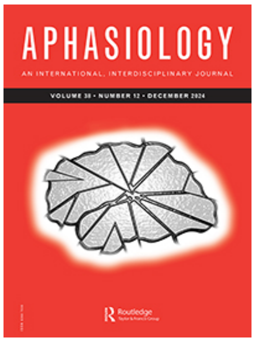

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ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/paph20

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To cite this article: Merve Savaş, Miraç Gönüldaş, Senanur Kahraman Beğen & İlayda Çelik Başoğlu (26 Sep 2024): The effect of cerebellar lesıons on language in Turkısh speakıng indıvıduals, Aphasiology, DOI: 10.1080/02687038.2024.2406578

To link to this article: https://doi.org/10.1080/02687038.2024.2406578

Published online: 26 Sep 2024.

APHASIOLOGY
https://doi.org/10.1080/02687038.2024.2406578

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The effect of cerebellar lesıons on language in Turkısh speakıng indıvıduals

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ABSTRACT

Background: The cerebellum is approximately 10% of the brain volume and is responsible for attention, language, emotion and cognitive functions. Linguistic processing difficulties and cognitive impairments may be observed in individuals with cerebellar lesions depending on the location and severity of the damage. There is no study evaluating language in Turkish-speaking individuals with cerebellar lesions.

Objective: To determine the differences in linguistic and visuospatial skills of Turkish speaking individuals with cerebellar lesions compared to control groups, including a right hemisphere lesion group and a healthy control group.

Method: Fifteen patients with cerebellar lesion (without hemispatial neglect and dysarthria), 15 patients with right hemisphere lesion due to right arter cerebri media (without hemispatial neglect) and 15 healthy control were included. To clarify the language impairment specific to cerebellar lesions, we also included individuals with right hemisphere lesions, which are typically assumed not to present with aphasia. The Language Assessment Test for Aphasia (ADD), Benton Judgment of Line Orientation Test, Benton Facial Recognition Test, Single Letter Deletion Test were used. The "Accident Scene" picture was used for collecting narrative speech samples. After a three group comparison a post-hoc pairwise analysis was performed.

Results: Among the microstructural parameters in the narrative language analysis, the effort ratio was significantly higher in the cerebellar lesion group compared to the healthy control group. Among the non-verbal cognitive tests, the Benton Facial Recognition Test score was significantly lower in the cerebellar and right hemisphere lesion group compared to the healthy control group. Total score, naming and grammar scores in the ADD test were significantly lower in the cerebellar lesion group compared with the healthy control group. There was no difference between cerebellar and right hemisphere lesions in terms of ADD score, ADD subtests and narrative parameters.

ARTICLE HISTORY
Received 1 August 2023
Accepted 9 September 2024

KEYWORDS
Cerebellar lesion; visuospatial dysfunction; language impairment; cerebellum

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Conclusion: In Turkish-speaking individuals with cerebellar lesions, verbal productivity may be interrupted by effort behaviours, and standard aphasia assessment tests may reveal impaired grammar and naming performance without a diagnosis of aphasia. In addition to reduced efficiency in verbal production, facial recognition may be impaired. We found no difference between individuals with lesions in the cerebellum and right hemisphere. This suggests that ischemic damage may affect different components of language independently of the diagnosis of aphasia.

Introduction

The classical "Wernicke-Lichtheim-Geschwind" model, which has been used for many years to explain the neurobiology of language, has become outdated because it does not take into account subcortical structures and the large axonal pathways that connect them to cortical areas (Tremblay & Dick, 2016). With the contribution of contemporary neuroscience research, it is now accepted that linguistic processing is the product of a neurocognitive network represented in both cerebral hemispheres, including some thalamic nuclei, basal ganglia, various brainstem structures and the cerebellum, in addition to language-related core areas such as Broca's and Wernicke's areas (Teichmann et al., 2015).

The cerebellum is a central nervous system structure located in the posterior cranial fossa and is approximately 10% of the brain volume (Roostaei et al., 2014). It is understood that its functions are important for interpersonal interactions, social relations and behavior (Heyder et al., 2004; Lacy et al., 2016), sequential and coordinated movements (Manto et al., 2012) and visual functions (Drepper et al., 1999) as cerebrovascular lesions, trauma and tumors in the cerebellum have shown. Clinical observations revealed that cerebellar damage may play a role in pathologies such as dyslexia, schizophrenia, depression and autism (D'Angelo, 2010). Studies on patients with cerebellar lesions have reported language, speech and movement disorders. In addition, cerebellar lesions have been found to cause neuropsychiatric involvement by negatively affecting cognitive and affective functions (Schmahmann & Sherman, 1998). The critical importance of the cerebellum in linguistic functions has gained attention following the identification of bilateral cerebellocortical fibers connecting the cerebellum and Broca's area (Leiner et al., 1991; Starowicz-Filip et al., 2017). The literature suggests that the cerebellum is involved in linguistic processing. Accordingly, it is known that cerebellar lesions can cause language disorders (Mariën & Borgatti, 2018).

