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THE IMPACT OF FUNCTIONAL ASYMMETRY OF THE CEREBRAL HEMISPHERES IN STUDENTS OF A PHYSICS AND MATHEMATICS LYCEUM ON THE LEARNING OUTCOMES

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Abstract. The functional asymmetry of the human brain hemispheres (motor, sensory, and mental) reflects the differences in the distribution of neuro-psychic functions between the left and right hemispheres. The left hemisphere is responsible for the brain's abstract-logical, inductive thinking, and verbal-analytical functions. The right hemisphere provides visual-figurative, deductive thinking. The dominance of the left hemisphere determines left-hemispheric thinking, while the dominance of the right hemisphere determines right-hemispheric thinking. The synchronous functioning of both hemispheres indicates balanced-hemispheric thinking. According to this distribution, different styles and effectiveness of students' cognitive activities will be observed. Therefore, our goal was to investigate and compare the types of cerebral hemisphere dominance in students of a physics and mathematics lyceum studying in classes with physics-mathematics and chemistry-biology specializations. We found that 84.4% of students of both genders, regardless of their chosen specialization, had left-hemisphere dominance with an average level of functional asymmetry. Among students of the chemistry-biology specialization who actively participate in Olympiads, there are representatives with left hemispheric (high, medium, and low asymmetry coefficients), right hemispheric, and balanced-hemispheric functional organization of the brain. Among students of the physics-mathematics specialization involved in Olympiads, there were children with left-hemispheric thinking (low and medium asymmetry coefficients). Among 14 students who participated in Olympiads, 86% (12) were right-handed, and 14% (2) were left-handed. This indicates that the type of interhemispheric asymmetry is not a factor that causes learning difficulties or vice versa. The article summarizes the necessity of considering the individual psychophysiological characteristics of students in the educational process, particularly their functional asymmetry of the cerebral hemispheres. It emphasizes the need to implement appropriate forms, methods, and teaching techniques in lessons that align with specific types of thinking to activate the potential of both cerebral hemispheres in students of a physics and mathematics lyceum with mathematical and biological specializations.

Keywords*:* educational process, functional asymmetry, cerebral hemispheres, chemistry-biology specialization, physics-mathematics specialization.

1. INTRODUCTION

The central nervous system coordinates the functioning and interconnection of all other organs and their systems in the body. The higher part of the nervous system—the cerebral cortex—ensures the processes of higher nervous activity in humans, which include the ability to think, learn, develop, and improve. One of the important features of the structural and functional organization of the brain is its asymmetry. Anatomical asymmetry is manifested by a longer and flatter lateral sulcus in the left hemisphere, greater mass of the left hemisphere, and a higher number of neurons in it. However, the central sulcus, which separates the primary motor cortex from the somatosensory cortex, is larger and deeper on the right side, and there are many such examples (Kuo, 2022; Esteves, 2020). Moreover, the left hemisphere has a structural advantage for developing the language network even before birth (e.g., a larger temporal planum, which is the main structural unit of Wernicke's center) (Martin, 2023).

Although interhemispheric asymmetry exists at birth, which shifts the dominance of the left hemisphere for language processing, lateralization intensifies during brain development and cognitive growth (Martin, 2023). Early left-sided asymmetry is also shown for the white matter fibers of the arcuate fasciculus and the corticospinal tract (Dubois, 2009), which later determines functional lateralization (Dubois, 2009). Using the method of intrauterine fetal fMRI, it was found that the functional connectome (the complete set of functional connections in the brain) is formed from 20 to 40 weeks of the prenatal period and further determines the motor and cognitive behavior of an adult (Turk, 2019; De Asis-Cruz, 2021; Cara, 2022).

The peculiarity of the language system organization, which distinguishes it from many other systems, including motor and sensory, is its strong lateralization to the left hemisphere in most adults. The left hemisphere is responsible for language in 92–96% of right-handed individuals and 73–78% of left-handed individuals link (Martin, 2023).

Functional brain asymmetry determines not only that the left hemisphere is responsible for language, both spoken and gestural, but also determines the features of perception, memorization, thinking strategies, and the emotional sphere of a person. The formation of functional specialization of the cerebral hemispheres in ontogeny occurs slowly and non-linearly, with alternating dominance of the right and left hemispheres, as well as a gradual transition from duplication of functions to their interhemispheric specialization. First, asymmetry of bioelectric indicators is observed in motor and sensory areas, and later—in associative (prefrontal and parietal-temporal) zones of the cerebral cortex. The formation and development of functional asymmetry of the cerebral hemispheres with their division into dominant and subdominant occurs by the age of 14–16 (Ribtsun, 2013).

