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(EN) Higher linguistic functions in patients with cerebral strokes.

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SUMMARY/ABSTRACT

Starting point: In communication, not only the understanding and production of words and sentences is important, but also the processing of additional linguistic information, the so-called linguistic contexts. Most research focuses on the word and sentence level, less often on text and rarely on linguistic contexts. At the same time, their results are inconsistent: some claim that the subdominant brain hemisphere is responsible for the processing of contexts, according to others, both brain hemispheres participate in these processes. The aim of the research was to investigate with the Test of Linguistic Contexts patients with vascular strokes in the right or left cerebral hemispheres and to find out which of them has a greater influence on the processing of additional linguistic information.
Group: The sample consisted of 44 patients after stroke: 15 with a stroke in the left cerebral hemisphere and 29 with a stroke in the right hemisphere. For these clinical groups, control groups of healthy participants of the same education, gender and approximately the same age were created.
Methods: In the research, a set of tasks was created for the diagnosis of six areas: pragmatics, macrostructure and inferences, figurative language, semantic system, paralinguistics and spatial perception. The obtained data were statistically processed using the methods of descriptive and inferential statistics.
Results: Statistical processing confirmed significant differences between the clinical and respective control groups in almost all monitored areas. Between clinical groups, a significant difference appeared only in pragmatics and spatial perception.
Conclusions: The results indicate that both cerebral hemispheres are involved in the perception and processing of linguistic contexts, and problems with their interpretation are present in the case of a lesion of any of them. These deficits can have a significant impact on the patient's communication and daily life.

KEYWORDS
Linguistic contexts, cerebral stroke, right and left cerebral hemisphere.

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1 INTRODUCTION

Language processing occurs on three levels: word, sentence, and text. It has long been understood that damage to the dominant cerebral hemisphere can disrupt these processes, resulting in various types and degrees of aphasia with characteristic manifestations. In contrast, aphasia does not occur with damage to the subdominant (typically right) hemisphere. The right hemisphere was historically regarded as “silent” in terms of language and speech functions. This perspective began to shift in the mid-20th century,

especially in the 1970s, as pragmatics became central in speech and language research—a field focused on the practical use of language in communication and the role of contextual factors. Context in language encompasses elements that can significantly impact interpersonal communication and mutual understanding. As Davis (1998) identifies, three main types of language context affect communication: linguistic, paralinguistic, and extralinguistic. The linguistic context involves linking sentences coherently, maintaining thematic continuity, and interpreting references such as pronouns. The paralinguistic context includes non-verbal communication cues like prosody (intonation, melody, stress), facial expressions, and gestures, which convey emotions and help distinguish between declarative and interrogative sentences, as well as assess the emotional state of communication partners. Extralinguistic context, on the other hand, includes variables such as the number of participants, social status, and personal knowledge and experiences activated during communication. Another essential component of the communication process is the ability to make inferences, or to interpret unstated information based on context, effectively "reading between the lines." These skills allow us to recognize communicative intentions, discern hidden meanings, and interpret metaphors and irony.

Toward the end of the last century, cases of patients with right hemisphere damage—and descriptions of their altered communication—began to draw attention. As Myers (1999) noted, family members of these patients observed a noticeable difference in communication, even though the patient continued to communicate. Recently, Dixon et al. (2024) highlight the link between lifestyle choices and both physical and mental health, emphasizing the importance of maintaining a holistic approach to well-being.

2 GROUP AND METHODS

The research sample consisted of 44 patients, each with confirmed damage to either the right (n=29) or left (n=15) cerebral hemisphere. In all cases, the brain damage resulted from a cerebrovascular accident (stroke). Detailed information regarding the patient demographics and characteristics is provided in Table 1.

Table 2 Characteristics of the Clinical Samples

Patients with Right Hemisphere Stroke (n=29)			n	%
Gender	Male		10	34.48
	Female		19	65.52
Education	Primary		7	24.14
	Secondary		17	58.62
	University		5	17.24
Age	Under 50 years		4	13.79
	50-70 years		15	51.72
	Over 70 years		10	34.48
Communication assessment		Aphasia	0	0.00
		Dysartria	9	31.03
		No deficits	20	68.97
Patients with Left Hemisphere Stroke (n=15)				
Gender	Male		4	26.67

	Female		11	73.33
Education	Primary		1	6.67
	Secondary		5	33.33
	University		9	60.00
Age	Under 50 years		3	20.00
	50-70 years		3	20.00
	Over 70 years		9	60.00
Communication assessment		Aphasia	11	73.33
		Dysartria	2	13.33
		No deficits	2	13.33

For each clinical group, we created matched control groups of equal size, composed of participants without neurological or psychological disorders, matched by gender, education, and age.

