason, we must start from the assumption that both are mental operations accompanied by an inner experience and are capable of guiding behavior and making the necessary physiological adjustments. Both reason and emotion are aspects of the same continuous organism, called the mind. Fear is a feeling initiated by various stimuli. The manifestations of fear are linked to preparing the body for an intense physical effort that could result in a fight or flight. Emotions are autonomic occurrences, however, they can be modulated by the use of reason, that is, by the action of the prefrontal cortex, which can alter behavior to favor the situation. Anger is the emotion that determines the behavior of aggression, whether it is defensive (related to fear) or offensive. Like fear, the region responsible for the initial trigger of aggression is the amygdala, which is connected to the hypothalamus. The study of pleasure relationships is extremely limited. Human beings have various forms of communication. They all involve two individuals: a sender of the signal (which must be standardized among the community) and a receiver of the signal. All languages have spoken communication and only a few have written communication. This characteristic stems from the fact that speech has a large innate neurological basis, while writing is a cultural construction whose learning depends on teaching. Writing is a means of communication restricted to a few languages and is the result of learning certain motor patterns of the hands in order to produce certain symbols that represent phonemes. This text seeks to delve into the human mind and highlight the main global and specific mechanisms that lead from perception to emotions in the light of current discussions on learning, teaching and the apprehension of knowledge.

Keywords: Neuroscience, Memory, Decision-making.

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INTRODUCTION

NEURONAL SIGNALING AND ITS MECHANISMS

A detailed approach to synapses in the nervous system

When we started our studies in neuroscience, it was possible to understand that the signaling of nerve cells and the transmission of signals depend on the existence of synapses. As seen earlier, the synapse consists of a specialized anatomical junction between two neurons, in which the electrical or chemical activity of one neuron influences the activity of the other. Let's not confuse it with synaptic transmission, which is the passage of information between one neuron and another. It is noteworthy that the action potential of the nerve cell is generated and propagates along the axon due to the fact that its membrane is composed mainly of voltage-gated sodium channels. However, this depolarization follows a path and has a goal within the human organism, but for this, it is important that such signals are transmitted to other neurons, such as motor neurons that control muscle contraction, as well as neurons located in the brain and spinal cord that coordinate the reflex response (BEAR, 2010).

This topic is fundamental in understanding electrical transmissions and especially synapses that use chemical transmitters. Knowing this topic will help us understand how psychoactive drugs work, the causes of mental disorders, and the foundations of learning and memory (BEAR, 2010).

Electrical Synapse

The electrical synapse is fewer in number within the central nervous system (CNS), and it is evolutionarily more primitive. Electrical synapses occur mainly at GAP-type junctions, or gap junctions, and are separated from the pre- and postsynaptic membrane by means of a 3nm cleft. Most GAP junctions allow ionic current to pass properly in both directions, so unlike chemical synapses, which are unidirectional, electrical synapses are bidirectional (BEAR, 2010).

Electrical synapses are very fast, and if the synapse is of great intensity, it is infallible. Therefore, an action potential in the presynaptic neuron can produce, almost instantaneously, an action potential in the postsynaptic neuron (BEAR, 2010).

The functions of electrical synapses in mammals and invertebrates are different. In invertebrates, these synapses are present between sensory and motor neurons mediating the escape response. In mammals, on the other hand, these synapses are found in places where the normal function of nerve cells requires neighboring neurons to work in a highly synchronized manner – as happens in smooth and cardiac muscles (BEAR, 2010).

Chemical Synapse

In a chemical synapse, the electrical signal from the presynaptic membrane is converted into a chemical signal, in the form of neurotransmitters, which migrate to the extracellular protein matrix, whose function is to keep the pre- and postsynaptic membranes adherent, and bind to the receptor on the membrane of the postsynaptic cells (BEAR, 2010).

NOW LET'S START THE STUDY OF THE RELEASE OF THESE NEUROTRANSMITTERS!!!

The action potential reaches the axon terminus due to the influx of sodium. Voltage-gated Ca^{2+} channels present in the active zones of the axon open. This leads to an influx of Ca^{2+} ions into the cell that signals the migration of the vesicles to the inner membrane of the neuron. Anchored vesicles release neurotransmitters into the synaptic cleft, which eventually bind to postsynaptic membrane receptors, activating signal transduction pathways (BEAR, 2010).

In the Central Nervous System (CNS) there are several ways synapses occur:

- Axodendritic – when the postaxonal membrane is located in a dendrite.
- Axosomatic – when the postaxonal membrane is located in a cell body.
- Axoaxons – when the post-axonal membrane is located in an axon.
- Dendrodendritic – occurs in certain special neurons – dendrites form synapses with dendrites.

Synapses don't just occur in the brain and spinal cord. Axons of the autonomic nervous system innervate glands, smooth muscles, and the heart. Chemical synapses also occur between axons and motor neurons of the spinal cord and skeletal muscles. These synapses are called neuromuscular junctions and have structural aspects very similar to the chemical synapses that occur in the CNS (BEAR, 2010).

Neuromuscular synaptic transmission is rapid and infallible, i.e., a potential in the axon always generates an action potential in the muscle fiber innervated by that axon. Its most important specialization is size, as it is one of the largest synapses in the body. The presynaptic terminal contains many active zones. In addition, the postsynaptic membrane, also called the motor terminal plate, contains a series of folds on the surface. The active zones are precisely aligned with these folds at the junctions and the postsynaptic membrane of the folds (BEAR, 2010).

HOW DOES SYNAPTIC TRANSMISSION OCCUR? LET'S UNDERSTAND A LITTLE ABOUT THIS PROCESS!!

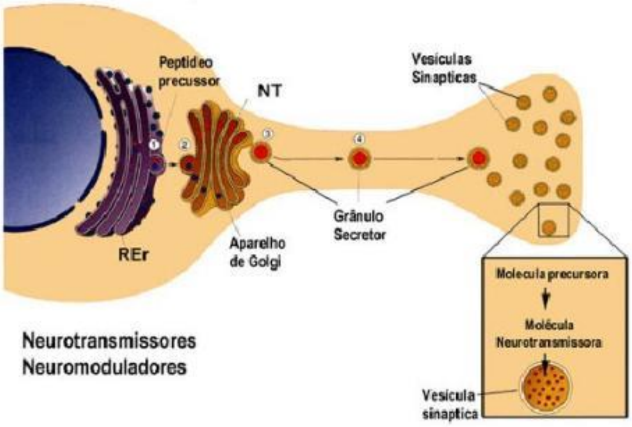
Principles of Synaptic Transmission

For chemical synaptic transmission to occur, the synthesis of neurotransmitters and, consequently, their storage in synaptic vesicles is necessary. A mechanism is also needed that allows the shedding of neurotransmitters from the vesicles into the synaptic cleft due to the occurrence of a presynaptic action potential. From there, you need to remove these neurotransmitters from the local cleft. All of these mechanisms must work efficiently and very quickly for the process to be completed.