The left hemisphere is responsible for abstract-logical, inductive thinking, which is associated with the verbal function of the brain. It works sequentially, builds algorithms, operates with facts, symbols, and signs. The right hemisphere provides spatial-intuitive, deductive, figurative thinking, perceives information as a whole, and processes it in parallel. In conditions of insufficient information, it is capable of restoring the whole from its parts. The work of the right hemisphere is associated with human creativity, intuition, and the ability to adapt. The right hemisphere ensures a holistic perception of reality in all its diversity and complexity (Mykhailovska, 2015; Ikkert, 2023).

The type of interhemispheric asymmetry, motor and sensory lateralization, affects learning processes. Many authors have shown that there are differences in the learning outcomes of students with different levels of hemisphere dominance; they differ in thinking type, temperament features, and emotional state (Tymchyk, 2015; Nevedomska, 2010; Vozniuk, 2019; Melykh, 2014).

The Physics and Mathematics Lyceum at Ivan Franko National University of Lviv (hereinafter referred to as LPML) is a highly specialized educational institution where students are selected through a competitive process, and education is conducted in several specializations. Therefore, the study aimed to assess the distribution of LPML students according to the coefficient of cerebral hemisphere asymmetry depending on their chosen specialization (chemistry-biology or physics-mathematics), as well as to analyze approaches to organizing the educational process depending on the type of interhemispheric asymmetry.

2. RESEARCH METHODS

The study involved students of the Physics and Mathematics Lyceum at Ivan Franko National

University of Lviv (Ukraine). The research was conducted during biology lessons (joint research of the Department of Human and Animal Physiology of Ivan Franko National University of Lviv and the Physics and Mathematics Lyceum at Ivan Franko National University of Lviv). The testing involved 173 students of the Physics and Mathematics Lyceum aged 14-15 years, studying in the 9th grade. Of these, 62 students studied in chemistry-biology classes and 111 students – in physics-mathematics classes. The uneven distribution is because the educational institution enrolls more students in physics-mathematics classes. In chemistry-biology classes, there were 21 boys and 41 girls, and in physics-mathematics classes – 78 boys and 33 girls.

All participants in the study had no health complaints. The functional asymmetry of the cerebral hemispheres was assessed by determining the coefficient of functional brain asymmetry (Nevedomska, 2010). To do this, each student performed a series of 12 tests that assessed motor and sensory asymmetry, and marked the result of each test with the letter L or R, provided that the left or right half of the body prevailed, respectively. In the absence of predominance, the test result was marked with the letter O. The asymmetry coefficient (AC) was calculated using the formula:

$AC = [(EP–EL)/(EP+EL+EO)] \times 100[(EP–EL)/(EP+EL+EO)] \times 100$

where: ER – the number of tests in which the task was performed predominantly by the right side of the body; EL – the number of tests in which the task was performed predominantly by the left side of the body; EO – the absence of predominance. According to the asymmetry coefficient, the following groups were distinguished: ambidexters – 0–9%; low AC—10–55%; high AC – 56-100%. Negative values of the asymmetry coefficient indicate the dominance of the right hemisphere of the brain.

3. RESULTS AND DISCUSSION

Because of the conducted research, the majority of students (84.4%) of both genders, regardless of their chosen specialization (chemistry-biology or physics-mathematics), showed left-hemisphere dominance (Tables 1 and 2), which fully corresponds to the generally known data, as well as the fact that the average level of functional asymmetry predominates.

Tab. 1

Analysis of the distribution of chemistry-biology class students according to the coefficient of cerebral hemisphere asymmetry

All	**LH dominance**			**Ambidexters**	**RH dominance**
n =62	Low	Medium	High		
Asymmetry coefficient (M±m)	15,5±0,3	42,6±2,2	80,4±3,2	5,8±1,3	-16,7±3,4
n (%)	3 (4,80)	40 (64,60)	5 (8)	10 (16,10)	4 (6,50)
Boys	1	15	1	3	1
Girls	2	25	4	7	3

Source: Own elaboration

The average level of functional asymmetry with left-hemisphere dominance was observed in 64.6% of chemistry-biology students and 71.2% of physics-mathematics students with an asymmetry coefficient of 42.6% in chemistry-biology students and 41.2% in physics-mathematics students.