In Slovakia, there is no standardized diagnostic tool available for assessing higher-order language functions. Therefore, we developed a set of tasks and created a test designed to evaluate specific language areas commonly affected by brain damage, as documented in the literature. This test, called the Test of Language Contexts comprises six key subtests: pragmatics, inferences, figurative language, the lexical-semantic system, paralinguistics, and spatial perception. Below is a brief description of each subtest.

Subtest A focuses on various aspects of pragmatics, including the exchange of communicative roles, topic maintenance, making corrections, the relevance of information, and maintaining eye contact. The participant answers five questions, such as providing address, description of a typical day, or describing activities from the previous day.

Subtest B includes tasks that assess the ability to build macrostructure and make inferences. It includes tasks for creating inferences from pictures, forming inferences based on heard statements, and generating higher-order inferences, such as attributing emotions to individuals in described situations or providing verbal responses to emotional scenarios.

Subtest C evaluates the participant’s ability to understand metaphorical language. Tasks include explaining a verbally presented metaphor, selecting the correct image from four options for a given metaphor, and justifying their choice. It also tests the understanding of irony (expressed through a short story and supported by an audio recording) and the ability to comprehend jokes by choosing the correct ending of the joke from four options.

Subtest D assesses lexical-semantic processing by selecting the correct image from six options, including distractors such as two semantic, one phonological, one visual, and one functional option. It also measures the ability to activate meanings of polysemous words, and to describe familiar activities step by step (creation of so called scripts or procedural discourse). The last task asseses the ability to semantic absurdities in images (e.g., a duck with four legs).

Subtest E contains tasks related to paralinguistics, such as completing sentences with the appropriate stressed word, based on a model provided by the examiner, distinguishing linguistic prosody—such as identifying whether a recorded sentence is declarative or interrogative, recognizing the speaker's emotion (e.g., sadness, happiness, anger), and identifying emotions from facial expressions.

Subtest F measures spatial awareness, right-left orientation, and the ability maintain symmetry in drawn and redrawn images. It also considers motor skills required for task performance.

For this test, we established percentile norms for three age categories, allowing us to determine whether a participant’s performance is within the normal range or falls to the 10th percentile or lower. These standards were derived from assessments of 235 adults without mental or neurological conditions.

For data analysis in the current research, the IBM SPSS Statistics 21 and JASP software were used. Descriptive statistics were calculated for both clinical and control groups, and group comparisons were conducted using the non-parametric Mann-Whitney U-test, due to non-normal data distribution confirmed by the Kolmogorov-Smirnov test. The effect size of differences between groups was expressed using the rank biserial correlation index (r).

3 STARTING POINT, OBJECTIVE, TASKS

Abusamra et al. (2009) identify four primary profiles associated with damage to the right cerebral hemisphere, summarized in Table 2.

Table 2 Profiles of Patients with Right Cerebral Hemisphere Damage

Profile	Symptoms
Lexical-semantic	Difficulty with divergent tasks (e.g., semantic and phonological verbal fluency - naming as many words as possible based on a specific criterion), reduced ability to find relationships between words, and challenges with figurative language.
Prosodic	Production: Monotonous intonation and reduced pitch variability when expressing emotions. Perception: Difficulty understanding intentions conveyed through prosody in sentences with neutral linguistic content, inability to distinguish emphasis, and challenges in recognizing sentence melody and type.
Discursive	Production: Less informative speech despite a comparable number of utterances and words, simpler text organization, lack of coherence, tendency toward digressive information, inappropriate comments, and loss of the main theme. Perception: Difficulty connecting story elements into a cohesive whole, impaired inference-making, inability to identify the main theme or idea of the text.
Pragmatic	Production: Lack of adherence to cooperative conversation principles, disruptions in role exchange and eye contact, difficulty in developing topics and maintaining coherence, and inability to adapt speech to the listener's knowledge. Perception: Challenges in understanding intentions expressed indirectly, and difficulty with humour, irony, and metaphors.