There are a variety of neurotransmitters and these are divided into three categories: amino acids, amines and peptides. Rapid synaptic transmission at most CNS synapses is mediated by the amino acids Glutamate (Glu), gamma-aminobutyric acid (GABA), and Glycine (Gli). On the other hand, the rapid synaptic transmission of all neuromuscular junctions is mediated by the amine acetylcholine (Ach), while in the slow forms, the transmission both in the CNS and in the periphery is mediated by neurotransmitters of all categories (BEAR, 2010).

For the synthesis of peptide neurotransmitters, their peptide precursor is synthesized in the granulosum endoplasmic reticulum. In the Golgi apparatus, the peptide is cleaved, resulting in an active neurotransmitter, which is eliminated through a vesicle in the trans cistern of this organelle (Fig 1). The neurotransmitter is transported to the axonal terminal, where it is stored. The precursors of neurotransmitters, amino acids, and amines are activated by enzymes in the cytosol. In this case, it is the protein transporters that carry the neurotransmitters into the synaptic vesicle at the axonal terminal where they will be stored (BEAR, 2010).

FIGURE 1 - Image demonstrating the peptide precursor synthesized in the granulosum endoplasmic reticulum until it results in an active neurotransmitter.



Source: www.google.com.br.

The release of neurotransmitters is triggered by the arrival of the action potential at the axonal terminal and the amount of neurotransmitter released depends directly on the influx of calcium. Depolarization of the axon terminal membrane causes voltage-sensitive channels to open in the active zones, a phenomenon similar to voltage-gated sodium channels. From there, the channels are permeable to Calcium (Ca2+) ions. It is worth remembering that the concentration of calcium ions in the cytosol is very low and, when the voltage-gated calcium channels open, there is a large influx of calcium ions to the inner face of the axonal membrane generating an electric current. Calcium has another very important function in the neuron: the higher the extracellular concentration of calcium, the lower the permeability of sodium in the neuronal membrane, that is, there is a drop in the excitability of sodium channels. That is why when there is a hypercalcemia, a depression of the nervous system occurs, and the reverse also happens with a hyperexcitability of the nervous system (BEAR, 2010).

Vesicles release their contents through exocytosis. For this process to occur, the membrane of the synaptic vesicle fuses with the presynaptic membrane and thus allows the contents of the vesicles to be released into the synaptic cleft. A peculiarity of the release of peptide neurotransmitters is that the secretory granules are found outside the active zones. Therefore, for the release of these neuropeptides to occur, high-frequency waves are required. On the contrary, it can be noted that the release of the neurotransmitters of amino acids and amines is a slow process (BEAR, 2010).

The neurotransmitters released in the synaptic cleft bind to the postsynaptic receptors like a key in a lock and affect these neurons. Although there are more than 100 types of receptors, we can divide postsynaptic receptors into two main groups: ion channels activated by neurotransmitters and receptors coupled to protein G. Ion channels activated by neurotransmitters are transmembrane proteins, which receive neurotransmitters at their specific sites, inducing a conformational change, which causes the channel to open. The functional consequences of this episode depend on the ions that pass through the channel (BEAR, 2010).

On the other hand, ion channels activated by neurotransmitters do not have the same ion selectivity as voltage-gated ion channels. If the ion causes a depolarization, such as the sodium ion (Na+), the action will be excitatory and the phenomenon is called a postsynaptic excitatory potential. If the ion causes a hyperpolarization, such as the chloride (Cl^-) ion, the action will be inhibitory, and the phenomenon is called postsynaptic inhibitory potential. Receptors coupled to the G protein undergo rapid chemical transmission (muscle fibers), which is mediated by neurotransmitters, amino acids, and amines. Two examples of G protein-coupled receptors happen in the heart and skeletal muscle. In the first case, the acetylcholine receptor is coupled by a G protein to a potassium channel. The opening of the potassium channel hyperpolarizes the heart fibers. In skeletal muscle, the receptor is an ion channel whose opening depolarizes muscle fibers, activated by acetylcholine and permeable to the sodium ion (Na^{+}) (BEAR, 2010).

After the transmission of information, the recycling and degeneration of neurotransmitters is necessary. This fact is important to avoid some disorders, such as desensitization in the neuromuscular junctions, that is, despite the presence of acetylcholine in the synaptic cleft, the ion channels activated by neurotransmitters remain closed. To avoid the continued presence of neurotransmitters in the synaptic cleft, neurons use some techniques:

1) Diffusion of neurotransmitters away from synapses absorbed by astrocytes;
2) Amino acid and amine receptors are transported, by means of transport enzymes, back to the interior of the neuron presynaptic reception;
3) Degradation of neurotransmitters in the synaptic cleft. This is how acetylcholine is eliminated from neuromuscular junctions.

LET'S UNDERSTAND NOW WHAT SYNAPTIC INTEGRATION IS?!!!

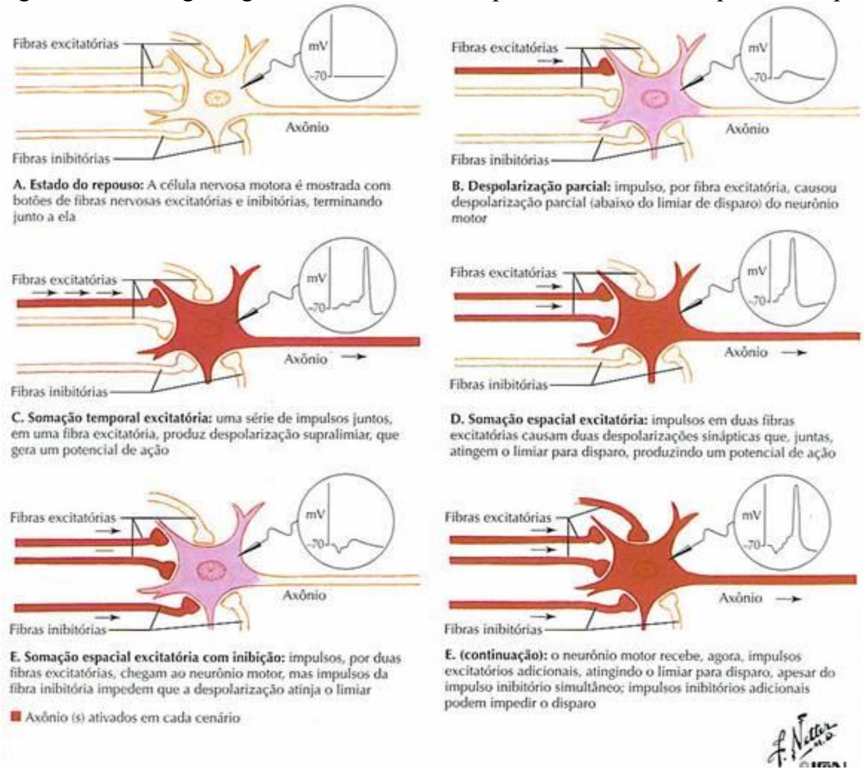
Principles of Synaptic Integration

First, let's assume a multipolar neuron of the central nervous system. This neuron is receiving various chemical stimuli in its dendrites, in the soma and in the axon itself (both in the cone and in the distal part of the axon). These stimuli are excitatory, such as the postsynaptic excitatory potential, and inhibitory, such as the postsynaptic inhibitory potential. These processes, both excitatory and inhibitory, are important because a single depolarization, either in the dendrite or in the soma, would hardly reach the axonal cone with a sufficient potential of -45 mV to open the voltage-gated sodium channels and generate a current in the postsynaptic axon. This happens because the currents generated in these regions are decremental, that is, they are lost along the way.