The indicator of a high level of hemisphere asymmetry with left-hemisphere dominance did not differ between chemistry-biology and physics-mathematics students and was 80.4% and 83.1%, respectively. Similarly, the number of students with a high asymmetry coefficient and left-hemisphere dominance did not differ: 8% of chemistry-biology students and 9% of physics-mathematics students.

The coefficient of functional asymmetry of a low level was 15.5% in chemistry-biology students and 16.8% in physics-mathematics students (Tables 1, 2).

Tab. 2

Analysis of the distribution of physics-mathematics class students according to the coefficient of cerebral hemisphere asymmetry

All n =111	**LH dominance**			**Ambidexters**	**RH dominance**
	Low	Medium	High		
Asymmetry coefficient (M±m)	16,8±0,3	41,2±1,4	83,1±2,7	3,3±1,2	-66,6
n (%)	9 (8,1)	79 (71,2)	10 (9)	12 (10,8)	1 (0,9)
Boys	7	56	6	8	1
Girls	2	23	4	4	0

Source: Own elaboration

However, the relative number of students with a low coefficient of functional asymmetry of the cerebral hemispheres was higher among those surveyed in physics-mathematics classes and amounted to 8.1%, while in chemistry-biology classes – 4.8% (Tables 1, 2).

Right-hemisphere dominance was found in only 2.9% (5) of the students who participated in the study. These results fully confirm the information about predominantly left-hemisphere dominance (Badzakova-Trajkov, 2010). However, if we consider this indicator among students of different specializations, right-hemisphere dominance was found in 6.5% (4 students) in chemistry-biology classes and 0.9% (1 student) – in physics-mathematics classes. The same trend was observed in ambidexters: among chemistry-biology students, they accounted for 16.1%, while among physics-mathematics students – only 10.8%.

Left-hemisphere dominance was also confirmed by the fact that the majority of the studied students predominantly used their right hand, i.e., they were right-handed. Their number is 93.6% of the total sample and 95.2% of chemistry-biology students and 92.8% of physics-mathematics students. Accordingly, left-handed students accounted for 4.8% of chemistry-biology students and 7.2% of physics-mathematics students.

Since only 5 students of both educational specializations were found to have right-hemisphere dominance, and 11 students used their left hand (Table 3), this confirms that not all left-handed children have a dominant right hemisphere.

It has been proven that in some left-handed people, the conditionally dominant hemisphere is not the right, but the left hemisphere (Johnstone, 2021). Moreover, in the work of Knecht et al. (2000), cases of right-hemisphere dominance in right-handed people (4% among the examined healthy individuals) were shown (Knecht, 2000).

Tab. 3

Distribution of students according to the dominant hand

	Chemistry-biology specialization (n=62)	**Physics-mathematics specialization (n=111)**
Right hand, n (%)	59 (95,2)	103 (92,8)
Left hand, n (%)	3 (4,8)	8 (7,2)

Source: Own elaboration

The analysis of the distribution of students who predominantly use their left hand, depending on hemisphere dominance and the coefficient of asymmetry, indicates that among chemistry-biology students, left-handedness was found in children with right-hemisphere dominance, ambidexterity, and a low coefficient of asymmetry (two girls and one boy). At the same time, among physics-mathematics students, left-handedness was found among students with low and medium coefficients of asymmetry, mainly among boys (6 boys and 2 girls) (Table 4).

Tab. 4

Type of functional asymmetry of the hemispheres in students who use their left hand

	Hemisphere Dominance				**Ambidexters**
	Left			Right	
	Low AC	Medium AC	High AC		
Chemistry-biology	⊚(B)	-	-	⊚ (G)	⊚ (G)
Physics-mathematics	⊚(B)	⊚(2G+5B)	-	-	-

Note: ⊚ — left-handedness; G – girl, B – boy.
Source: Own elaboration

LPML is designed to teach gifted high school students, many of whom participate in Olympiads. Therefore, we decided to see if there would be a relationship between the type of functional asymmetry and high academic achievement. Since the works (Melykh & Romanyuk, 2014) showed that students with left-hemisphere dominance have better abilities to study exact subjects, and those with right-hemisphere dominance have better abilities to study subjects that require a creative approach, and also provided facts that girls have higher success rates than boys.

