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The Specifics of Higher Mental Functions in Children with a Leading Left Hand

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The article describes the study of higher mental functions in children of primary school age with a leading left hand. The materials of two empirical studies obtained on a sample of primary school students from two Moscow educational complexes are presented. The study no. 1 is longitudinal. It describes the dynamics of the formation of mental functions in left-handed children. The study no. 2 describes the specifics of spatial perception in left-handed children. The results of the study confirm the presence of the specifics of the development of mental functions in children with a leading left hand. Based on the results of the study, recommendations on working with left-handed children for specialists of the education system are proposed.

Keywords: neuropsychology; higher mental functions; spatial perception; primary school age; left-handed children.

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Специфика высших психических функций у детей с ведущей левой рукой

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Представлены материалы исследования высших психических функций у детей младшего школьного возраста с ведущей левой рукой. Целью исследования было выявление особенностей нейродинамических показателей, показателей памяти, внимания, мышления, пространственных функций и грамматических отношений леворуких младших школьников в сравнении с праворукими сверстниками. Показаны результаты двух эмпирических исследований, полученные на выборке учеников начальной школы из двух московских образовательных комплексов. Первое исследование являлось лонгитюдным и предполагало изучение динамики формирования психических функций у детей с ведущей левой рукой (приняло участие 70 детей младшего школьного возраста с ведущей левой рукой). Второе исследование было направлено на изучение специфики пространственного восприятия у леворуких детей (приняло участие 60 респондентов). Полученные данные подтверждают наличие специфики развития психических функций у детей с ведущей левой рукой. На основе результатов исследования предложены рекомендации для специалистов системы образования по работе с леворукими детьми.

Ключевые слова: нейропсихология; высшие психические функции; восприятие пространства; леворукость; младший школьный возраст.

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Introduction

In recent decades, the number of left-handed children has been growing [3, 18, 20]. Left-handed children have mental characteristics that make it difficult to master subject and universal competencies, and complicate adaptation to the educational process, that has been proven during the research [4, 5, 8, 11, 12]. According to meta-analysis data, doctors and educators are increasingly faced with children impaired coordination and motor development, and this trend is parallel to an increase in the number of left-handed children in the population [17]. Methods for detecting deviations from the left-hemisphere profile of the organization of mental functions are also being improved [13], however, the question of the relationship of the profile of lateral organization with cognitive development remains debatable. There is no reliable data on the deficiency of a particular cognitive function in children with a right-hemisphere profile of lateral organization [19]. At the same time, both the practical observations of teachers and the data of modern meta-analysis indicate that children with a dominant left-hand experience difficulties in understanding texts and writing [16].

Modern educational programs focus on the left-sided profile of the lateral organization and involve the development of verbal and logical thinking and consistent information processing in the student [8]. In the case of left-handedness, the profile of the lateral organization is predominantly right-sided, and information processing occurs differently [22], which leads to difficulties in mastering the curriculum [7, 12, 15]. At the same time, a number of indicators of attention distribution, visual and spatial orientation turn out to be universal for left- and right-handed children, which indicates the high importance of cultural, in particular, educational and educational factors [14, 21].

A neuropsychological approach was used to investigate the nature of these difficulties. Neuropsychological diagnostics is an objective method of studying the structural features underlying higher mental functions [9]. The syndromic neuropsychological analysis assumes not so much a statement of the presence of a functional disorder, as its qualitative qualification, comparison of primary and secondary disorders, determination of the structure of the disorder [6]. With the help of neuropsychological diagnostics, it is possible to establish the features of the formation and course of mental processes in children with a leading left hand and further take into account the identified features for the personification of the educational process.

Organization of the Study

The study of the specifics of mental functions in left-handed children was conducted in two stages. At the first stage, left-handed primary school students were examined. A longitudinal method was used to track the dynamics of students over the year and a slice method to compare the characteristics of first-graders and fourth-graders. At the second stage, the features of spatial perception of left-handed and right-handed elementary school students were compared by the method of slices.

The first stage of the study

At the first stage of the study, 70 left-handed primary school students of School #2107 (Moscow) were examined (Table 1).