In order to circumvent the difficulty in generating an action potential in the postsynaptic axonal membrane, the neuron uses two "traps": temporal summation and spatial summation. Shall we understand them?

First, let's explain what this temporal summation means. Suppose a +30 mV depolarization occurs in the dendrite of the neuron (Fig. 2). This depolarization shifts the resting potential from -70mV to -35mV. This current will reach the axonal cone with a much lower value. Let's assume that it reaches the value of +2 mV. I repeat, this happens because the current is lost along the way. This depolarization is insufficient to generate an action potential, which should increase from -70 mV to -45 mV. However, it can take up to 15 milliseconds for the neuron's membrane to repolarize. Remembering that we are not talking about an action potential, in which the membrane takes 01 milliseconds to repolarize. Here, repolarization is slower because potassium ions extravasate occurs. Fifteen milliseconds is a long time for the neuron, as it can emit an action potential every millisecond at a frequency of 1000 Hertz. Therefore, in that time it would be possible to generate up to 15 action potentials (15 synaptic transmissions) that would keep the region active and the voltage-gated channels open, accumulating a flood of neurotransmitters. As a result, several action potentials are generated in the active region by the neuron that generated the first +30 mV potential. Suppose it emits +30 mV, then +20 mV, then +25 mV, and so on. These triggers accumulate until they reach a point where the potential will be sufficient to generate, in the axonal cone, a depolarization of -45mV, resulting in an action potential along the postsynaptic axon.

FIGURE 2 - Diagram illustrating the generation of an action potential and the temporal and spatial summation.



Source: Netter (2011).

In spatial summation, the following episode occurs: the neuron is bombarded from all sides by neurotransmitters that generate postsynaptic excitatory potential and postsynaptic inhibitory potential. Generally, the excitatory potential is generated in the dendrites, while the inhibitory potential is generated in the cell body. Suppose dozens of presynaptic neurons are shedding excitatory neurotransmitters into the dendrites. The chance of this excitability generating an action potential in the axonal cone of the postsynaptic neuron increases exponentially. However, at the same time that there are neurotransmitters generating postsynaptic excitatory potential, there are neurotransmitters in the cell body generating a postsynaptic inhibitory potential.

Often the excitatory potential is insufficient to reach the postsynaptic axonal cone and generate an action potential. However, if there is an excitatory potential closer to the cell cone and/or a higher number of presynaptic neurons releasing excitatory neurotransmitters into neuronal dendrites, the potential can overcome the postsynaptic inhibitory potential and reach the axonal cone with a sufficient potential to generate an action potential. It is worth remembering that in temporal summation, the postsynaptic inhibitory potential is also present.

WHAT NOW? IS IT COMPLICATED? LET'S TRY TO SUMMARIZE...

Let's go back to our example by summarizing the whole process. In our assumption, the neurotransmitter generated a potential of +30 mV in the dendrite. Most of the potential is dissipated in the dendrite itself, because the cell body is larger and makes it difficult for current to dissipate. Now let's assume that the potential reaches the cell body with a power of +15mV. Between neurons there are postsynaptic inhibitory potentials confronting excitatory ones, which leads to an even greater decrease in excitatory potential. When this current reaches the axonal cone, the potential is +2mV, according to our arbitrary example. This potential is insufficient to open voltage-gated sodium channels and insufficient to generate an action potential.

Every millisecond, the neuron has the function of deciding: to fire the action potential or not to fire the action potential. This is the language of neurons. Synaptic integration is exactly the combination of all impulses in order to realize or not an action potential that travels through the axon and releases neurotransmitters to other neurons, thus propagating the information generated. Therefore, as in software, neurons follow binary language: when it is at rest, its state is 0; And when an action potential is generated, its state is 1. So every millisecond, the neuron can be in state 0 or state 1 and this is called 1 bit of information.

Worth knowing!!

A given neuron can intensely depress the shedding of neurotransmitters into the synaptic cleft. The pain pathway and endogenous opioid system is an example of depression in neurotransmitter release. When endogenous opioid peptides are released into the synaptic cleft through the axoxoxonoal connection, calcium channels are blocked due to the action on myoopioid receptors, and thus, the pain message is blocked and the individual will not perceive any painful sensation.

Understanding synapses is essential to understanding neuronal signaling and the physiological and pathological processes of the nervous system, as well as the processes related to human consciousness!!

HUMAN PERCEPTION AND ITS SENSORY BASES

UNDERSTANDING HUMAN PERCEPTION, ITS CHARACTERISTICS AND DISORDERS

When we begin the study of human perception, we come across its concept. Perception is the ability to associate sensory information with memory and cognition in order to form concepts about the world, about ourselves, and guide our behavior. From this concept, we understand that perception is a dependent factor of the senses, memory, cognition and behavior. Each object produces a different visual image and is recognized in different ways by the sensory organs, however, for perception it is the same object. This is the concept of Perceptual Constancy, an important property of the nervous system.

The sensory system initially promotes the analytical phase of the object (recognition of the object's own properties). After this process, the synthetic phase occurs, in which the parts and properties of each object are brought together, presenting them to memory and cognition. The deficiency in the process of perception is called agnosia. In this disability, the individual successfully uses his or her senses, but is unable to recognize or name objects. Its cause is usually related to lesions of the cerebral cortex.

The study of patients with agnosia revealed that the main areas related to perception are the posterior parietal cortex, inferotemporal cortex and the lateral aspect of the occipital lobe. These areas are known as the associative cortex.

LET'S GO BACK TO THE PREVIOUS CHAPTER AND REVIEW THE PARTS OF THE BRAIN!!

In the study of the pathways related to the perception of objects, the presence of several pathways within each direction was evidenced. The most studied sense is the sense of sight and, as such, it will be the most detailed within this text. In the view, the five pathways that identify the different properties of each object (from V1 to V5) have been described. The V1 route identifies simple geometric shapes. The V4 area contains neurons that are sensitive to the wavelength of light stimuli, i.e., it is responsible for color discrimination. The V5 area, on the other hand, is sensitive to movement. The division of the vision pathways is evidenced from the retina and follows the visual pathway through the thalamus, primary visual cortex and adjacent regions.

Through the understanding of the various decomposer pathways of the object, the Americans Leslie Ungerleider and Mortimer Mishkin proposed the division of the vision perception pathway into the ventral and dorsal pathways. The dorsal pathway is responsible for spatial perception (V5 area of the temporal cortex through V1, V2 and V3). The ventral pathway, on the other hand, is responsible for the perception of shapes and colors (it connects the V4 area of the temporal cortex through V1, V2 and V3). In this way, we can recognize that the ventral pathway allows the recognition of visual objects and the dorsal pathway allows us to identify the three dimensions of objects and how they relate to each other and to the observer.