Ataxic dysarthria seen in patients with cerebellar lesions reveals its role in the motor control of speech, while symptoms such as anomia, agrammatism, agraphia, dyslexia and dysprosody reveal its critical importance in linguistic processing (see review of Silveri, 2021). Cerebellar lesions may impair language functions such as verb production, lexical stem completion and verbal fluency. Phonemic and semantic fluency, which are considered as a component of verbal fluency, are negatively affected by cerebellar lesions (de Smet et al., 2013).

Studies examining the cerebellar correlates of various linguistic tasks in healthy individuals have shown that phonetic and semantic fluency activates the right part of the cerebellum; bilateral lobule VI and crus I are involved in phonological processing; and there is specialization in lobes VI, V and crus I of the left cerebellar hemisphere with respect tosemantic processing (Sarica et al., 2015). It is also observed that the right part of the cerebellum is activated during phonological encoding and reading tasks (see review of Turker et al., 2023). Similarly, a systematic review of individual case studies of language disorders caused by cerebellar lesions suggested that rather than a cerebellar-specific pattern of language involvement, the cerebellum makes a modulatory contribution to language processing through its reciprocal connections with supratentorial structures of the central nervous system (Vlasova et al., 2023).

Studies in patients with cerebellar lesions and healthy individuals with foci on phonology, semantics, syntax and prosodic dimensions of language as well as studies examining the pragmatic component of language are limited. The pragmatic component of language refers to all of the linguistic skills necessary for maintaining social communicative continuity and providing relevant verbal/non-verbal aspects of meaning in interpersonal interactions. Pragmatics also forms the basis for other language components (see review of Martin & McDonald, 2003). The multilayered nature of language makes it difficult to assess pragmatic skills and many pragmatic disorders that are not reflected in standard language assessment tools can easily be overlooked (Botting, 2002; Mackenzie et al., 2007). Therefore, analyzing narrative samples in addition to classical aphasia testing in acquired brain injuries allows for a comprehensive examination of all dimensions of language (Marini et al., 2011). In a study examining the effect of focal brain damage on narrative performance (Karaduman et al., 2017), it was found that left hemisphere lesions can disrupt theme integrity and reduce the number of evaluative explanations by causing microlinguistic impairments, while lesions in the dorsolateral prefrontal cortex, the anterior and superior temporal gyrus, the middle temporal gyrus, and the supramarginal gyrus in the right hemisphere make it difficult to create story main elements. Although there are no direct studies indicating pragmatic-linguistic impairments detected by narrative analysis in patients with cerebellar lesions, executive function problems observed in Cerebellar Cognitive Affective Syndrome, as described by Schmahmann and Sherman (Schmahmann & Sherman, 1998), along with impairments such as mild anomia, dysprosody, and decreased verbal fluency, may be interpreted as indicative of problems in the linguistic pragmatic component. Corticopontocerebellar fibers projecting from the cerebral cortex and paralimbic areas to the pons and connectivity between the reticular formation and the cerebellum reveal the role of the cerebellum in limbic functions such as affect, behavior, motivation, and other higher cortical functions (Gordon, 1996). Reports of disinhibition, impulsivity, blunt affect, pathological laughing-crying, and infantile behaviors further support this interpretation. These symptoms, which are classified as hypermetric or hypometric responses to external and internal stimuli, are conceptualized as intellectual dysmetria as an analogue of dysmetria, a cerebellar motor finding (Schmahmann et al., 2007).

Pragmatics is by definition a very broad domain. In order to describe pragmatic disorders in clinical groups, spontaneous, unstructured conversations of healthy and language-impaired individuals of different ages were analysed and evaluated in terms of pragmatic components from a taxonomic perspective. This taxonomy includes verbal (choice of topic, maintenance, turn taking and correction of pauses, etc.), non-verbal (physical proximity, physical contact, gestures and facial expressions, eye contact, etc.)

and paralinguistic (intelligibility, prosody, fluency, etc.) categories. It was found that the pragmatic profiles of the clinical and healthy groups differed and that certain patterns existed between the clinical groups (Prutting & Kittchner, 1987).