A comparative analysis of the results of students in the first grades (25 left-handed children) and fourth grades (24 left-handed children) was carried out separately. Left-handed fifth graders were also examined, who corresponded in age to fourth grade students (10 left-handed children). Of the total number of children, 31 students were examined twice — in October 2018 (“Group 1”) and a year later, in September 2019 (“Group 2”). Thus, 101 observations were carried out during the examination of

Table 1

Distribution of children by gender and age

Age	Gender		In total, age
	Boys	Girls	
7 years	6	7	13
8 years	9	3	12
9 years	12	9	21
10 years	6	9	15
11 years	6	3	9
In total, gender	**39**	**31**	**70**

70 children (66 of them were boys, 35 were girls. The class distribution is as follows:

Grade 1 — 25 observations (24.8%);
Grade 2 — 21 observations (20.8%);
Grade 3 — 21 observations (20.8%);
Grade 4 — 24 observations (23.8%);
Grade 5 — 10 observations (9.9%).

Neuropsychological techniques were used to assess the level of formation and features of mental functions [1]:

1. "Proof-reading test"
2. Memorizing two groups of three words
3. Making up a story based on a series of plot pictures
4. Exclusion of items
5. Copy with re-encryption
6. Head Samples
7. The Ozeretsky sample
8. Graphic test
9. A test for dynamic praxis
10. "Choice reaction" (conflict test)
11. Memorizing difficult-to-visualize shapes
12. A test for understanding logical and grammatical constructions [1, 2, 10, 13].

To interpret the data obtained, all indicators were reduced to complex parameters (Table 2). The indicators themselves and the principle of their assessment correspond to the standards and the general diagnostic logic of neuropsychological examination of younger schoolchildren aged 6—9 years [1]. The evaluation of particular indicators was carried out on scales similar to the Wasserman scale, where "0" indicates the absence of a disorder or dysfunction, and "3" indicates gross and/or multiple disorders and dysfunctions.

To study the significant results of the dynamics of indicators, the Pearson crite-

Table 2

Complex parameters of neuropsychological assessment and corresponding samples

Complex parameters	Diagnostically significant indicators of samples
The I structural and functional block of the brain	
Tonus	Symptoms of a tonus disorder in a graphic test for dynamic praxis
	Symptoms of impaired tone in a reciprocal coordination test
	Positional and tonus errors in the dynamic praxis test
	Observation data: various types of manual activities (writing, drawing, manipulation, etc.)
The pace of activity	The speed in the graphic test for dynamic practice

Complex parameters	Diagnostically significant indicators of samples
	The speed in the reciprocal coordination test
	The time of the proofreading test
	Observation data: various types of manual activities (writing, drawing, manipulation, etc.) and problem solving
Fatigue	The number of errors at the initial, middle and final stages of the proof-reading test
	Observation data: work with tasks of varying duration and complexity
The II structural and functional block of the brain	
The volume of auditory-speech memory	Memorization of 2 groups of 3 words
The volume of visual-spatial memory	Memorization of difficult-to-visualize shapes
Resistance to interference	Memorization of 2 groups of 3 words
	Memorization of difficult-to-visualize shapes
Integrative* indicator of left-hemisphere functions	Memorization of 2 groups of 3 words
	Memorization of difficult-to-visualize shapes
Integrative* indicator of right hemisphere functions	Memorization of 2 groups of 3 words
	Memorization of difficult-to-visualize shapes
Perception of spatial Relations	The Head's Test
	Copying with 180 degree rotation
Understanding logical and grammatical constructions	A test for understanding logical and grammatical constructions
The III structural and functional block of the brain	
Assimilation of instructions	Conflict test
	The Head's Test
	Copying with 180 degree rotation
Level of verbal and logical thinking	The fourth-is-undue test
Level of visual and imaginative thinking	Telling a story based on a series of plot images
Integrative* indicator of left-hemisphere functions	Telling a story based on a series of plot images
	Copying with 180 degree rotation
Integrative* indicator of right hemisphere functions	Telling a story based on a series of plot images
	Copying with 180 degree rotation
Serial organization of movements	A test for dynamic praxis
	A test for reciprocal coordination
	A graphic test for dynamic praxis

**Remark: based on the results of calculating the characteristic "left-hemisphere" and "right-hemisphere" errors when performing a number of tests (according to [1]).*

rion $\chi 2$ for nominative scales and the Wilcoxon criterion for quantitative and ordinal scales were used. More successful performance of the majority of samples during repeated diagnosis was noted (after a year, in Group 2).