Despite this parallel division of the pathways, it is known that they have numerous reciprocal connections between them and between the homologous areas of different hemispheres. For example, V5 neurons activated by colored stimuli have been identified moving on the background of another color (with the same brightness).

Note the complexity involved in the sense organs!! Remember how important they are in recognizing objects!!

SENSORY PERCEPTION AND OBJECT RECOGNITION

To recognize objects, we start from the assumption that the nervous system is capable of separating different objects from the same scene and keeping them constant (even with the movement of other objects in the scene). In view of the distribution of the connections already described, it is believed that the main flow of visual information goes from V2 to V2, then to V4 on the lateral and ventral surface of the cortex and then to the regions of the inferotemporal cortex, from where it will be distributed to other regions linked to memory and emotions. Therefore, it is understood that in the inferotemporal cortex there is an association of information from the ventral and dorsal pathways, thus forming complex images such as stars and half moons, for example. After this occurrence, the final images are checked in memory and will later guide the individual's behavior.

As described, the ventral pathway is responsible for identifying the shape, color or texture of visual elements, that is, it is responsible for assimilating the invariable elements of the object. These elements are extremely important, as they are the ones that are compared to memory for the final recognition of the piece. Despite the understanding of the division of perceptual functions, the American psychologist Charles G. Gross found in the inferotemporal cortex of monkeys some neurons capable of responding selectively to hands and faces. The so-called gnostic neurons are a possible finding that leads us to a reductionist theory, in which there would be specialized neurons for each identifiable object. However, this theory is unlikely given the large number of identifiable items, but it leads us to recognize that we still do not know at what point in the nervous system the final synthesis of the object occurs.

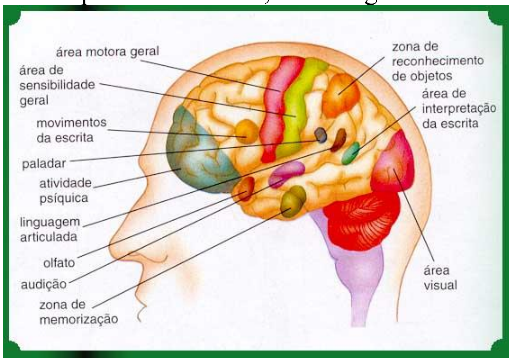
Thus, regarding the recognition of the activated region in each stage, we can only distinguish the participation of the fusiform gyrus of the inferior temporal lobe in the recognition of objects and faces; the hippocampus in the recognition of faces, objects in general, and written verbal material; and the posterior portion of the ventral surface of the temporal lobe in color perception.

LET'S UNDERSTAND THE WAYS OF PERCEIVING AN OBJECT UNTIL THE COMPLETE FORMATION OF ITS IMAGE IN THE BRAIN!!

Spatial perception of the object

To understand the location of the object, it is necessary to coordinate sensory and motor information. This association is made by the posterior parietal areas of the cerebral cortex (Fig. 3), which is an area of convergence of fibers from motor, somesthetic and visual regions. In this area, the response of neurons is strongly influenced by attention. It also identifies a large number of mirror neurons, which participate in motor learning obtained through visual observation and imitation of motor acts performed by other people. Patients with lesions in this region have indifference syndrome. This syndrome presents with the patient's condition of ignoring everything that is going on on one side of their vision (more common on the left side, as the most common lesion is in the right hemisphere).

FIGURE 3 - Brain regions and their respective functions, including the areas responsible for object recognition.



Source: http://www.sogab.com.br/anatomia/sistemanervosojonas.htm.

Auditory perception

Knowledge about auditory perception is less extensive than about visual perception. This comes from the ease of studying visual perception and the difficulty in studying auditory perception, given the fact that it does not exactly reflect the sound reality from a physical point of view, that is, there is a variation between the sound emitted by the sound source, the individual's perception and also the variation between different people. Although knowledge is extremely limited, it has also been identified that this system has two parallel pathways.

Among the pathways, we have the ventral auditory pathway, which is believed to be responsible for the analysis and then synthesis of sound characteristics (identification of timbre, melody, words and phrases). This pathway presents a sequence of information flow from A1 (primary auditory area) to the lateral auditory belt, then to the auditory belt, and finally to a series of regions of the temporal cortex. The other pathway is the dorsal auditory pathway, which would be responsible for identifying the origin of the sound, determining an association between the auditory system and the motor system. This pathway directs the flow of information from A1 to regions of the frontal cortex (including motor regions).

THE PROCESS OF ATTENTION AND HUMAN CONSCIOUSNESS

Attention is the process of focusing consciousness, concentrating mental processes on a single main task and leaving the others in the background. This process is only possible if we selectively sensitize a set of neurons in certain brain regions responsible for performing the main task, inhibiting the others. Therefore, the principles of attention are: the creation of the general state of sensitization called alertness and the focusing of the state of sensitization on a certain neurological process. In this way, we can divide attention into mental or selective cognition and into sensory attention or selective perception.

Attention can also be subdivided into explicit, when the focus of attention coincides with that of visual fixation and the object of attention is present in the center of the fovea, and implicit, when the focus of attention does not coincide with the focus of vision, being in peripheral regions. Explicit attention is an automatic operation and usually remains for most of the day. Implicit surgery, on the other hand, is a voluntary operation and tends to be used in special cases.

To explain the sensitization of the areas of attention, experiments were carried out to record electroencephalogram potentials and magnetic fields. They revealed that attentional focusing causes an increase in the amplitude of the signals registered in the neurons belonging to the sensitized pathway, chosen by the individual's will. This response occurs in all cortical areas studied in the visual system, however, it is strongest in associative areas (such as V4 and the inferotemporal cortex).

It was also found that the pulvinar nucleus (located in the thalamus) is possibly an important structure in the modulation of attention. This understanding comes from the knowledge that it has reciprocal connections with practically all sensory areas and its injury or pharmacological treatment with GABAergic agonists and antagonists causes attentional changes in the individual. Another structure that has been related to attention is the frontal ocular field, an area of the frontal cortex involved in the planning of eye movement. It is related because it programs ocular saccadic movements, which are used to move the explicit attentional focus.

Reading tips

Read the scientific article to understand a little more about bone remodeling.

GONÇALVES, L. A.; MELO, S. R. The biological basis of attention. Arq. Ciênc. Saúde Unipar, Umuarama, v. 13, n. 1, p. 67-71, Jan./Apr. 2009. Available at: http://revistas.unipar.br/saude/article/viewFile/2800/2086.

THE STUDY OF THE HUMAN MIND IN RELATION TO EMOTIONAL REACTIONS

THE HUMAN MIND AND THE RELATIONSHIP BETWEEN REASON AND EMOTION

To understand the study of emotions and reason, we must start from the assumption that both are mental operations accompanied by an inner experience and are capable of guiding behavior and making the necessary physiological adjustments. Both reason and emotion are aspects of the same continuous organism, called the mind. In its rational extreme, logical thinking and mental calculation are presented, and in its emotional extreme, aggressiveness and pleasure. Between these extremes there are occurrences such as social adjustment, appreciation, and decision-making.

