SPECIALIZATION OF CEREBRAL HEMISPHERES IN HUMANS

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Summary

Greek physicians of the Classical Era, considered that right brain hemisphere is specialized in perception, and left for understanding and comprehension. The raise of modern neuroscience intensified studies in differences between hemispheres. The present findings highlight the fact that there is asymmetry of the hemispheres at almost all levels, as well as numerous interhemispheric differences in neuropsychological function. Differences exist in the size and weight of the hemispheres, in the size and shape of the defined areas of the brain, in the in the number and the size of the neurons, in relation to the extent of branching of dendrites within the area and in the structure of the gray and white matter .There are also considerable differences in relation to the dopaminergic and noradrenergic transmission. All these differences, mostly on histological and physiological level are prerogative for hemispheric functional specialization i.e. assymetry.

The left hemisphere is specialized for verbal functions, calculia and skillful learned movements (praxis). The right hemisphere is specialized for processing visual information, such as the perception of complex geometric shapes, facial recognition, observation of non-verbal sounds, performing various spatial functions, tactile perception of complex structures, musical ability, prosody, non-verbal thinking and memory. The left hemisphere is analytical, sequential, and the right is synthetic, holistic. The left hemisphere has more capacity for abstract or impersonal, while the right hemisphere is less prone to abstraction and prioritize the individual.

Interhemispheric interaction is a very important function. Corpus callosum allows functional independence of the hemispheres, but also the integration, contributing to the wholeness of our perception of the world and our adaptive behaviors.

Key words: cerebral hemispheres, specialization, neuropsychological functions.

INTRODUCTION

History of human curiosity about the brain structure and its significance can be traced for more than two millennia. Greek physicians of the Classical Era, three centuries B.C., considered that right brain hemisphere is specialized in perception, and left for understanding and comprehension [1]. The raise of modern neuroscience in 19th and particularly in 20th century, intensified studies in differences between hemispheres [2].

In the second half of the 19th century and especially in the 20th century, after the first calosotomy (cutting the corpus callosum) conducted by Sperry and Bogen, a number of theories about the specificities of the functions of brain hemispheres have been proposed. The first consideration of cerebral lateralization emphasized, despite the existence of lateralization, equal participation of cerebral hemispheres in almost all brain functions [3]. The present findings highlight the fact that there is asymmetry of the hemispheres at almost all levels, as well as numerous interhemispheric differences in neuropsychological function. Differences exist on the anatomical level in the size and weight of the hemispheres [4, 5]. There are also differences in the size and shape of the defined areas of the brain, in the number and the size of the neurons [6], in relation to the extent of branching of dendrites within the area and in the structure of the gray and white matter [7,8,9].

There are also considerable differences in relation to the dopaminergic and noradrenergic transmission. The transfer of information from left to the right hemisphere is slower compared to the transfer of information from the right to the left hemisphere [10]. All these differences, mostly on histological and physiological level are prerogative for hemispheric functional specialization i.e. assymetry.

FUNCTIONAL ASYMMETRY OF CEREBRAL HEMISPHERES

The left hemisphere is specialized for verbal functions such as speech, comprehension and repetition of speech, perception of speech sounds, reading, writing, verbal thinking and memory, calculia and skillful learned movements (praxis) [11]. The right hemisphere is specialized for processing visual information, such as the perception of complex geometric shapes, facial recognition, observation of non-verbal sounds, performing various spatial functions, tactile perception of complex structures, musical ability, prosody, non-verbal thinking and memory [2]. The left hemisphere is analytical, sequential, and the right is synthetic, holistic. Lateralization should be understood, however, relatively. In virtually every function or type of behavior, both hemispheres are participating, even in highly asymmetric functions such as speech [12].

Lower level of lateralization or specialization of brain hemispheres may cause the global deficits in all forms of reasoning, verbal and nonverbal functions. There is only one published study linking slowness of thought with a lesion of the left dorsolateral prefrontal cortex. Most of the studies of lateralization are conducted in healthy subjects and they confirm the dominant role of the right hemisphere in attention [13].

Selectivity of attention may be damaged by a lesion of both hemispheres but it was found that the lesion of the left cau-

date nucleus and the left anterior cingulum, caused severe damage to the selectivity of attention. Lesions of the right inferior parietal lobe cause the greatest damage to global attention [14].

One of the most consistent early findings concerning hemispheric specialization was that whenever a fragment of an image had been presented so that the information is only partially available, the right hemisphere had been superior [15].