The pace of activity. In both groups, the pace of activity is rather slow. In Group-1, at the trend level, there is a more pronounced tendency to slow down relative to Group-2 ($\chi 2(2)=5.596$, $p=0.061$).

Fatigue. Fatigue in the process of completing tasks in Group 1 and Group 2 is poorly expressed, signs of fatigue are not observed in 58% of the subjects, without significant differences in groups. However, when comparing the groups "1st grade" and "4th grade", there is a more pronounced fatigue of first-graders ($\chi 2(2)=11.618$, $p=0.003$); by the end of primary school, children mostly do not show high fatigue.

Indicators of impulsivity and fatigue were expressed in both groups without significant differences. At the same time, fatigue is mostly average, and impulsivity is noted in the majority of the sample (71%), unchanged over time.

The volume of auditory-speech memory. Significant differences between the results of the first ($W(31)=89.5$, $p=0.016$) and delayed ($W(31)=75.5$, $p=0.002$) reproductions were revealed between the groups. Group 2 demonstrates more successful completion of the task than Group 1. In this case, we can talk about a larger volume of auditory-speech memory in the subjects of Group-2 relative to the subjects of Group-1. A comparison of first-graders with fourth-graders gives a similar result: older children have a large amount of auditory-speech memory ($U(49)=194$, $p=0.032$).

The volume of visual-spatial memory. Indicators of visual-spatial memory also differ significantly: Group-2 has a more productive task performance relative to Group-1: the third ($W(31)=86.5$, $p=0.027$) and delayed ($W(31)=83$, $p=0.019$) playback improved. A comparison of first-graders with fourth-graders gives a similar result: older children have a large amount of visual-spatial memory ($U(49)=184$, $p=0.03$). Probably, this dynamic is associated with the improvement of visual-spatial representations and the development of the mnestic sphere.

Resistance to interference. Group 2 showed significantly higher resistance to interference ($\chi 2(2)=9.207$, $p=0.010$) when memorizing stimuli of various modalities — auditory and visual-spatial. Accordingly, the "4th class" also demonstrates significantly higher interference compared to the "1st class" group ($\chi 2(2)=15.312$, $p<0.001$)

An integrative indicator of left-hemisphere functions. In Group 1, there is a greater number of errors ($W(31)=82.5$, $p=0.010$) characteristic of weak left hemisphere functions. Such errors include distortions and substitutions of words when memorizing them, simplification or "improvement" of shapes, omission of details when copying complex shapes. In Group 1, "left-hemisphere" errors were not found in only 3% of the subjects, in Group 2, this type of error was not found in 19% of the subjects.

An integrative indicator of right hemisphere functions. The subjects of both groups are prone to "right-hemisphere" errors without significant group differences. This manifests itself in a violation of the word order in the study of auditory-speech memory and in a violation of proportions, the division of the figure into parts and dysmetry in the study of visual-spatial memory.

Perception of spatial relations. In Group 2, the perception of spatial relations is more formed, which is expressed in significantly more productive performance of tests for visual-spatial orientation ($\chi 2(2)=6.035$, $p=0.049$). The "mirroring" of the samples is observed in 87% of all subjects, regardless of the group: it occurs in Head samples, in a sample for copying an image with re-encoding and when reproducing stimuli in samples for visual-spatial memory. A comparison of first-graders with fourth-graders gives a similar result: older children cope with tasks with significantly higher productivity ($\chi 2(2)=10.598$, $p=0.005$).

