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Visual-spatial Search in Tasks with Verbal and Non-verbal Stimuli in Patients with Negelect Syndrome

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Abstract

Introduction. The article deals with the possibilities of using new methodological tools for diagnosing left-sided spatial neglect (nonglect) occurring in the clinic of local brain lesions. The novelty of the study lies in testing the hypothesis that the success of diagnostic tests performed by patients with left-sided spatial neglect depends not so much on the nature of the stimuli used (speech or non-speech) as on the place occupied by the process of visual search in the structure of activity according to A. N. Leontiev, namely, whether visual search is an independent action or an operation as part of another action. **Methods.** To test this hypothesis, we developed an author's method aimed at diagnosing nonglect, which was used along with classical methods of neuropsychological diagnostics developed by A. R. Luria and his followers. Results. It is indicated that the author's method is a valid method for diagnosing left-sided spatial neglect. The nature of the stimuli used in it does not play a significant role in the productivity of its performance by patients with non-glect. At the same time, the place of visual search in the structure of activity when performing the author's diagnostic method significantly affects the success of its performance. **Discussion of the results.** The place of visual search in the structure of activity appears to be a significant factor in the performance of diagnostic tests aimed at detecting this type of disorders of higher mental functions arising in connection with brain damage in patients with left-sided spatial neglect.

Keywords

left-sided spatial neglect, neglect, neuropsychological diagnosis, activity structure, visual search, brain damage, diagnosis of neglect

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Introduction

Unilateral spatial neglect (neglect), or inattention to one half of space, more commonly the left (Andrews, 2016) is one of the most disabling syndromes occurring in patients with brain injury. The mechanisms of neglect remain controversial. A number of researchers associate this phenomenon with perceptual impairment (Dobrokhotova, 1966; Korchazhinskaya and Popova, 1976), as neglect is not compensated for when the patient's attention is drawn to it. Most often, such a rough degree of expression of the syndrome depends on the involvement of deep structures of the brain in the pathological process. Most experts believe that neglect is an attention deficit disorder (Heinke & Humphreys, 2003; Schmahmann & Pandya, 2006; Corbetta & Shulman, 2011; Vallar & Ronchi, 2021), as perceived objects are recognisable after a cue. In the presence of this syndrome, damage is noted more often to the convexitals of the cortex. However, after right-sided unilateral seizures, whether left-sided neglect occurs or not, preferences for the right side of the field are observed. This fact does not fit into the traditional understanding of neglect as a deficit of attention to the left side of space (Nikolaenko, 1993).

The contribution of disorders of consciousness (awareness) (Daini, 2019; Dalla Barba et al., 2018) and interhemispheric interaction processes (McFie, Piercy & Zangwill, 1950; Hecaen, 1962; Nikolaenko, 1993; Bahrainwala et al., 2014; Baldassarre et al., 2014; 2016) to this disorder has also been suggested.

There are a number of models explaining the phenomenon of non-glect. One of the earliest is the hemispheric competition model of M. Kinsbourne (1970, 1977, 1987), according to which arbitrary shifts of attention are provided by the appropriate work of one hemisphere and stopped on the target due to negative feedback from the other hemisphere.

Consistent with this model is a study by Posner, Walker, Friedrich & Rafal (1984), who showed that neglect may be related to difficulties in diverting attention away from target stimuli in a non-ignorable part of space.

Another model of non-glect, the anisometric hypothesis, suggests that in non-glect the image of space "shrinks" towards the affected hemisphere of the brain (Bisiach, Neppi-Modona & Ricci, 2002; Nikolaenko, 1993). This model is consistent with the hemispheric competition model.

Karnath (2015) suggests that neglect syndrome is associated with dissociation between bottom-up and top-down attention networks. Patients with neglect are more likely to have impaired attention associated with low-level, involuntary, non-conscious information processing. Consequently, the bottom-up network is more affected. At the same time, goal-oriented attention (top-down network) is more preserved. Therefore, high-level, conscious and arbitrary mental processes can act as a compensatory reserve in rehabilitation work.