As can be seen from Table 5, among chemistry-biology students, representatives of each type of asymmetry participate in Olympiads: left-hemisphere dominance with high, medium, and low AC, right-hemisphere dominance, and balanced-hemisphere dominance. Among physics-mathematics students, students with low and medium AC participated in Olympiads. In addition, it is worth noting that among 14 students (10 boys and 4 girls) who participated in Olympiads, 86% (12) were right-handed, and 14% (2) – left-handed.

These results align with the prevailing view in recent years that we teach the student, not the hemisphere (Coch, 2021), and that a properly organized educational process involving both hemispheres allows for high achievements. By the way, in the report by C.E. Chambers et al., it is noted that infants and young children have brains with a certain degree of super ability: while adults process most discrete neural tasks in specific areas of one or the other hemisphere of their brain, children use both the right and left hemispheres to perform the same task (Chambers, 2020).

Tab. 5

Type of functional asymmetry of the hemispheres in students who participated in Olympiads

	Hemisphere Dominance				**Ambidexters**
	Left			Left	
	Low AC	Medium AC	High AC		
Chemistry-biology	⊚ (B)	⊚ (2B+2G)	⊚ (B)	⊚ (B)	⊚ (G)
Physics-mathematics	⊚ (B)	⊚ (1G+4B)	-	-	-

Note: ⊚ – participation in the Olympiads; D – girl, X – boy.
Source: Own elaboration

Therefore, to activate the mental and cognitive activities of gifted students, it is necessary to harmonize the functions of the hemispheres. For this purpose, verbal educational information, the perception of which relies on abstract-logical thinking (left hemisphere), should be combined with graphical images, which will help engage the right hemisphere and make the perception of the material more holistic and integrated. In turn, this will contribute to a more complete and deep understanding of the essence of new information and its transformation into long-term memory (Vozniuk, 2019). In the case of large volumes of theoretical material, mathematization, and algorithmization of material in the study of humanities with reduced emotionality of presentation, dry language, and the absence of vivid examples, the work of the left hemisphere is predominantly activated with reduced involvement of the right hemisphere. This leads to the fact that students can only competently reproduce the learned material but are helpless in the practical application of knowledge. The defining trend of modernity is the constant growth of information flow, the increasing role of the individual, the intellectualization of their activities, and the rapid development of technology and technologies in the world. Together, this necessitates a qualitatively new level of teaching both basic and specialized disciplines, as well as ensuring the intellectual, psychological, and moral readiness of all participants in the educational process to work and perform tasks in new conditions (Vozniuk, 2019).

The use of a significant amount of illustrative material in textbooks, presentations, diagrams, emotional coloring of language, and vivid examples from life promotes the involvement of both hemispheres in the work.

It is known that a person perceives information through analyzers: visual, auditory, and somatosensory, one of which is usually dominant, which also affects the learning process. According to the type of dominant analyzer, students are divided into visual, auditory, and kinesthetic learners. There are no absolute auditory, kinesthetic, or visual learners; we only speak of the dominance of one of the types of perception. Accordingly, the three main learning styles are visual, auditory, and kinesthetic. Visual learners are students who learn by seeing. For them, it is important to know the teacher's facial expressions, gestures, and expressions. They usually prefer to sit at the front desks to avoid visual obstacles such as people's heads, body movements, etc. Visual learners like to think in pictures and learn best from visual images, namely diagrams, illustrated textbooks, videos, charts, handouts, etc.

Auditory learners are students who learn by listening. Auditory learners learn best through verbal lectures, discussions, and listening to what others say. They are not afraid to speak in class and cannot remain silent for long, often talking to themselves. Kinesthetic learners are students who learn by doing and moving things. They learn best through a hands-on approach, actively exploring the physical world around them. Usually, such students cannot sit still for long and may be distracted by their need for activity and exploration (Zhang, 2011).

Zhang (2011) analyzed the correlation between the type of interhemispheric asymmetry and learning style. According to his data, students with left-hemisphere dominance in the learning process perceive information using visual and auditory analyzers, often in combination. In contrast, students with right-hemisphere dominance mainly perceive information visually (Zhang, 2011). The teacher should modify and present the material and tasks in such a way as to adapt them to all students in the class, regardless of the type of interhemispheric asymmetry.

When motivating students to activity in the broad sense of the word (including learning), it is necessary to remember that the activation of the right hemisphere is achieved by emphasizing the social significance of the type of activity, forming the need for self-realization, self-knowledge, and supporting and praising students. The aesthetic aspect of subjects is also essential. The left hemisphere is activated by emphasizing cognitive motives and stimulating mental activity.