LET'S LEARN A LITTLE MORE ABOUT HUMAN EMOTION?!!

To understand the physiology of emotion, it is important to conceptualize it. In this way, we can consider that the mind is a subjective experience accompanied by detectable physiological and behavioral manifestations. Emotions have uses within an individual's life. They are: the survival of the individual, the survival of the species and social communication. Among the emotions, each one has a fundamental utility and a different alteration. The main emotions are: joy and sadness, love and hate, enchantment, agony, contempt, despair, panic, envy and fear. In this way, the only common element between the various emotions is reinforcement, that is, it is the prolongation or interruption of an emotional experience by a positive (pleasurable) or negative (unpleasant) stimulus.

We can divide emotions into two groups: positive ones, which bring pleasure such as love, joy and enchantment; and the negative ones, which bring displeasure, such as fear, agony, hatred, and sadness. It is also possible to divide emotions into primary, secondary, and background emotions. Primary emotions are innate and exist in all people. They are: joy, sadness, fear, disgust, anger, and surprise. Secondary ones, on the other hand, are influenced by the social and cultural context, that is, they are learned, such as guilt, shame and pride. And the background emotions are the emotions that refer to general states of well-being or malaise, namely: anxiety, apprehension, calm and tension. This subtype influences primary and secondary emotions and is related to the set of information that our body conveys to the brain through the interoceptive or protopathic somesthetic system.

How are emotions expressed?

Each emotion has a characteristic (but not exclusive) pattern of physiological manifestations, which are altered by the individuality of each one. These emotional manifestations are autonomic responses and can promote behavioral changes, which can be stereotyped, such as crying, or complex, such as the attitude of an energetic individual. The autonomic and behavioral responses that occur right after an emotion are called immediate emotional responses and are typically related only to the triggering factor. On the other hand, manifestations that become chronic (due to an affective disorder or a permanence of triggering stimuli) are related to immune and hormonal changes.

Recall the topics about the Limbic System? Let's now review some details about it related to emotions!!

The limbic system, defined as a set of regions located on the medial aspect of the hemispheres and in the diencephalon, includes the cingulate cortex, the hippocampus, the amygdala, the hypothalamus, and the anterior ganglia of the thalamus. This system is strongly interconnected with emotions and with the associations between emotions and other brain functions. The cingulate cortex receives several projections from other associative cortical regions and thus provides the basis for the subjective experience of emotions. The hippocampus, on the other hand, has limited action within emotions, as its function is related to the consolidation of explicit memory, a process that is linked to emotional factors (as previously described in the memory chapter). The hypothalamus is the control region of the physiological manifestations of emotions. The nuclei of the thalamus are little studied, but they are considered to be influential in the physiology of emotions. And the amygdala acts as a trigger and modulator of the entire emotional experience.

AND WHY IS THIS IMPORTANT? LET'S UNDERSTAND SOME BEHAVIORAL CHARACTERISTICS THAT ARE PRESENT IN OUR PERSONAL AND PROFESSIONAL DAILY LIVES!!

Neurophysiology and fear behavior

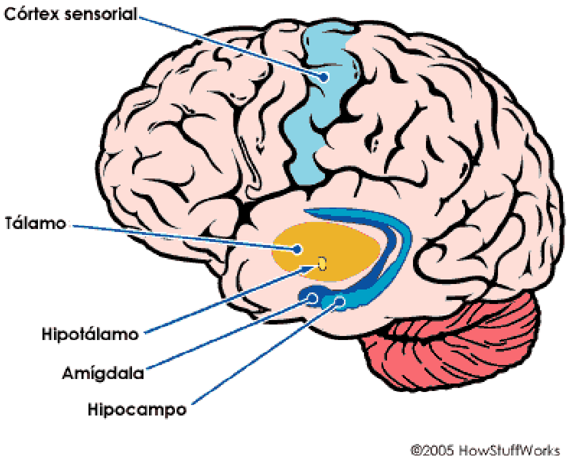
Fear is a feeling initiated by various stimuli. Some produce fear without any prior context (unconditioned fear), such as very loud and sudden sounds and very large visual stimuli. On the other hand, other (conditioned) stimuli are associated with previous threatening situations, such as the barking of a dog at people who have suffered an attack by these animals. The emotion of fear can be fast-moving (a fright) or slow-moving. This differentiation depends on the stimulus, which may be threatening for a few brief moments or for a longer period. In some moments, the stimulus may be virtual, that is, non-existent (such as the tension of a test). In these stimuli, the fear is prolonged even longer, which promotes a continuous state of tension and stress, called anxiety. Intense anxiety in an individual is a pathology called panic disorder, which presents itself as a feeling of imminent death with no identifiable external cause. Therefore, we can reason that fear is a feeling of defense against a threat, which varies between fright and anxiety.

The manifestations of fear are linked to preparing the body for intense physical exertion that may result in a fight or flight. Autonomic acting is linked to the sympathetic autonomic system. The individual becomes extremely alert, in a defensive posture, with tense trunk muscles and with half-bent arms in front of the body. It presents a noisy reaction (screaming) as an indication of willingness to cope, the heart rate increases, there is cutaneous vasoconstriction (directing blood flow to the muscles and CNS), increased respiratory rate for oxygenation of the body, cessation of digestive peristalsis (decrease in energy expenditure), sweating and piloerection (increased heat exchange), in addition to an increase in circulating lymphocytes and an increase in the production and accumulation of glucose.

As has been studied, the amysilloid complex is an important region for emotions. It is made up of a basolateral group, a central group, and a corticomedial group. The basolateral group receives projections from the auditory and visual thalamus, so it is the most possible region to receive fear-forming stimuli. The basolateral group emits projections to the central group, from which axons emerge to the hypothalamus and bulbar nuclei, which are related to the physiological manifestations of fear. The core group also communicates with the periaqueductal griesis in the midbrain, which is the organizer of fear-related behavioral changes.

Unconditioned stimuli are usually sent directly from the sensory organs to the amygdala (Fig. 4). However, complex (usually conditioned) stimuli are primarily processed by the cerebral cortex. Visual stimuli pass through the inferotemporal cortex and the associative regions of the medial temporal lobe; and auditory stimuli pass through the cortex of the superior temporal gyrus. It also occurs, when the stimulus is even more complex, processing in the prefrontal and cingulate cortex.

FIGURE 4 - Parts of the brain involved in the reaction to fear.



Source: http://pessoas.hsw.uol.com.br/medo.htm.

Conditioned fear is a form of implicit memory, depending entirely on the interaction of the amygdala and with the capacity for neuroplasticity (mainly long-term potentiation). However, the action of the amygdala is not limited to this point in memory. It is also responsible for modulating explicit memory according to emotional stimuli (amygdala and cortex association around the hippocampus).