Understanding logical and grammatical constructions. There are no significant differences between Group-1 and Group-2 in the understanding of logical and grammatical constructions. However, the Group-1 subjects admit a greater number of errors in understanding prepositions in logical and

grammatical constructions (W(31)=81.5, p=0.009) and a smaller number of errors in "reversibility tests" (W(31)=96.5, p=0.043). Fourth graders make significantly fewer mistakes in understanding logical and grammatical constructions (U(49)=178, p=0.014).

Learning the instructions. Subjects of both groups mostly need to be re-presented with instructions; no significant differences were found. At the same time, if children have practically no difficulties in learning instructions in grade 4, then in grade 1 a significantly larger number of students need help and repeat tasks (χ2(2)=6,870, p=0.032).

The level of verbal and logical thinking. Almost all children show high results in the test for the study of verbal and logical thinking, which indicates that this type of thinking is sufficiently formed in left-handed students, regardless of age.

The level of visual and imaginative thinking. There is a difference in the level of tendency in the formation of visual-imaginative thinking (χ2(3)=7,728, p=0.052): the subjects of Group 2 demonstrate slightly more successful completion of the tests.

An integrative indicator of left-hemisphere functions. Many children have omissions of semantic links in the process of building a story, there are no significant differences between the groups. Only 18% of the total number of subjects do not make "left-hemisphere" mistakes when composing a story and copying an image with re-encoding.

An integrative indicator of right hemisphere functions. 87% of all subjects have "right-hemisphere" errors, consisting in a violation of the connection between events or an unrealistic interpretation of events in the construction of the story and topological errors and asymmetries when copying an image with 180-degree reencryption. There are no significant differences between the groups.

Serial organization of movements. There are no significant differences between the groups, only 8% of the total number of subjects perform all the tests according to the standard. Most children simplify execution relative to the sample, automation of execution occurs mainly after several failures. Children from Group 2 make significantly fewer spatial and kinesthetic errors (W(31)=90,5, p=0,017).

Since visual-spatial perception and quasi-spatial relations underlie the educational process in the lower grades, largely determine the success of mastering the grammatical structure of speech and counting functions, the focus of attention was shifted to a comparative study of these indicators in groups of right-handed and left-handed schoolchildren.

The second stage of the study

At the second stage, a study was conducted on the specifics of the formation of the second structural and functional block of the brain in left-handed children — visual-spatial and quasi-spatial factors. The results of neuropsychological tests performed by left-handed and right-handed children were compared.

60 primary school students were examined (school #2107 and The Pokrovsky Quarter School, Moscow). Of these, 26 were left-handed (experimental group, EG) and 34 were right-handed (control group, CG) (Table 3).

Neuropsychological techniques were used, the results of which revealed a number of complex parameters (Table 4):

1. Graphical sample
2. The praxis of the finger pose
3. Copying the table and cube
4. Understanding logical and grammatical constructions [1, 2, 10, 13]

Statistical processing was carried out in Excel and SPSS programs using the Mann-Whitney U-test. This criterion was chosen as a nonparametric method for comparing two independent samples.

An indicator of visual-spatial functions. There are no significant differences between the groups. However, left-handed

Table 3

Distribution of children by gender and dominant hand

Dominant hand	Gender		In total, dominant hand
	Boys	Girls	
Experimental group (EG)	17	9	26
Control group (CG)	16	18	34
In total, gender	33	27	60

Table 4

Complex parameters of neuropsychological assessment and corresponding samples

Parameter	Sample	Tests
Indicator of visual-spatial functions	Metric errors, perspective errors Errors in the three-dimensional image Spatial errors Non-compliance with the line	Copying the table and cube Finger pose praxis The graphic test for dynamic praxis
Quasi-spatial factor	Productivity of understanding passive, active, prepositional constructions	Understanding of logical and grammatical constructions

children are more likely to make three-dimensional image errors and draw the table flat (U(60)=514, p=0.021).