In Russian psychology, the determining role of high-level, conscious and arbitrary processes has been emphasised repeatedly. Thus, in the theory of N. A. Bernstein (1966), the motor composition of a movement is subordinated to its semantic side. In the work of P. Y. Galperin and T. O. Ginevskaya (1947), a change in the motor task in the structure of activity changes the efficiency of movements; in the studies of Yu. B. Hippenreiter (1983) the effectiveness of attention increases with greater meaningfulness and relevance of the task.

According to the theory of A. N. Leontiev (2005). N. Leontiev (2005), visual search as a component of visual attention can be represented either as an action corresponding to a certain goal or as an operation that is performed as part of another action. A change in the structure of activity of patients with unilateral spatial neglect of the place occupied by visual search can improve the results demonstrated by them, which was shown in the work of A. S. Mironchuk (2019). In the first series of the experiment, the patient had to turn over all the cards on the table. Here, visual search acted as an action corresponding to such a goal as direct detection of objects; apart from this, nothing else was required from the subject. In the second series, the patient's goal was to put together a jigsaw puzzle of the cards on the table. In this case, the search acted as an operation as part of the action of putting the puzzle together. In the third series, the patient with neglect syndrome had to compose a sentence, which was previously voiced by the specialist, from the letters written on the cards on the table. In these conditions, visual-spatial search also acted as an operation as part of an action, but now, from the author's point of view, the action corresponded to an even more meaningful task, compared to the second series, i.e. obtaining a sentence.

The results showed that patients' task performance increased when visual-spatial search was presented as an operation (Mironchuk, 2019). At the same time, the efficiency of visual search when performing a verbal task was higher than when performing a non-verbal task. From our point of view, the difference between the verbal and non-verbal task used in this experiment, in addition to the material of the stimuli themselves, was due to two characteristics. First, the difference was the degree of visibility of the task goal. In the case of the nonverbal task, the content of the goal was limited to the simpler, more visual properties of the stimuli, namely the shape of the puzzle pieces. In the case of the verbal task, the content of the goal was already related to the more complex, speculative sphere of verbal meanings. This difference in target content depth is consistent with the well-known theory of information processing levels (Craik & Lockhart, 1972; Craik & Tulving, 1975; Rogers, Kuiper, & Kirker, 1977; Bransford, Franks, Morris, & Stein, 1979). Second, the tasks differed in the degree of goal certainty. While in the nonverbal task of the second series of the experiment the subject was not told what his final result should be (low degree of goal certainty), in contrast, in the verbal task the required phrase was initially formulated (high degree of goal certainty).

An alternative explanation for these features could also be the difference in the stimuli used, verbal or non-verbal. The **present work is** devoted to testing which of these parameters influenced the results obtained in the described study.

Methods

The work included approbation of the author's method of assessing visual-spatial search in patients with non-glossal speech and testing the hypothesis about differences in the efficiency of visual-spatial search for verbal and non-verbal stimuli at a high degree of certainty of the result image.

Sampling

The study was conducted at the Department of Medical Rehabilitation of Patients with Central Nervous System Dysfunction of the N.I. Pirogov National Medical and Surgical Centre of the Russian Ministry of Health. Sixty-six right-handed patients with localisation of the lesion focus in the region of the right cerebral hemisphere participated. The experimental group consisted of patients with left-sided neglect (33 patients), the control group - without neglect (33 patients).

Methods

Patients from both groups underwent neuropsychological examination according to A. R. Luria (2020) to assess the state of higher mental functions; Trail making test (TMT), part A, and The Bells Test.

The time of performance, performance/failure to perform the test (1/0) were evaluated, in some tests errors were evaluated separately. The scale 0-2 was used, where 0 - no violation, 1 - not severe degree of error severity, 2 - severe degree of severity.

Also, all participants were presented with the author's method of assessing visual-spatial search (verbal/nonverbal variants): 18 cardboard cards (6 x 6 cm) with letters printed on one side. On 9 of them on the back side were glued parts of the object image, which could be used to make a puzzle.

Study series

In the first series, 18 cards were laid out in front of the subject with the letter up (3 piles of 6 cards each: centre, left and right).