Emotions are autonomic occurrences, however, they can be modulated by the use of reason, that is, by the action of the prefrontal cortex, which can alter behavior to favor the situation. Evidence of this action is present in experiments with neuroimaging, which show an activation of the prefrontal cortex when the individual tries to contain his emotions and a consequent decrease in the activation of the amygdaloid complex. A curious fact in this action is that the prefrontal cortex of the right hemisphere is related to negative emotions and the left hemisphere to positive emotions. The action of the prefrontal cortex also occurs in the way the individual deals with emotions, as this function is developed by the ventromedial prefrontal cortex and the orbitofrontal cortex.

NEUROPHYSIOLOGY AND ITS ASSOCIATION WITH ANXIETY AND STRESS

As already discussed, in some circumstances the fear becomes chronic, such as in cases of unconditioned stimuli that remain nearby, conditioned stimuli that remain continuous, future expectations of danger, and prolonged situations of stress. In these cases, a process of anxiety develops. The physiological adjustments both in the state of stress and in the state of anxiety go beyond the action of the Autonomic Nervous System (ANS), because this branch of the nervous system promotes a stimulation of the medulla of the adrenal gland, which produces the hormones adrenaline and noradrenaline, which are sympathomimetics, that is, they simulate the action of the sympathetic ANS. In this way, the action of hormones promotes an increase and prolongation in the expected response to fear.

The high concentration of these sympathomimetic hormones stimulates the hypothalamus to release adrenocorticotropic hormone, which will excite the adrenal cortex. This excitation causes this endocrine organ to promote a systemic release of glucocorticoids, which are active in promoting gluconeogenesis, the accumulation of glucose and glycogen in the liver and the decrease of immune and inflammatory responses.

NEUROPHYSIOLOGY OF ANGER AND AGGRESSION

Anger is the emotion that determines the behavior of aggression, whether it is due to defensive (relationship with fear) or offensive. Physiological manifestations are not very different from those that occur in fear. An increase in heart and respiratory rate, increased blood pressure and blood oxygenation, and piloerection and sweating occur. The physiological difference is that during fear, urination and defecation can occur. Such occurrences are rare during rabies. As for behavior, anger promotes aggressive and generally offensive gestures and movements, such as approaching and attacking the opponent.

As well as fear, the region responsible for the initial firing of aggression is the amygdala, which from its connections with the hypothalamus (in this case between the medial posterior hypothalamus and the periaqueductal griese; and between the ventral posterior hypothalamus and the ventral integumentary area) promotes attack behavior. Although it is difficult to differentiate the influencing factors, they are considered to be biological, hormonal and social influences. Within the hormonal influence, there are several androgen hormones (mainly testosterone) responsible for the increase in aggressiveness.

As for the biological analysis of aggression, we have that it is dependent on the Sry gene present on the Y chromosome in males and the Sts gene present on the X chromosome in females. However, the presence of the chromosome is not definitive for aggressive behavior. Serotonin is synthesized by neurons in the brainstem, whose fibers ascend to the upper regions (cerebral cortex) forming circuits that control the triggering of aggressive behavior. Serotonin is recognized by specific postsynaptic receptors that, when activated in the cortex, promote the blocking of aggressive behaviors. Thus, we notice that the action of reason (cortical action) strongly interferes in the limitation of aggressive behavior. Therefore, we can conclude that individuals with a genetic predisposition to aggressiveness and a violent social environment have a tendency to engage in inappropriate aggressive behaviors.

NEUROPHYSIOLOGY OF POSITIVE EMOTIONS AND REASON

The study of pleasure relationships is extremely limited. However, it is known that the nucleus accumbens related to cortical areas such as the insular cortex, the anterior cingulate and orbitofrontal, are related to the promotion of laughter and euphoria. The action of dopamine, a neurotransmitter that connects the ventral tegmental area of the midbrain to the basal ganglia, is also known, whose action is related to consumer behaviors, therefore acting on the compulsive consumption of drugs and food.

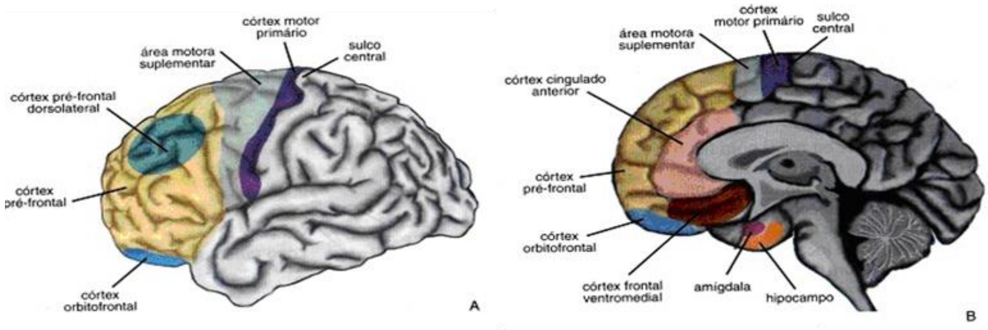
But in the face of so many emotions, what about our reason?

Reason is synonymous with cognition, a brain function that enables cognitive control, that is, it makes it possible to elevate your thoughts and actions to a level above just reactions to the environment, making them abstract and proactive. Therefore, cognitive control allows anticipations of the future by coordinating actions and thoughts. This control is a highly complex brain action, as it involves receiving, processing and interpreting an infinity of information that enters the sensory channels vertiginously and under temporal succession.

Intelligent actions (under the influence of cognition) differ from automatic actions (only ascending information) by the presence of descending information, that is, information controlled by our wills and thoughts. Given the complexity of cognition, we can reflect that it requires an efficient coordination of several brain processes. This coordination is done by the prefrontal cortex, which acts as a pole of convergence communicating with numerous sensory and motor systems. This pole is also responsible for the selection of information (attention), for the operational memory and for the management of the flow of information.

The prefrontal cortex is located in the frontal lobe, anterior to the motor regions, occupies 25% of the human cortex and is made up of a dozen cytoarchitectural areas. It has 5 functional regions: the ventromedial and orbitofrontal regions, related to action planning, reasoning, social adjustment of behavior, and emotional processing; the ventrolateral region, in charge of working memory; the dorsolateral region, responsible for the cognitive manipulation of working memory data; and the anterior cingulate region, which is involved with emotions and attention (Fig. 5).

FIGURE 5 - The figure above shows key brain regions, by means of a lateral socket (A) and a medial socket (B). There are several subregions of the frontal cortex, including the prefrontal cortex. It is formed by distinct sub-regions, among them, the dorsolateral prefrontal cortex, which is fundamental for cognitive functioning; the orbitofrontal cortex, involved in impulse regulation and decision-making; and the anterior cingulate cortex, implicated in selective attention.



Source: Reproduced from Stahl, S. M. Psicofarmacologia: bases neurocientíficas e aplicaciones praticas, 3.ed. RJ: Guanabara Koogan (2010, p. 138).

The activations of the different areas are done by different routes. The lateral prefrontal cortex (dorsal and medial) and orbitofrontal cortex are activated during cognitive activities, while the orbitofrontal cortex is activated during tasks related to rewards and punishments, and the lateral prefrontal cortex is activated by information manipulations and working memory. Neurons in this part of the cortex are multimodal and activated by sensory stimuli. Its activity is regulated by dopaminergic receptors.