As noted by Vozniuk (Vozniuk, 2019), the fact that each hemisphere controls the opposite side of the body must be taken into account when preparing visual material, conditionally dividing the visual field into the left (figurative) and right (verbal) parts. Accordingly, figurative information is best presented on the left side of the slide, while letters, words, and numbers should be placed on the right side.

When choosing methods for testing students' knowledge, it is also necessary to remember the interhemispheric asymmetry of the brain. Using different types of tasks, it is possible to identify the level of knowledge better and reveal the potential of each child. Written problem-solving allows students to demonstrate their analytical abilities (activates the left hemisphere). Oral questioning methods and "open-ended" questions allow them to demonstrate creative abilities and provide a detailed answer (activates the right hemisphere).

Students with opposite learning styles can help each other. For example, a student with right-hemisphere thinking, working on a task in pairs with a left-hemisphere student, can show their partner such learning strategies as synthesis, the use of diagrams, contextual data, identifying the essence, searching for known information, and comparing facts. A student with left-hemisphere dominance can share with their partner ways to identify necessary details, detect differences, and create categories.

4. CONCLUSIONS

Thus, the educational process should be carried out taking into account the individual psychophysiological characteristics of students in general and the functional asymmetry of the cerebral hemispheres in particular. When planning lessons, it is important to consider not only the content, forms, and methods of teaching that correspond to a certain type of thinking but also to use various teaching techniques aimed at developing and activating the capabilities of the brain's left and right hemispheres. Even though the majority of students have left-hemisphere dominance when organizing the educational process, it is necessary to use teaching techniques aimed at developing and activating both the left and right hemispheres of the brain to achieve maximum learning outcomes.

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Оксана Іккерт, Тетяна Король, Катерина Глазунова, Ірина Цінкевич. Вплив функціональної асиметрії півкуль мозку в учнів фізико-математичного ліцею на результати їх навчання. *Журнал Прикарпатського університету імені Василя Стефаника*, **12** (1) (2025), 142-150.

Функціональна асиметрія півкуль головного мозку людини (моторна, сенсорна та психічна) відображає відмінність у розподілі нервово-психічних функцій між його правою та лівою півкулями. Ліва півкуля відповідає за абстрактно-логічне, індуктивне мислення та вербально-аналітичні функції головного мозку. Права півкуля забезпечує наочно-образне, дедуктивне мислення людини. Домінування лівої півкулі головного мозку визначає лівопівкульний тип мислення, правої – правопівкульний, синхронне функціонування обох півкуль – рівнопівкульний тип мислення. Відповідно до цього розподілу буде спостерігатися різний стиль та результативність навчально-пізнавальної діяльності учнів. Саме тому нашою метою було дослідити та порівняти типи домінування півкуль головного мозку в учнів фізико-математичного ліцею, які навчаються у класах з фізико-математичним та хіміко-біологічним профілями. З'ясували, що у 84,4% учнів обох статей незалежно від обраного профілю навчання домінувала ліва півкуля із середнім рівнем функціональної асиметрії. Серед учнів хіміко-біологічного профілю навчання, які активно беруть участь в олімпіадах, є представники з лівопівкульною (високий, середній та низький коефіцієнтом асиметрії), правопівкульною та рівнопівкульною функціональною організацією головного мозку. Серед учнів фізико-математичного профілю навчання, залучених до олімпіад, були з лівопівкульним типом мислення (низький та середній коефіцієнт асиметрії). Серед 14 учнів, які брали участь в олімпіадах, 86% (12) більшою мірою володіли правою рукою, а 14% (2) – лівою рукою. Це свідчить про те, що тип міжпівкульної асиметрії не є фактором, що зумовлює проблеми з навчанням чи навпаки. У статті підсумовано необхідність урахування в освітньому процесі індивідуальних психофізіологічних особливостей учнів, зокрема їх функціональної асиметрії півкуль головного мозку. Наголошено на потребі впровадження на уроках відповідних форм, методів і прийомів навчання, що відповідають певному типу мислення задля активізації можливостей обох півкуль головного мозку в учнів фізико-математичного ліцею з математичним та біологічним профілем навчання.

Ключові слова: освітній процес, функціональна асиметрія, півкулі головного мозку, хіміко-біологічний профіль, фізико-математичний профіль.