In the second series, the cards were arranged in the same way: 9 cards (3 piles of 3 cards each) and a sample image of the object was presented. The experimenter recorded the time of execution, the number of ignored cards and their location, and overall search activity (number of head/torso turns to find a card).

Statistical analysis

The Mann-Whitney test for comparison of two unrelated groups and the Wilcoxon test for comparison of visual-spatial search performance within a group (IBM SPSS Statistics 26 programme) were used for statistical analysis of the obtained data.

Results

Visual-spatial analysis and synthesis, visual gnosis

Copying Taylor's figure

When copying the Taylor figure, significant differences between the experimental and control groups were observed in the number of copied elements ($p < 0.001$), the expression of structural-topological errors ($p < 0.001$), coordinate errors ($p = 0.01$), the expression of neglect ($p < 0.001$), and the use of fragmentary ($p < 0.001$) or chaotic ($p < 0.01$) copying strategies (Table 1).

Table 1
Comparison of the control and experimental groups in terms of scores and severity of errors in copying the Taylor figure. The values with statistically significant differences are highlighted in bold font

	Number_elem	Strukt_top	Metric	Naegle	Fragm	Chaotic	Coord	Verbal	Microgr	Macrogr
U Mann-Whitney	96,0	316,0	486,5	99,0	248,5	415,5	410,5	525,0	461,0	528,5
Wilcoxon's W	657,0	877,0	1047,5	660,0	809,5	976,5	971,5	1086,0	1022,0	1089,5
Z	-5,824	-3,19	-,817	-6,507	-6,507	-2,655	-2,565	-,327	-1,799	-,384
Asympt. value (bilateral)	***,000***	***,001***	,414	***,000***	***,000***	***,008***	***,010***	,744	,072	,701

Reproduction of the Taylor figure

When reproducing the Taylor figure, significant differences between the experimental and control groups were noted in the number of copied elements ($p < 0.001$), the severity of coordinate errors ($p < 0.05$), the severity of non-glect ($p < 0.001$) and the use of fragmentary ($p < 0.001$) or chaotic ($p < 0.05$) copying strategies (Table 2).

Table 2
Intergroup comparison in terms of scores and severity of errors in reproducing the Taylor figure. Statistically significant differences are highlighted in bold font

	Number_elem	Strukt_top	Metric	Naegle	Fragm	Chaotic	Coord	Verbal	Microgr	Macrogr
U Mann-Whitney	159,5	389,5	464,5	76,5	358,	379,5	373,5	493,0	490,5	465,0
Wilcoxon's W	720,5	885,5	960,5	572,5	854,5	875,5	869,5	989,0	1051,5	961,0
Z	-4,744	-1,782	-,69	-6,282	-2,296	-2,395	-2,011	-,329	-,431	-,953
Asympt. value (bilateral)	***,000***	,075	,49	***,000***	***,022***	***,017***	,044	,742	,667	,340

Independent drawing of a cube, a table, a house

In the test for independent drawing of a table, a cube and a house, significant differences between the groups are noted both in the number of correctly drawn objects ($p < 0.001$) - more in the control group; and in the severity of inertia ($p < 0.001$), projection errors ($p < 0.001$), which may be associated with a greater degree of severity of impairment in patients with non-glect (Table 3).

Table 3
Intergroup comparison of scores and severity of errors in the independent table, cube and house drawing test. Statistically significant differences are highlighted in bold font

	Number_ paint	Inert	Projectz	Microgr	Macrogr
U Mann-Whitney	211,000	254,500	259,000	479,000	526,500
Wilcoxon's W	772,000	782,500	787,000	1007,000	1087,500
Z	-4,317	-4,510	-3,756	-1,196	-,039
Asympt. value (bilateral)	***,000***	***,000***	***,000***	,232	,969

Recognising realistic and superimposed images

In recognising realistic and superimposed images, there were significant differences in the number of named items ($p < 0.01$) (which was associated with ignoring some of the items by respondents with non-glossal language), and in naming ($p = 0.001$), which is probably due to fragmentation-type errors ($p < 0.05$), as well as in the number of impulsive responses on an isolated feature ($p < 0.05$), which was evident in the experimental group in the Poppelreiter test, and in the severity of left-sided visual neglect ($p < 0.001$) (Table. 4).