The typical use of reason is based on logical reasoning to solve a problem and make a decision. For this process to occur, it is necessary to focus attention on the information coming from the sensory systems. The cingulate cortex is responsible for this step, that is, it acts by modulating the information processed by the dorsolateral prefrontal cortex (receiver of sensory information). Subsequently, the new information is compared with that present in the working memory. This stage is promoted by the lateral prefrontal cortex (dorsal and ventral). And finally, the ventromedial prefrontal cortex adapts the processed data, organizing the individual's reasoning with the individual's objective, the temporal relationship, and the social circumstances.

HUMAN BEHAVIOR AND ITS FORMS OF EXPRESSION AND COMMUNICATION

NEUROBIOLOGICAL ASPECTS INVOLVED IN SPOKEN LANGUAGE

Humans have many ways of communicating. All involve two individuals: a sender of the signal (which should be standardized among the community) and a receiver of the signal. Virtually every organ of the sensory system is used to receive and interpret the signals produced by another individual's motor system. In this way, we can define language as communication systems with defined rules that must be employed by a sender so that the message can be understood by the receiver.

Language can be both spoken and written. However, it should be noted that all languages have spoken communication and only some have written communication. This characteristic comes from the fact that speech has a large innate neurological basis, while writing is a cultural construct whose learning depends on teaching. The fundamental unit of speech is the phoneme, which are characteristic sounds of each language and when together form syllables. The syllables joined together form words, which together in sentences (respecting appropriate grammatical orders), form the syntax. Finally, for the functional understanding and the relationships of words and phrases, semantic organization occurs.

Speech is the primary form of human communication. In addition to the relationships common to any type of language (such as syntax and semantics), it employs the relationship between sounds and gestures and facial expressions, which provide an emotional basis. This peculiar characteristic is called prosody. The primary purpose of speech is to express a thought. In this way, speech uses the very ways of thought to format its sentence. This is what happens with complex communications (such as the report of an event), where first the memory is consulted to organize the facts and feelings, and then there is a phase of speech planning (with the search for the appropriate words, search for phonemes to form them and organization of the words in syntactic rules) and, subsequently, the articulation of speech occurs.

IS EASY TO SAY!! AND LEARN HOW IT OCCURS?!!!

As previously described, the first stage of speech formation is the search in the individual's memory. Thus, we start from the assumption that there are "internal dictionaries" called mental lexicons, which store various elements of language. Within our CNS, there are several lexicons, each organized according to the information they store (for example: the semantic lexicon, which has about 50 thousand words and idiomatic expressions). Thus, like any mnemonic content of human beings, the use promotes the fixation of information, therefore, words or semantic rules that we do not use can be forgotten by lexicons.

SO REPETITION IS NECESSARY FOR THE CONTENT TO BE FIXED!!

The topographical knowledge that indicates the location of these memory centers is based on studies of patients with lesions. The semantic errors of these people are typical of patients with rostral lesions of the temporal lobe, and errors about instruments and objects in general are typical of patients with caudal lesions of the temporal lobe.

As evidenced earlier, the phoneme is the fundamental particle of speech. They are stored in lexicons and are emitted sonically by extremely precise movements of the structures of the vocal apparatus, which are commanded by the M1 cortical area of the motor cortex. By comparing the different languages, we can trace some phonemes that are uniform in several of them. This uniformity is an important evidence that speech is a universal and innate process of the human being, as they are considered innate collections of movements of the vocal apparatus, and are also understood in a unique way in the CNS.

The phoneme store lexicon is the phonological lexicon. Its location is still undefined, however, functional imaging studies have revealed several active areas around the lateral sulcus (of Sylvius) of the left hemisphere, involving the inferior parietal cortex, angular and supramarginal gyri of the region between the parietal and occipital lobes, the inferior lateral frontal cortex, the superior temporal cortex and also the M1 region. Another important finding is the fact that phonological processing occurs laterally to the left in men and bilaterally in women. This difference comes from several phoneme search strategies.

AND HOW DOES THE CONSTRUCTION OF SENTENCES OCCUR?

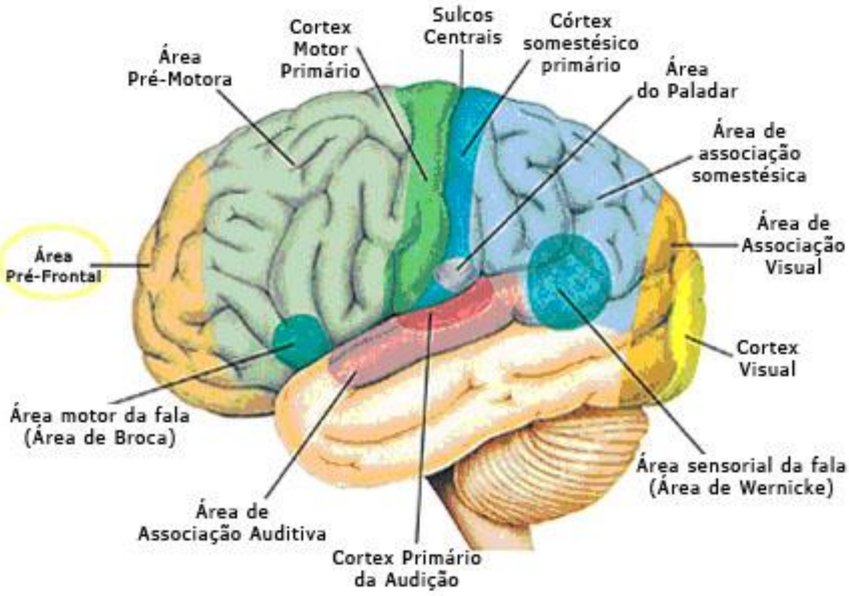
Sentences are constructed from syntactic rules. Although these rules are taught during childhood, they are strongly fixed in our memory through observation and introspection of patterns noticed during conversations in our language formation. This property is evidenced through the analysis that we don't need to think in order to utter sentences correctly.

Sentence construction begins with the conceptualization phase, where we plan the content of our message (macro speech planning). The regions involved in this step are unknown, although they are called conceptualizers, because they search the semantic lexicon to find appropriate concepts for our goal.

The second stage is the formulation, which corresponds to the search for phonemes, words, syntactic rules and the association between these structures (microplanning). The regions related to this step are called formulators and involve the inferior lateral frontal region (Broca's area) located in the left hemisphere.

The last stage in the emission of the message is articulation, that is, the formulation of the sequence of movements necessary for the emission of the appropriate sounds. The sending of this command comes from M1 to the motor nuclei of the brainstem, which controls the muscles related to the emission of the voice. Speech articulation is an essentially motor function and involves the premotor regions of the left frontal cortex and the representation sectors of the face in the precentral gyrus (Fig. 6).

FIGURE 5 - Representative diagram of the regions of the cerebral cortex and their respective functions, including the areas responsible for speech.