The new stimuli lead to the release of noradrenaline in the right hemisphere. The neurons of right hemisphere are relatively resistant to fatigue, so that the attention of searching is constantly maintained during the exploration of space and time. The right hemisphere also has larger working memory so it is capable of processing a larger amount of information at the same time. It is able to carry more information over a longer period, with higher specificity (which also means less sensitivity to time degradation [16].

Pertaining attention, the left hemisphere has dominance of local and narrowly focused attention, while the right hemisphere is responsible for a broad, global and flexible attention. Such divisions and differences between the hemispheres have a significant impact on the experience of the world that surrounds us.

THE IMPACTS OF HEMISPHERIC SPECIALIZATION ON THE PHENOMENOLOGICAL EXPERIENCE OF THE WORLD

The right hemisphere has the ability to detect and draw attention to the presence of the so-called new experience located in the periphery of consciousness which seeks to enter into the sphere of our awareness regardless of the side it comes from [17]. All new stimuli and experiences that come into our experiential world cause immediate release of noradrenaline, mainly in the right hemisphere [18].

The difference is present in various domains. Not just a new experience, but also learning new information or new skills, engage more attention to the right hemisphere than the left, even if the information is by its nature verbal [19]. However, when skills become familiar with practice they cross into the domain of the left hemisphere control [17], even skills such as musical skills, otherwise typical for the right hemisphere in non-musicians [20].

Right hemisphere has greater capabilities when it comes to changes [21]. Right frontal lobe is particularly important for the flexibility of thought, and damage to this area can lead to perseveration [22]. In terms of problem solving, the right hemisphere represents and provides different solutions. It remains active while exploring alternative ways, in contrast to the left hemisphere, which gives one possible and already known solution [1,4, 23].

Differences exist in all domains and apply equally to both verbal and visuospatial domain. For example, the left hemisphere is limited and focused in a particular situation, and suppresses the verbal meanings that are not currently relevant, while the right hemisphere recruit a wider semantic association [24].

The connection between the right hemisphere and the general or gestalt perception is one of the most reliable general difference between brain hemispheres, resulting from differences in the nature of attention [25]. The right hemisphere "sees" the whole picture, which is not based

on a set of individual fragments, as the right hemisphere is constantly looking for patterns of things.

The left hemisphere has more capacity for abstract or impersonal, while the right hemisphere is less prone to abstraction and prioritize the individual. The left hemisphere is dominant in assessing analytical or mechanical structure, while the right hemisphere is better when it comes to the whole, such as the living beings that we can not partially observe. The left hemisphere holds codes, i.e. the schemes of movements of how to use tools and machines [26]. In the case of damage to the right hemisphere the ability to use simple tools remains unchanged, while the left hemisphere lesions prevents a person to perform skilled actions such as the use of a hammer and nails or a key and a lock.

However, lesions of the right hemisphere especially disturb everyday activities that involve a number of steps, such as making coffee or gift wrapping. It has been presumed that the left hemisphere is responsible for everything that represent the products of human inventions, including language production In contrast, right temporal region has certain areas that concern not only living beings, but also further contribute to the understanding and recognition of human beings [27,28].

HEMISPHERE AND EMOTIONAL ISSUES

There is also lateralization of emotions. In lesions of the left hemisphere there is more frequent occurrence of depression and lesion of the right hemisphere show flatness of emotions [29]. Catastrophic reactions occure in patients with motor aphasia and anosodiaphoria in the right hemisphere damage. Epilepsy with attacks of laughter (gelastic epilepsy - gelolepsy) occurs more often with the foci in the left hemisphere, and epilepsy with crying (dacristic epilepsy) mainly in epileptic foci in the right hemisphere [11]. The wider scope of attention of the right hemisphere allows a person to see and conclude in relation to other people and mediates understanding of social relations, including the "theory of mind" and the expression of social emotions.

LANGUAGE AND BRIN HEMISPHERES

Language functions are lateralized. In about 90% of people left hemisphere is dominant for language, both for understanding and production of speech. Right-handers are in the 95-99% left hemisphere dominant for speech. Left brain hemisphere is dominant for speech in 60-70% of left-handed persons. The left hemisphere has more sophisticated syntax and greater semantic range, while the right hemisphere processes words in the context [30]. It specializes in the sense of pragmatism, art, contextual understanding of the meaning and the use of the metaphor [31].

Right temporal region appears to be essential for the integration of different abovementioned seemingly unrelated concepts in a metaphorical phrase that has also the meaning [32]. The left hemisphere is decontextualized and tends to draw relatively inflexible conclusions, following internal logic regardless of the current experience [7, 33].