The quasi-spatial factor. Significant differences between the groups were revealed (U(60)=424, p=0.002). In left-handed children, the quasi-spatial factor is less formed than in right-handed children. At the same time, left-handed people have a weaker understanding of passive constructions (U(60)=512, p=0.02). No significant differences were found in the groups in understanding prepositional constructions and cases, and differences in understanding active constructions were revealed at the trend level — right-handed children coped with tasks more successfully (U(78)=556, p=0.054).

Discussion

According to the data obtained, left-handed children have certain features of mental functions.

Left-handed children have been found to be exhausted and hyperactive, which can affect the course of all mental processes and manifest itself in increased fatigue, absent-mindedness, difficulties concentrating on lessons. By the end of high school, left—handed children's neurodynamic indicators improve — their tone stabilizes, impulsivity decreases, and the pace of activity levels out.

The dynamics of the development of the second functional block of the brain, responsible for receiving, storing and processing information, is expressed to a greater extent. The productivity of memorizing stimuli of different modalities increases, both auditory and visual-spatial. The resistance to interference in older children is higher, and the volume of delayed reproduction is increasing.

The rate of development of auditory-speech memory exceeds the rate of visual-spatial memory, which allows us to judge the active development of the left hemisphere. Metric errors and perspective errors, non-compliance with the line and incomplete three-dimensional image are observed in left-handed children more often than right-handed peers, which may indicate a weakness of visual and spatial functions. With the improvement of neurodynamics, there is no improvement in spa-

tial gnosis, which indicates the importance of timely correction of spatial perception of left-handed children, even with their high compensatory capabilities.

With age, the assimilation of the grammatical structure occurs, and quasi-spatial errors in the perception of logical and grammatical speech structures are less common. At the same time, difficulties appear in understanding reversible structures, which, according to T.V. Akhutina [1], can occur with a lag in the development of one of the hemispheres. Presumably, this is due to the compensatory development of the left hemisphere, due to which the right hemisphere can slow down the pace of its development. This may be associated with an increase in "right—hemisphere" errors in older children — fourth grade students.

The development of the third block of the brain is characterized primarily by an increasing level of instruction assimilation in accordance with age — 1st grade students more often need to re-present instructions or simplified formulation of task conditions. Starting in the second grade, children are able to learn instructions more successfully and "slow down" their immediate reactions.

Conclusion

Thus, the dynamics of higher mental functions in left-handed children is uneven: the active development of auditory-speech memory and the functions of the third structural and functional block of the brain comes to the fore.

Despite the peculiarities of higher mental functions in left-handed children, with timely correction, it is possible to achieve effective compensation for concomitant learning difficulties associated with atypical development of mental processes. Given the possible difficulties associated with the weakness of the neurodynamic component, it is possible to achieve significant results and minimize difficulties in the learning process.

Based on the survey data, the main recommendations for primary school teachers are proposed:

1. Take into account the possible weakness of neurodynamic parameters and regulatory functions. Left-handed children often need more time to analyze incoming information. Therefore, you need to repeat the upcoming tasks several times, ask if the task is clear, and repeat the instructions if necessary. It is better to give instructions in simple words and divide it into several stages.

2. It is better to present the material for assimilation and memorization not only by ear, but also to actively use the stimuli of other modalities. For example, to correct the mirrored spelling of letters, you can place the alphabet on the student's desk to create support for visual images of letters.

3. To correct difficulties in understanding texts when reading, special attention should be paid to prepositions and conjunctions (use didactic tools and methodological techniques that allow schematizing the relationship between the members of sentences — to place events on a timeline, visualize spatial relationships, etc.), active and significantly rarer passive constructions (semantic analysis of text, "shifter" games, during which children can visualize direct and reverse actions or imagine what the situation would look like if the subject and object of action "swap" places, for example).

4. In the first grades, together with a teacher-psychologist or in the form of extracurricular activities, conduct a cycle of adaptation classes for left-handed children (in the format of additional extracurricular activities or thematic training cycles) aimed at developing arbitrariness, inhibition processes, improving spatial perception and quasi-spatial gnosis. Such classes, unlike academic school lessons, should be as active as possible, involve all sensory systems and rely on the principle of learning in motion, through bodily sensations and experience.

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