Table 4

Intergroup comparison in terms of scores and severity of errors in the subject gnosis tests. Statistically significant differences are highlighted in bold font

	Score_ realist	Score_ over-head1	Score_ over-head2	Recog-nition	Nomi-nation	Fragm	Im-pulse	Na-egle	Pseudo-agn
U Mann-Whitney	350,500	369,50	220,0	478,5	396,0	421,0	462,0	363,0	544,5
Wil-coxon's W	911,500	930,5	781,0	1039,5	957,0	982,0	1023,0	924,0	105,5
Z	-3,121	-2,790	-4,575	-1,14	-3,204	-2,168	-2,308	-3,594	,000
Asympt. value (bilateral)	***,002***	***,005***	***,000***	,254	***,001***	***,030***	***,021***	***,000***	1,00

Praxis

Kinetic praxis

The kinetic (dynamic) praxis test revealed a significant difference between the groups in the number of reproduced elements of the motor programme ($p < 0.001$), expression of difficulties in forming ($p < 0.01$) and retaining ($p < 0.001$) the programme, increase in the number of programme elements ($p < 0.001$), expression of element-by-element programme execution ($p < 0.05$), and weakness of speech regulation ($p < 0.05$) (Table 5).

Table 5

Intergroup comparison by scores and degree of severity of errors in the kinetic (dynamic) praxis test. Statistically significant differences are highlighted in bold font

	Score	Form_ progr	Hold_ program	Uvel_ numbers_el	Desautom.	Persevere	Slab_Rech_ Reg
U Mann-Whitney	225,5	312,000	207,000	320,500	299,500	412,000	429,000
Wil-coxon's W	786,5	840,000	735,000	848,500	827,500	940,000	957,000
Z	-4,150	-3,075	-4,535	-3,731	-3,415	-2,074	-2,072
Asympt. value (bilateral)	***,000***	***,002***	***,000***	***,000***	***,001***	***,038***	***,038***

Letter

The writing test revealed significant differences between groups in writing items on the right side of the sheet ($p < 0.001$) and in the expression of micro- or macrographia ($p < 0.05$) (Table 6).

Table 6

Intergroup comparison of scores and severity of errors in the writing test. Statistically significant differences are highlighted in bold font

	Score	Naegle	Verbalise	Microgr	Macrogr	Grammat_ str.
U Mann-Whitney	511,50	306,000	511,500	445,500	462,000	511,500
Wil-coxon's W	1072,5	867,000	1072,500	1006,500	1023,000	1072,500
Z	-,681	-3,795	-1,425	-2,548	-2,308	-,681
Asympt. value (bilateral)	,496	***,000***	,154	***,011***	***,021***	,496

Memory

Memorising 6 words

When memorising 6 words, there was a higher number of errors in the experimental group by type of inertia ($p < 0.01$), lower memorisation efficiency ($p < 0.01$), and less delayed reproduction ($p < 0.05$) (Table 7).

Table 7

Intergroup comparison of scores and severity of errors in the six-word recall test. Statistically significant differences are highlighted in bold font

	Directly	Postpo-nement	Total_point	Low_ef_ study	Dean_ Zauch	Izbir	Inert
U Mann-Whitney	459,500	354,500	378,000	369,000	504,000	512,500	383,00
Wilcoxon's W	1020,500	915,500	939,000	897,000	1032,000	1040,500	911,000
Z	-,946	-2,347	-2,015	-2,612	-,440	-,249	-2,919
Asympt. value (bilateral)	,344	***,019***	***,044***	***,009***	,660	,804	***,004***

Thinking

The story "The Hook."

In the story comprehension and memorisation test, no significant differences were found between the two groups (Table 8).