As shown in Table 2, right-hemisphere damage can substantially impact everyday communication. Patients generally have no issues naming pictures, repeating sentences, answering questions, or describing simple images, but their primary challenges lie in processing contextual information (Blake, 2018). Heilman (2021) describes deficits in recognizing emotions expressed through facial cues in patients with right-hemisphere damage, and Parola et al. (2015) further discuss challenges in processing linguistic, extralinguistic, and paralinguistic contexts in this patient group.

Interestingly, contextual processing difficulties are not exclusive to patients with right-hemisphere damage; they also occur in those with left-hemisphere lesions. Kasher et al. (1999) found that both patient groups struggle with interpreting communicative implicatures, where the meaning must be inferred rather than taken literally, though the mechanisms underlying these deficits may differ. For instance, these difficulties are evident in understanding jokes, irony, sarcasm, metaphors, and proverbs. Giora et al. (2011) demonstrated that left and right hemisphere lesions influence the interpretation of sarcasm and metaphors differently. Right-hemisphere patients showed slightly lower comprehension of sarcasm compared to left-hemisphere patients but performed better in metaphor comprehension. Both groups scored significantly lower than the control group in interpreting sarcasm, while only patients with left-hemisphere damage performed significantly worse in metaphor comprehension compared to controls.

In the domain of paralinguistics, similar patterns emerge. Baum et al. (1997) observed that both patient groups had difficulty perceiving phrase boundaries compared to healthy controls and used fewer acoustic cues to distinguish them. Abhishek (2023) found that patients with aphasia struggled with interpreting linguistic prosody but could process emotional prosody adequately. Hielscher (2004) also demonstrated that patients with right- and left-hemisphere lesions exhibit similar deficits in perceiving emotions expressed verbally and non-verbally.

So far, in Slovak speech therapy practice and research, this area has received limited attention, prompting the creation of a diagnostic tool and the initiation of our research.

The goal of our study was to determine whether contextual deficits are present in Slovak-speaking patients with cerebral hemisphere damage. This research was supported by grant Vega 1/0122/22 and approved by the Ethics Committee of the Faculty of Education, Comenius University in Bratislava.

4 RESULTS

In this section, we present the results obtained from patient groups, comparing their performance not only with established percentile norms but also with that of the corresponding control group. Many stroke patients scored at the 10th, 7th, and even 2nd percentiles, either on the overall score of Test of Language Context or on specific subtests. This included nearly 67% of patients with left hemisphere damage and 62% of those with right hemisphere lesions. Tables 3 and 4 provide descriptive statistics for the performance of patients in each clinical group, as well as for the corresponding control groups.

Table 3 Performance of Patients with Left Hemisphere Stroke (LHS) and the Control Group (CG)

Research sample	Subtest	Minimum	Maximum	Mean	SD
LHS	Overal score	115	173	149,60	14,41
	Overal score %	63.9	96.1	83.11	8.01
	A	20	30	26.00	3.44
	B	21	29	25.80	2.48
	C	9	29	19.13	6.06
	D	16	29	24.93	3.43
	E	14	29	24.87	4.32
	F	28	30	28.87	0.83
CG for LHS	Overal score	157	180	168.67	6.78
	Overal score %	87,2	100	93.70	3.77
	A	30	103	97.73	18.76
	B	23,5	30	27.70	2.31
	C	19	30	25.60	3.89
	D	27	30	28.73	1.22
	E	23	30	27.83	2.01
	F	27	30	29.20	1.01

Table 4 Performance of Patients with Right Hemisphere Stroke (RHS) and the Control Group (CG)

Research sample	Subtest	Minimum	Maximum	Mean	SD
RHS	Overal score	127	176	154.88	14.45
	Overal score %	70.6	97.8	86.04	8.03
	A	25	30	29.17	1.31
	B	17	30	25.74	3.24
	C	12	30	21.10	5.36
	D	20	30	25.48	2.97
	E	18	30	25.93	3.37
	F	20	30	27.45	2.39
CG for RHS	Overal score	157	180	170.52	6.98
	Overal score %	87.2	100	94.73	3.88
	A	27	30	29.77	0.63
	B	23	30	28.17	1.96
	C	20	30	26.97	2.85
	D	22	30	28.18	2.27
	E	21	30	28.13	2.18
	F	26	30	29.27	1.11

Tables 3 and 4 illustrate the differences in average performance between the clinical and control groups. The clinical samples show greater variability, as indicated by the larger standard deviations (SD).

