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The Relationship Between Speech Disorders and Brain Function

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Abstract: The article examines the concepts of the relationship between speech disorders and functional brain activity. Particular attention is paid to modern classifications of speech disorders, features of brain activity associated with various types of speech disorders, and neurological foundations of speech disorders. The results of the study will contribute to the development of neurolinguistics and the creation of new methods for diagnosing and correcting speech disorders.

Key words: neuropsycholinguistics, brain, speech, speech disorders, brain activity, aphasia

Introduction

Historically, the ability of humans to engage in oral communication has been viewed as a key indicator of cognitive capacity and as the foundation of social interaction. Nonetheless, a considerable proportion of the population experiences various forms of speech disorders that impede speech formation, articulation, and fluency. Such disorders can substantially diminish individuals' quality of life by constraining their educational, social, and professional potential. In recent decades, an interdisciplinary field known as neuropsycholinguistics has been developing rapidly; it examines the intricate relationships among brain functions, cognitive processes, and human speech abilities. This article focuses on analyzing speech as a complex psychophysiological function, on the issues surrounding the classification of speech disorders, and on modern approaches to the diagnosis and correction of speech pathologies.

LITERATURE REVIEW

Historically, the earliest documented study of the neurological foundations of speech disorders can be traced back to the works of P. Broca (1861) and K. Wernicke (1874). Their discoveries concerning the localization of speech centers in specific areas of the cerebral cortex (Broca's area and Wernicke's area) laid the groundwork for subsequent research in the field of aphasiology. In L. Lichtheim's (1885) and K. Wernicke's (1885) works, the first classification schemes for aphasia were proposed, based on assumptions about the connection between distinct "centers" in the cortex and mental functions.

A. R. Luria further developed ideas on the systemic nature of higher mental functions, demonstrating that speech, like other cognitive processes, emerges from the complex interaction of multiple cortical regions. E. D. Khomskaya (2017) emphasized the systemic character of aphasia, defining it as a disruption of previously established speech as a result of localized lesions in the cortical and subcortical structures of the left hemisphere. In Western literature (commonly using the term "dysphasia"), aphasia is viewed as an acquired impairment in the use of words (both in the expressive and receptive domains), despite the preservation of basic vocal abilities.

Contemporary research in neuropsycholinguistics underscores the need for a comprehensive approach to studying speech disorders—one that integrates data from neurology, psychology, linguistics, pedagogy, and medical disciplines. It is precisely this interdisciplinary nature that enables a deeper understanding of the essence of speech disorders and fosters the development of new methods of diagnosis and correction, ultimately improving the quality of life for individuals with speech pathologies.

METHODOLOGY

1. Theoretical Analysis

A systematic review of the scientific literature was conducted, including seminal works in aphasiology, neuropsychology, speech therapy, and related fields. Primary sources (P. Broca, K. Wernicke, A. R. Luria, E. D. Khomskaya) were used alongside recent articles in peer-reviewed journals that address scientific and practical aspects of identifying and correcting speech disorders.

2. Interdisciplinary Approach

The analysis drew upon research from related disciplines—neurology, otorhinolaryngology, special education, and psycholinguistics—to form a more holistic view of the biological, social, and psychological factors influencing the development, manifestation, and correction of speech disorders.

3. Classification Analysis

Particular emphasis was placed on comparing various classification approaches to speech disorders (clinical, pedagogical, psychological). By juxtaposing different classification systems (Lichtheim–Wernicke, A.R.Luria's neurolinguistic models, and modern speech therapy classifications), the advantages and limitations of each were assessed for clinical application.

4. Practical Experience and Case Studies

In the final phase of the analysis, data on the results of therapeutic work and rehabilitation of patients with aphasia and other speech pathologies were reviewed, as presented in several contemporary publications. The effectiveness of therapeutic interventions and the potential for improving methodological techniques were evaluated.

The main part

Speech communication, functioning as a key medium of social interaction, is considered a crucial aspect of modern life. It plays a decisive role in the transmission of knowledge and emotions, the strengthening of interpersonal relationships, and the preservation of cultural heritage for future generations. Inability to effectively formulate and convey thoughts and feelings may significantly reduce an individual's quality of life.

In contemporary neurolinguistics, a substantial body of research is devoted to understanding and addressing the causes of cognitive speech disorders (aphasiology). This branch of neurolinguistics investigates language and speech impairments in both children and adults.