Table 8
Intergroup comparison of scores and severity of errors in the story retelling test

	Score_ meaning_ part	Loss_of_ parts	Loss_of_ meaning	Side_assoc	Izbir
U Mann-Whitney	423,500	447,000	460,000	502,000	525,000
Wilcoxon's W	951,500	1008,000	988,000	1063,000	1086,000
Z	1,422	-1,270	-1,423	-,436	-,059
Asympt. value (bilateral)	,155	,204	,155	,663	,953

Arithmetic problem and serial counting 100-7

In the arithmetic problem solving test, differences in difficulties in programme formation ($p < 0.01$), reduced control ($p = 0.001$), and difficulties in switching when changing the solution algorithm ($p = 0.001$) were observed. In the serial counting test, there is a greater number of errors in the experimental group by the type of programme loss ($p < 0.05$), errors in passing through the tens ($p < 0.01$) (Table 9).

Table 9
Intergroup comparison in terms of scores and severity of errors in arithmetic tasks and serial counting. Statistically significant differences are highlighted in bold font

	Arithm-_z_ball	Ponim_ usl	Form-progr	Cont-rol_z	Regu-lus	Pe-reckl_ alg	Score_ point	Poter_ prog.	Coun-ter_ acc	Pereh_ des	Inner_ des
U Mann-Whitney	247,5	482,0	339,5	322,5	425,5	379,5	334,0	391,5	468,5	334,5	486,0
Wil-coxon's W	808,5	1043,0	900,5	883,5	986,5	940,50	895,0	952,50	1029,5	895,5	1047,0
Z	-4,449	-,934	-2,820	-3,413	-1,679	-3,407	-2,805	-2,226	-1,089	-2,905	-1,025
Asympt. value (bila-teral)	***,000***	,350	***,005***	***,001***	,093	***,001***	***,005***	***,026***	,276	***,004***	,305

Analysing serial images

In the serial image analysis sample, there was a significant difference in the severity of errors such as formal description of story elements (p <0.01) and failure to describe the story independently (p <0.01) (Table 10).

Table 10

Intergroup comparison of scores and severity of errors in serial picture analysis tests. Statistically significant differences are highlighted in bold font

	Score_ser_card	Fragm_an.	Decrease_ur_general	Side_assoc	Formal_Opis	Reso-nance	Impos-sible_Opis
U Mann-Whitney	521,000	444,000	539,500	491,000	350,500	465,500	390,000
Wilcoxon's W	1082,000	1005,000	1100,500	1052,000	911,500	1026,500	951,000
Z	-,333	-1,410	-,080	-,897	-2,854	-1,702	-2,712
Asympt. value (bilateral)	,739	,158	,936	,370	***,004***	,089	***,007***

Tracking Test (TMT), Part A and The Bells Test.

Significant differences were found between groups in the time to complete the tracking test (TMT) part A (p<0.001), the time to complete the bell test before cueing (p<0.05), the number of bells detected before cueing (p<0.001) and the total time to complete the test (p<0.001), and the difference between right and left bell misses (p<0.001), all better in the control group (Table 11).

Thus, between the two groups, in addition to manifestations of left-sided neglect, there were differences in the neurodynamic parameters of mental activity, in the regulatory and visual-spatial spheres. The revealed disorders may be related to the fact that patients with non-glect disorder often have a greater cognitive deficit.

Table 11

Intergroup comparison of scores and error severity in TMT and The Bells Test. Statistically significant differences are highlighted in bold font

	TMT	BELLS1t	BELLS1	BELLS2t	BELLS 2	BELLST	BELLS_R-L
U Mann-Whitney	80,000	301,500	99,000	354,500	415,000	192,000	120,000
Wilcoxon's W	576,000	766,500	477,000	819,500	911,000	657,000	498,000
Z	-5,777	-2,196	-4,991	-1,509	-,060	-3,814	-4,712
Asympt. value (bilateral)	***,000***	***,028***	***,000***	,131	,952	***,000***	***,000***

In the phrase and puzzle methods, significant differences were found between the groups in the number of left card omissions in both the verbal and non-verbal tasks (p <0.001). There were also significant differences in the time of completing these tasks (p <0.001) - patients with non-glossal speech took longer to complete them (Table 12).