Finally, Table 5 presents the results of the group comparison using the Mann-Whitney U-test, along with the effect size of the differences expressed as the correlation coefficient *r*.

Table 5 Comparison of Clinical and Control Group Performance

Statistics	Overal score	Overal score %	A	B	C	D	E	F
Left Hemisphere Stroke and Control Group for Left Hemisphere Stroke								
U	19	19	1.5	60	43.5	20,5	57,5	86,5
Z	-3.884	-3.884	-4.733	-2.196	-2.869	-3.86	-2.303	-1.142
p	<0.001	<0.001	<0.001	0.028	0.004	<0.001	0.021	0.253
r	0.831	0.831	0.987	0.467	0.613	0.818	0.489	0.231
Right Hemisphere Stroke and Control Group for Right Hemisphere Stroke								
U	151	151	330	213.5	156.5	197	247,5	200
Z	-4.31	-4.31	-2.038	-3.42	-4.246	-3.65	-2.879	-3.69
p	<0.001	<0.001	0.042	0.001	<0.001	<0.001	0.004	<0.001
r	0,653	0.653	0.241	0.509	0,64	0.547	0.431	0.54
Left Hemisphere Stroke and Right Hemisphere Stroke								
U	174	174	87.5	209.5	180	208	188	133
Z	-1.078	-1.078	-3.427	-0.2	-0.931	-0.237	-0.736	-2.125
p	0.281	0.281	<0.001	0.841	0.352	0.813	0.462	0.034
r	0.2	0.2	0.598	0.037	0.172	0.044	0.136	0.389

According to Table 5, the control group performed significantly better than the clinical group across all areas for patients with right hemisphere stroke. For patients with left hemisphere stroke, this difference also holds true for all areas except for subtest F (perception of space), where no statistically significant difference was observed. When comparing the two patient groups (right and left hemisphere stroke), differences were found only in subtests A (pragmatics) and F (perception of space). In subtest A (pragmatics), patients with right hemisphere lesions performed better, while in subtest F (perception of space), it was the left hemisphere lesion group that had a better performance. The effect sizes of these statistically significant differences range from medium to high, indicating substantial practical relevance.

5 DISCUSSION

In our study, we assessed 44 patients with right or left cerebral hemisphere damage due to stroke using the Test of Language Contexts.

Deficits were observed not only in patients with right-sided lesions but also in those with left hemisphere damage. Speech and language therapy assessments conducted on several patients with left-sided lesions using aphasia diagnostic tests revealed the presence of aphasia (n=11), mild to moderate. The patients were examined by experienced speech and language therapists who could assess whether the failure in the task is caused primarily by language difficulties, or whether the patient is unable to cope with the task for other reasons.

In the Test of Language Contexts, patients with left-sided lesions performed similarly poorly to those with right-sided lesions. Abusamra et al. (2009) report that a key difference between patients with aphasia and those with right-sided lesions lies in their ability to process context. While patients with aphasia can use language contexts in communication, patients with right-sided lesions face significant challenges in this area. Our findings suggest that these abilities may rely on both hemispheres, involving extensive neural networks distributed across both sides of the brain.

Milburn et al. (2018) found that patients with aphasia experience difficulty accessing figurative meanings when interpreting proverbs. Lada et al. (2022), in their systematic review of studies on proverb inter-

pretation in aphasia, highlight that performance can vary significantly based on methodology and proverb type, reflecting substantial heterogeneity. Additionally, Cieślicka et al. (2011) found that patients with left hemisphere lesions struggled with interpreting figurative language compared to healthy controls. They noted that patients performed better with conventional, familiar, and frequently used metaphors.

In our study, a comparison between the two clinical groups revealed differences only in subtest A (in favor of patients with right-sided lesions) and subtest F (in favor of patients with left-sided lesions). These findings suggest that, in aphasia, language processing difficulties manifest already at the word level and influence pragmatic language use (subtest A). Conversely, patients with right-sided damage may exhibit varying degrees of neglect (e.g., ignoring the left side of space) (Myers, 1999) or attention deficits (Tompkins, 2012), which may explain the significant difference in subtest F favoring patients with left-sided brain damage.