Early documented research on the neurological foundations of speech disorders dates back to the 19th century, specifically to the scientific works of Paul Broca and Carl Wernicke[1]. Broca's innovative observations of patients suffering from aphasia—a condition characterized by impaired speech—enabled him to pinpoint a specialized region in the left frontal lobe, now known as Broca's area, which is essential for speech development. Wernicke's subsequent research on individuals with receptive aphasia, a disorder marked by difficulties in language comprehension, further reinforced the idea that different regions of the brain are specialized for various aspects of speech processing[2].

These initial discoveries laid the foundation for the rapidly evolving field of neurolinguistics, shaping our understanding of the complex neural networks that underlie speech and language abilities. Special emphasis is placed on analyzing the

[1]Broca P. Remarks on the seat of the faculty of articulated language, following an observation of aphemia (loss of speech). Bulletin de la Société Anatomique, 6, 1861. – P. 330-357.

[2]Wernicke C. The aphasic symptom complex. A psychological study on an anatomical basis. In G. H. Eggert (Ed.), Memory, thought and experience. – Karger, Basel. 1874. – P. 93-97.

lexical units that reflect the characteristics of pathological changes. Such observations are crucial for diagnosing, treating, and rehabilitating individuals with speech impairments.

Modern classifications of speech disorders are based on two primary aspects:

Etiopathogenesis (clinical and pedagogical classification), which focuses on the causes and mechanisms of speech disorders.

Psychophysical organization of speech activity (psychological and pedagogical classification), examining speech disorders through disruptions in both the psychological and physical components of speech production.

Speech development disorders may arise due to a range of biological and social factors, with the former exerting influence at various stages of development.

In contemporary medicine and speech therapy, the principal approach to resolving speech impairments is comprehensive intervention, which typically combines:

1. Pharmacotherapy to stimulate brain development,
2. Psychological and pedagogical approaches, and
3. Speech therapy correction (remediation).

According to S. S. Lyapidevsky's classification, the following are regarded as speech disorders[3]:

1. Phonetic Disorders (dyslalia, dysarthria, rhinolalia).
2. Underdevelopment or Loss of Speech (alalia, aphasia).
3. Disturbance of Speech Tempo, Rhythm, and Sequence (involuntary): tachilalia (excessively rapid speech) and bradilalia (excessively slow speech).

RESULTS AND DISCUSSION

Aphasiology is a branch of neurology and medical psychology specialized in studying speech disorders, particularly aphasia. This field examines the relationship between thinking and speech, as well as other paralinguistic phenomena. Aphasiologists seek to develop methods for remediating aphasic conditions.

Aphasia is a speech disorder that typically arises after a stroke or other traumatic brain injury affecting the areas of the brain responsible for speech. It impairs an individual's ability to understand or repeat spoken language and can also affect other cognitive processes such as reading, writing, and memory.

In the majority of individuals, the speech centers are located in a single hemisphere of the brain, termed the dominant hemisphere. This dominant hemisphere primarily governs speech functions, while the other hemisphere, referred to as the subdominant hemisphere, plays a comparatively lesser role in speech.

[3]**Ляпидевский С.С.Патология речи / ред. С.С. Ляпидевский. – М., 1971. – 108 с.**

Speech disorders are impairments in the production or comprehension of speech that interfere with effective communication and social interaction. They are characterized by a persistent level of underdevelopment relative to age-appropriate norms in the psychophysiological mechanisms underlying speech function, which cannot be overcome without professional intervention. Such disorders have a negative impact on an individual's cognitive development.

The study and treatment of speech disorders in both children and adults belong to the fields of speech therapy and pedagogy. Moreover, a range of medical sciences—including neurophysiology, neurology, otorhinolaryngology, and dentistry—also contribute to the understanding and treatment of speech impairments.

The broad array of factors leading to disordered speech development can be divided into biological and social influences. Biological factors may affect speech development at various stages, for instance:

1) During intrauterine (prenatal) development and childbirth, factors such as fetal hypoxia, intrauterine infections, and birth injuries can adversely affect the maturity and functioning of a child's brain structures. Injuries, infections, and other incidents occurring within the first few months after birth can also impact speech development.

In older adults, speech disorders may result from vascular damage to the brain (e.g., stroke), severe head trauma, brain tumors, or neurosurgical interventions.

Causes of speech defects in adults may include extreme stress, damage to the speech apparatus, physical or psychological trauma, concussion, surgical procedures, infectious diseases, or hearing impairment.

In children, speech defects can be triggered by stress or intense fear, injuries, neurological disorders, cerebral palsy or other dysfunctions of the central nervous system, infectious diseases, damage to or malformation of the speech apparatus, hearing impairment, or hereditary factors, among other causes[4].