Source: http://liz.angel.blog.uol.com.br/arch2009-09-20_2009-09-26.html.

The beginning of the comprehension of the spoken message lies in the auditory processing of the various sounds present in the environment. During this processing, the CNS identifies certain linguistic patterns and forwards them to the regions responsible for speech understanding. Therefore, the inverse pathway of speech emission occurs, i.e., phonological identification (made in the phonological lexicon), lexical identification, syntactic comprehension and, finally, semantic comprehension.

In addition, as seen earlier, prosody is extremely important for identifying the purpose of the message. Its brain location is still uncertain, although it is considered to involve several brain functions, such as language, emotion, and motor control. It is known that these areas belong in most humans to the right hemisphere, in the same regions responsible for the cognitive aspects of language in the left hemisphere.

IN ADDITION TO KNOWING THE PHYSIOLOGICAL ASPECTS OF SPEECH, IT IS ESSENTIAL TO UNDERSTAND ITS DISORDERS, SINCE WE CAN COME ACROSS THEM!!

Speech and comprehension disorders

Spoken language disorders, related to lesions in regions involved in the linguistic process and not to motor processes, are aphasia. They have different symptoms depending on the injured region. Lesions in the lower lateral region of the left frontal lobe cause expression aphasia (Broca's) and they form a patient with great difficulty in finding words to express himself.

When the lesion is in the posterior cortical region, around the tip of the lateral sulcus (Sylvius's) on the left side, comprehension aphasia (Wernicke's) occurs. In it, the patient does not understand what is said to him and gives a nonsensical response (despite speaking fluently).

Speech expression occurs in Broca's area and comprehension occurs in Wernicke's area (Figure 5). Thus, for proper speech, both must be connected, which occurs with a bundle of fibers immersed in the cortical white matter called the arched bundle. Injury to this bundle leads to conduction aphasia, in which patients are able to speak spontaneously, but make errors in repetition and response to verbal commands.

Another type of aphasia occurs in patients with lesions of the middle and inferior temporal gyrus, known as anomic or nominal fluent aphasia, which presents with patients speaking fluently but unable to identify names of people and objects. We can identify this disease whose gyri are strongly related to specific semantic lexicons.

An anomie with dysarthria (speech articulation disorder - a motor disorder) occurs in lesions of Broca's area and adjacent anterior regions. Thus, the anterior frontal cortex of Broca's area is a candidate area to host the syntactic lexicon and the posterior cortex would be a seat of verbal expression.

NEUROBIOLOGICAL ASPECTS INVOLVED IN WRITTEN LANGUAGE AND READING

Writing is a means of communication restricted to a few languages and results from the learning of some motor patterns of the hands, in order to produce certain symbols that represent phonemes. These symbols are the graphemes and, like the phonemes, together they form written words, which will be associated with sentences and produce the effect of the passage of the message.

Reading, on the other hand, is the identification of the symbology of writing and the mental formation of the written message. It results from an eye scan of the written material. During the reading, the individual performs a sequence of fixations and saccadic movements. Pinned words are usually those with the most relevant content (such as verbs and nouns), and predictable or very short words can be skipped. It is also considered that words that are too long, rare or unexpected have a longer fixation time. Fixation control is a cognitive function and is under the control of attention.

Although not very expressive, there is evidence from functional images that indicate that the following parts are active during reading: visual cortex (V1 and V2) bilaterally, superior visual regions on the lateral surface of the left hemisphere, parietal and temporal perisylvian regions (with Wernicke's area and the angular and supramarginal gyri), as well as the left inferior prefrontal cortex.

It is believed that less than 100 ms after eye fixation on the word, V1 activation occurs. Between 100 and 200 ms, the shape of graphemes and words in the visual associative cortex is identified and attention is focused on the area. Between 200 and 300 ms, the semantic and phonological interpretation of the word occurs (in Wernicke's area) and then the eye movement for the next fixation.

Writing and reading disorders

Written language disorders are agraphia and alexias (dysgraphia and dyslexia). Agraphia are disorders related to difficulty writing. Alexias, on the other hand, are related to reading difficulties. An important part of its great epidemiology is dyslexia. This modality is associated with the loss of the ability to associate graphemes with phonemes, thus making a reading with pronunciation or semantic errors.

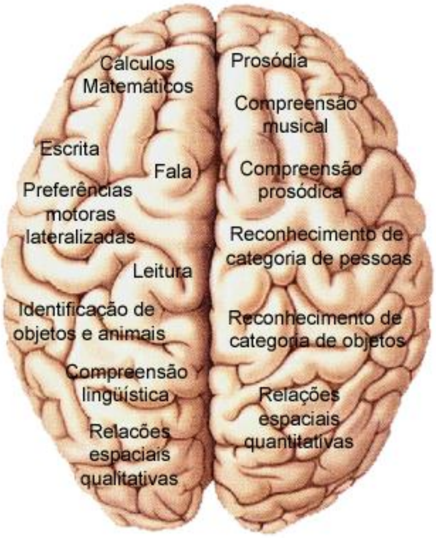
HEMISPHERIC SPECIALIZATION

Hemispheric specialization consists of understanding that each hemisphere is in charge of different brain functions. However, the understanding that each hemisphere has a functional differentiation does not remove the evidence that they work in association, through their communication between the corpus callosum, the anterior commissure and the hippocampal commissure.

Other concepts that can be confused with hemispheric specialization are hemispheric laterality and hemispheric asymmetry. Handedness is the understanding that while some functions are represented equally in both hemispheres, others are represented on only one side (such as speech). Hemispheric asymmetry, on the other hand, is the understanding that hemispheres are not symmetrical.

Hemispheric specialization does not mean functional exclusivity. This understanding is noted through the recognition that in 95% of human beings speech is controlled in the left hemisphere, but important properties of speech, such as prosody, are controlled by the right hemisphere. Some functional differences are: the left hemisphere is better at mentally performing mathematical calculations, detecting specific categories of objects and living things, recognizing qualitative spatial relationships, recognizing faces (finding out who owns the face), and commanding writing and reading; and the right hemisphere is better at perceiving musical sounds, identifying general categories of objects and living beings, detecting metric and quantifiable spatial relationships, and recognizing faces (identifying that the image is a face) (Fig. 6).

FIGURE 6 - Representative diagram of the functional differences between both cerebral hemispheres.



Source: http://www.infoescola.com/anatomia-humana/cerebro/.

A peculiar feature of this division consists in the fact that the left hemisphere produces more precise movements in the right hands and legs (in right-handed individuals), compared with the production of movements in the left limbs by the right hemisphere. Thus, the best possible generalization is that the right hemisphere perceives and commands global and categorical functions, and the left hemisphere commands more specific functions.

Reading tips

Read the scientific article to understand a little more about the motor cortical areas. Andrade, A.; Luft, C. B.; Rolim, M. K. S. B. Motor development, maturation of cortical areas and attention in motor learning. http://www.efdeportes.com/ Digital Magazine - Buenos Aires - Año 10 - N° 78 - November 2004. Available at: http://www.efdeportes.com/efd78/motor.htm.

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