Already in 2000, research by Beeman demonstrated that both hemispheres are involved in creating inferences and understanding narratives. Similarly, Long et al. (2005) argue that both hemispheres contribute to text comprehension and production by constructing mental representations of the text. Witteman et al. (2011), in their meta-analysis, showed that both hemispheres are essential for processing linguistic and emotional prosody. Specifically, emotional prosody is predominantly processed by the subdominant hemisphere, while linguistic prosody is processed bilaterally. This evidence suggests that deficits in linguistic context processing may arise from damage to either hemisphere.

Concluding from the abovementioned information, deficits in the area of language context in case of damage to both cerebral hemisphere can occur. Following diagnosis, appropriate therapy should target the affected areas. Patient-centered therapy, which considers individual preferences, needs, and values, is increasingly emphasized across various fields (Dinkel et al., 2024). In cases where in-person speech therapy is unavailable, online therapy may be a viable alternative, as demonstrated by successful rehabilitation efforts for patients unable to attend in-person sessions (Babicová et al., 2024).

6 CONCLUSIONS

Our research demonstrated the presence of higher-order language deficits in patients with brain damage in both the right and left cerebral hemispheres due to stroke. Regardless of the specific roles of each hemisphere in supporting these advanced language functions, it is crucial to acknowledge these issues, as they can significantly impact daily communication and the quality of life for both patients and their families.

7 ZUSAMMENFASSUNG

Ausgangspunkte: In der Kommunikation kommt es nicht nur auf das Verstehen und die Produktion von Wörtern und Sätzen an, sondern auch auf die Verarbeitung zusätzlicher sprachlicher Informationen, der sogenannten Sprachkontexte. Die meisten Untersuchungen konzentrieren sich auf die Wort- und Satzebene, seltener auf Texte und selten auf sprachliche Kontexte. Gleichzeitig sind ihre Ergebnisse widersprüchlich: Einige behaupten, dass die subdominante Gehirnhälfte für die Verarbeitung von Kontexten verantwortlich sei, andere meinen, beide Gehirnhälften seien an diesen Prozessen beteiligt. Ziel der Forschung war es, mit dem Test of Linguistic Contexts. Patienten mit Gefäßereignissen in der rechten oder linken Gehirnhälfte zu untersuchen und herauszufinden, welche davon einen größeren Einfluss auf die Verarbeitung zusätzlicher sprachlicher Informationen haben.

Forschungsdatei: Forschungsstichprobe bestand aus 44 Patienten nach Schlaganfall, 15 mit einem Schlaganfall in der linken Gehirnhälfte und 29 mit einem Schlaganfall in der rechten Gehirnhälfte. Für diese klinischen Gruppen wurden Kontrollgruppen aus gesunden Teilnehmern mit gleicher Bildung, gleichem Geschlecht und ungefähr gleichem Alter erstellt.

Methode: In der Forschung wurde ein Aufgabenkomplex zur Diagnose von sechs Bereichen erstellt: Pragmatik, Makrostruktur und Schlussfolgerungen, Bildsprache, semantisches System, Paralinguistik und räumliche Wahrnehmung. Die gewonnenen Daten wurden mit den Methoden der deskriptiven und inferenziellen Statistik statistisch aufbereitet.

Ergebnisse: Die statistische Verarbeitung bestätigte in fast allen überwachten Bereichen signifikante Unterschiede zwischen der klinischen und der jeweiligen Kontrollgruppe. Ein signifikanter Unterschied zwischen den klinischen Gruppen zeigte sich lediglich in der Pragmatik und der räumlichen Wahrnehmung.

Schlussfolgerung: Die Ergebnisse deuten darauf hin, dass beide Großhirnhemisphären an der Wahrnehmung und Verarbeitung sprachlicher Kontexte beteiligt sind und bei einer Schädigung einer dieser Hemisphären Proble-

me bei deren Interpretation vorliegen. Diese Defizite können erhebliche Auswirkungen auf die Kommunikation und das tägliche Leben des Patienten haben.

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