Currently, there is no single unified classification of speech disorders tested throughout the history of aphasiology and speech therapy as both a scientific and practical field. At the same time, various approaches to classifying and systematizing individual groups of speech disorders do exist.

Speech pathology is classified among the principal types of impairments affecting human bodily functions. To correctly interpret speech disorders, it is essential to have a clear understanding of the normal functioning of well-developed speech from the perspective of N. A. Bernstein's theory of the physiology of activity.[5] Speech, as a linguistic means of interaction, establishes communication between an individual and others.

Aphasia is an acquired impairment of verbal and nonverbal communication in adults, arising from damage to the secondary and associative areas of the left

[4] Мухиддинов А.Г. Основы нейролингвистики. – Фергана: «Classic», 2022. – 170 с.
[5]Бернштейн Н.А. Физиология движений и активность. – М., 1990. – 495 с.

hemisphere cortex[6]. According to E. D. Khomskaya, “aphasia is a disruption of previously established speech due to a localized lesion in the cortical regions of the cerebral hemispheres and the adjacent subcortical structures of the left hemisphere. It constitutes a systemic disorder that impacts various forms of speech activity”[7].

In Western literature, aphasia (or dysphasia) is defined as an acquired deficit in the use of words—both in pronunciation and comprehension—despite the preservation of basic vocal abilities. In its broadest sense, aphasia encompasses impairments in all forms of verbal communication, including auditory (oral speech), visual (reading and writing), and tactile modalities. In a narrower sense, however, the term refers specifically to disorders of spoken speech.

Aphasia is diagnosed when speech impairment is the dominant deficit among other cognitive disturbances[8]. In 1885, K. Wernicke and L. Lichtheim developed a classification system for aphasia. This system was grounded in the then-prevailing understanding of mental functions linked to specific brain centers.

Throughout human history, the ability to engage in oral communication has served as a crucial indicator of human cognitive capacity and as the cornerstone of social interaction. However, for many individuals, this innate ability is hampered by speech disorders—conditions that compromise the formation, articulation, or fluency of speech.

By delving deeper into the field of neuropsycholinguistics, we illuminate the complex interrelationships among brain function, speech processing, and speech pathologies, thereby showcasing a rich array of research and therapeutic possibilities.

In summary, neuropsycholinguistics leverages interdisciplinary collaboration to bridge the gap among neurology, linguistics, psychology, and clinical sciences. By fostering cross-disciplinary dialogue and integrating diverse viewpoints, we can develop a more comprehensive understanding of the intricate interplay between brain functions, cognitive processes, and speech and language abilities.

Through collaborative efforts and joint research, we can pave the way for more effective diagnostic tools, targeted interventions, and ultimately an enhanced quality of life for individuals with speech impairments, all while unraveling the mysteries of the human brain.

CONCLUSION

As an interdisciplinary field, neuropsycholinguistics offers a broad perspective for the research and correction of speech disorders. By unifying efforts in neurology, psychology, linguistics, and clinical sciences, this domain reveals the complex neural mechanisms underlying speech and suggests more precise diagnostic tools and more effective rehabilitation methods. The historical works of P. Broca and K.

[6]Кулеш С.Д. Нейропсихология. – 4-е изд. – Гродно, 2011. – 180 с.

[7]Хомская Е.Д. Нейропсихология. – 4-е изд. – СПб., 2007. – 496 с.

[8] Кулеш С.Д. Нарушения речи при локальных поражениях мозга // Актуальные проблемы неврологии в Беларуси. URL: https://cyberleninka.ru/article/n/narusheniya-rechi-pri-lokalnyh-porazheniyah-mozga

Wernicke, alongside the systemic approaches of A. R. Luria and contemporary aphasiology, have established a solid foundation for understanding the localization and functional specialization of various brain areas responsible for speech.

Although there is no single universally accepted classification of speech disorders, the diversity of existing approaches (clinical, pedagogical, psychological, neurolinguistic) underscores the need for a comprehensive assessment in each individual case. Recent studies highlight the importance of an integrative approach, incorporating pharmacotherapy, psychological and pedagogical practices, as well as speech therapy techniques. Promising directions include the development and implementation of innovative diagnostic technologies (such as neuroimaging and computer-assisted programs), along with improvements to rehabilitation strategies that enhance therapy effectiveness and patients' quality of life.

In conclusion, the future of neuropsycholinguistics as a scientific and practical discipline lies in further consolidation of knowledge from related areas, the advancement of interdisciplinary research, and the integration of modern technologies. Ultimately, these endeavors foster a deeper understanding of the laws governing speech activity and more successful assistance for individuals with speech disorders.

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