Table 12

Intergroup comparison in terms of execution time and number of omissions on the left in the experimental methods. Statistically significant differences are marked in bold

	Phrazat	Phrase_prop	Picture t	Picture_prop
U Mann-Whitney	139,500	117,000	34,500	104,000
Wilcoxon's W	667,500	468,000	385,500	455,000
Z	-5,002	-5,108	-5,774	-5,297
Asympt. value (bilateral)	***,000***	***,000***	***,000***	***,000***

In addition, an analysis of the relationships of the author's experimental methodology with standardised techniques for assessing non-glect, as well as errors associated with the presence of neglect (by Spearman's criterion) was carried out.

Significant positive correlations (p <0.001) were found between, on the one hand, the performance time and the number of omissions to the left in the verbal task and, on the other hand, ignoring the Taylor figure when copying and reproducing it, and the TMT performance time; between the number of omissions to the left in the verbal task and the number of omissions in the visual gnosis task (p < 0.001); between the verbal task performance time and the number of omissions in the visual gnosis task (p <0.05); between the verbal task completion time and the bell test completion time (p < 0.05); negative correlations (p < 0.001) between, on the one hand, the completion time and the number of omissions in the verbal and non-verbal tasks and, on the other hand, the number of bells found during the first series and the difference between the right and left bell omissions (patients with non-glossal speech are characterised by lower values).

The present results may indicate the presence of construct validity of the experimental techniques used.

The non-parametric Wilcoxon test was used to test whether there were differences in the success rate of the verbal and non-verbal task in the experimental group (sample - 33 individuals with Neglect Syndrome).

The results of the analyses showed that there were significant differences between conditions (verbal and non-verbal task) in task completion time ($p < 0.001$), finding letters and putting the phrase together was faster than finding parts of the picture and assembling it. There were no significant differences between conditions in the number of omissions and intrinsic activity (Table 13).

Table 13
Intragroup comparison of data in the nonverbal and verbal tasks. Statistically significant differences are highlighted in bold font

	Kartinkat-Frasat	Picture_prop-Phrase_prop.	Picture_act-Phrase_act.
Z	-3,579[a]	-,750[a]	,000[b]
Asympt. value (bilateral)	***,000***	,453	1,000

Note. *a - based on negative ranks, b - sum of negative ranks equals sum of positive ranks.*

Discussion

As a result of the study, intragroup differences in the success rate of diagnostic techniques were noted. Patients without neglect were on average more preserved, namely, they had less pronounced disorders of visual-spatial analysis and synthesis, regulatory difficulties, deficit of neurodynamic parameters of mental activity, etc., which is consistent with the data that the presence of left-sided spatial neglect often correlates with other disorders of functioning (Van Kessel, Geurts, Brouwer & Fasotti, 2013).

In the author's methodology, the differences between groups concerned the number of omissions and the time of task completion (Propustina et al., 2022). Probably, the significant parameter is the number of omissions, while the completion time is related to the general pace of activity.

According to M. V. Falikman (2016), visual-spatial search in both puzzle assembly tasks and classical bell test tasks will meet the tasks of detection and identification. Nevertheless, based on the study, it can be assumed that the place that visual search occupies in the activity structure of these tasks will not be the same. This search will also differ in such an important parameter as the presence or absence of distractors in the visual field (the latter is characteristic of the bell test, for example). Consequently, the process of performance and the results may be different, despite the fact that both techniques are aimed at investigating search and diagnosing non-glect.

Under the conditions of equalisation of the content depth and certainty of the tasks' goals, there are no significant differences in the number of omissions. It can be considered that both tasks are equivalent.

There are also no significant differences in search activity during verbal and non-verbal tasks. Consequently, the feature of stimuli is insignificant, unlike the place of search in the structure of activity (Mironchuk, 2019).

The difference in the timing of task completion may be due to the strategy of the activity rather than the specifics of the stimuli. The goal can be achieved in different ways: first collecting all the elements and then the puzzle/suggestion; or sequentially selecting the necessary element and immediately attaching it to the puzzle/suggestion.

Thus, in neuropsychological evaluation, A. N. Leontiev's (2005) provisions on the structure of activity allow us to reveal the actual psychological content of diagnostic tasks, which is often not taken into account in their formal description.

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Information on conflict of interest

The authors declare that there is no conflict of interest.