CORPUS CALLOSUM AND HEMISPHERIC INTERACTION

In maintaining of functional independence of hemispheres corpus callosum has the dominant role. Although the corpus callosum contains between 300 and 800 million fibers that connect the correspondent fields of brain hemispheres, only 2% of cortical neurons are connected via the corpus callosum [34]. A large number of these connections are inhibitory, so that electrical stimulation of neurons in one hemisphere causes a short initial excitatory response, and then emerges the long-term and widespread inhibition of the contralateral hemisphere [35].

The corpus callosum is necessary to integrate the activities of both hemispheres, i.e. the existence of a unique personality. The best way of understanding the functional relationships of the brain hemispheres is cutting the corpus callosum (callosotomy) resulting in "split brain".

Callosotomy does not lead to a loss of function, but rather to the loss of functional inhibition. It can be said that the inhibitory nature of the corpus callosum is adaptive and creative, rather than restrictive, and that the ability to maintain separation in the transfer of information is essential. In the case of callosotomy right hemisphere can not communicate verbally. Consequently, patients with separated hemispheres can not appoint the objects they see in the left half of the visual field because this information transfers only to the right hemisphere and can not reach the speech areas of the left hemisphere.

Studies that examine the lesions of the corpus callosum, with or without disconnection of its fibers, indicate that the frontal part of the corpus callosum is associated with interhemispheric inhibition in situations of semantic and visuospatial competition, while the posterior part of the corpus callosum is associated with interhemispheric facilitation of additional information on the visuomotor and cognitive level [36, 37].

It is interesting, however, that certain features, such as parallel visual search, may be performed more efficiently after callosotomy than in subjects with intact corpus callosum, because of the lack of reciprocal inhibition. People with severed corpus callosum may be twice as fast in tasks of visual attention, in such as the search in two parallel series of visual information presented in separate visual fields, compared to people with intact corpus callosum. On the other hand, the speed of search of one set is approximately the same in people with intact and severed corpus callosum [38, 39].

CONCLUSION

Specialization of cerebral hemispheres represents an evolutionary adaptation to the complex demands of the environment. In the broadest sense, we can say that the left hemisphere is analytical, sequential, and the right hemisphere synthetic, holistic. Interhemispheric interaction is a very important function, which can not be seen as a sum of simple parts, i.e., the nature and manner of functioning when both hemispheres are involved can not be predicted on the basis of information processing of the parts. Interhemispheric interaction gives a new dimension to the perception of information. Corpus callosum allows functional independence of the hemispheres, but also the integration and, therefore, the functional interaction and inhibition of the two hemispheres contributing to the wholeness of our perception of the world and our adaptive behaviors.

SPECIJALIZACIJA MOŽDANIH HEMISFERA

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Kratak sadržaj

Grčki lekari antickog doba smatrali su da je desna hemisfera mozga specijalizovana za percepciju, a leva za shvatanje i razumevanje. Tokom razvoja moderne neuronauke povećan je broj studija o razlikama između hemisfera. Sadašnji nalazi ističu činjenicu da postoji asimetrija hemisfera na gotovo svim nivoima, kao i brojne interhemisfene razlike u neuropsihološkim funkcijama. Razlike postoje u veličini i težini hemisfera, veličini i obliku definisanih area mozga, u broju i veličini neurona, u odnosu na opseg grananja dendrita unutar područja i u strukturi sive i bele mase. Postoje, takođe, značajne razlike u dopaminergičkoj i noradrenergičkoj transmisiji. Sve ove razlike, uglavnom na histološkom i fiziološkom nivou su neophodne za funkcionalnu specijalizaciju menisfera, tj asimetriju. Leva hemisfera je specijalizovana za verbalne funkcije, računanje i vešte naučene pokrete (praksija). Desna hemisfera je specijalizovana za obradu vizuelnih informacija, kao što su percepcije složenih geometrijskih oblika, prepoznavanje lica, percepciju neverbalnih zvukova, različite spacijalne funkcije, taktilnu percepciju složenih struktura, muzičke sposobnosti, prozodiju, neverbalno razmišljanje i memoriju. Leva hemisfera je analitička, sekvencijalna, dok je desna sintetička, holistička. Leva hemisfera ima više kapaciteta za apstraktno ili bezlično, a desna hemisfera je manje sklona apstrakciji i prioritet daje ličnom. Interhemisferična interakcija je veoma važna. Korpus kalozum omogucčava funkcionalnu nezavisnost hemisfera, ali i integraciju, doprinoseći celovitosti naše percepcije sveta i adaptivnom ponašanju.

Ključne reči: moždane hemisfere, specijalizacija, neuropsihološke funkcije

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