The study of communicative ability in acquired language disorders is challenging due to confounding factors such as the linguistic and cognitive abilities of the communication partners, their shared knowledge and experience of the outside world, and their individual interests. Due to the complex nature of human interaction, assessment of communicative ability in clinical settings is limited to tasks such as the ability to produce stereotyped discourse appropriate to social situations in standard aphasia tests. Discourse level assessmentis limited to tasks such as describing a picture or telling a story to assess pragmatic skills such as maintaining topic, coherence and consistency (Doedens & Meteyard, 2020). In individuals with aphasia, the description of a single picture and conversational speech show different linguistic patterns (Leaman & Edmonds, 2023).

Single picture description is less complex than semi-structured or unstructured conversational contexts in that it includes visual stimuli and context, but lacks conversation and multimodality (Carragher et al., 2024). However, it can be seen as an effective tool to reduce the effect of confusing factors that may arise in the context of conversation. The Accident Composition picture is designed to be suitable for naming, interpreting or creating a conversation and story around the picture. In a cross-sectional scene depicting a serious traffic accident, there are figures such as the injured, who may be seriously injured or deceased, the ambulance, health workers, traffic police and people who may have witnessed the accident or were present at the scene in some way (Toğram & Maviş, 2012). When these factors are considered together, the emotional valence of the event depicted in the accident scene is likely to be high. When describing the accident picture, establishing logical relationships between the figures and events in the picture and producing inferential expressions that are appropriate, reasonable, acceptable and related to each other may be useful in assessing the components of consistency and preservation of contextual structure, which are considered to be components of pragmatics.

Since expositional narrative contexts, obtained with single pictures or sequential pictures, require the processing of visual stimuli, narrative performance and the state of visuospatial functions in brain-damaged individuals should be taken into account (Bryant et al., 2016). Accordingly, attention, visuospatial and executive functions cannot be attributed to specific brain regions and that Lobule VI of the cerebellum is involved in executive and visuospatial functions in addition to language-related functions. Sinceocular movements and saccades, which may be impaired at various levels in cerebellar lesions, may limit contact with visual material, the present study used various neuropsychological tools to assess visuospatial functions in addition to narrative analysis (Bodranghien et al., 2016; Guell et al., 2018). In this way, we tried to understand possible visual spatial dysfunctions and their effects on language production in patients with cerebellar lesions.

The objective of this study was to investigate whether ischemic cerebellar lesions affect different components of language at the discourse level, in addition to results obtained from standard aphasia tests. Given the close relationship between the cerebellum and visuospatial and executive functions, visual perception tests were also performed in patients in whom hemispatial neglect was ruled out. This approach allowed us to examine the potential impact of cerebellar lesions on language and visuospatial abilities.

Method

The study, which was designed on a cross-sectional model to determine the effect of cerebellar lesions on language in Turkish-speaking individuals, included 45 participants. Fifteen individuals with cerebellar lesions (CL), 15 individuals with right hemisphere lesions (RHL) and 15 individuals as a healthy control group (HC) were included. Ethical approval for conducting the study and informed participant consent were obtained.

Participants

In our study, there are two control groups consisting of age- and gender-matched healthy controls and individuals with infarction of the superior division of the right middle cerebral artery. Patients with right hemisphere lesions were included as a control group for two reasons. First, pragmatic disorders are commonly observed in these patients. Right hemisphere lesions are associated with pragmatic disorders such as tangential and shallow speech, a tendency to concretize, discourse that may be considered socially inappropriate, difficulty in understanding metaphors and irony, and difficulty in making inferences and understanding the main idea (Martin & McDonald, 2003). The second reason is that visuospatial dysfunctions may occur in right hemisphere and cerebellar lesions. The ventral attention network, which is involved in the spatial orientation of attention, is dominant in the right hemisphere (Bernard et al., 2020). The cerebellum belongs to the vertebrobasilar arterial system in cerebral circulation. Since the occipital cortices, located in the irrigation area of the vertebrobasilar system, contain the primary and secondary visual association areas, lesions in this system typically lead to visuospatial disorders (Koçer, 2015). Therefore, comprehensive visuospatial function tests [Benton Judgment of Line Orientation Test (Benton et al., 1978), Benton Facial Recognition Test (Benton et al., 1983), Single Letter Cancellation Test (Diller et al., 1974)] were administered to patients with cerebellar and right hemisphere lesions and without hemispatial neglect.

Inclusion criteria for individuals with cerebellar and right hemisphere lesions were: Having a cerebellar or right hemisphere lesion on magnetic resonance imaging (MRI), not being diagnosed with dysarthria according to the oral-motor assessment test, not having major neurological diseases (e.g., Alzheimer's disease, Parkinson's disease or epilepsy), not having major psychiatric diseases, to be free of hemispatial neglect (assessed with the Line Division Test and Incomplete Circles Test) and to be able to establish a minimum level of communicative co-operation with the researcher during the tests and interviews. Previously obtained MRI were used to determine lesion location.

Table 1 shows the lesion location, stroke onset time in participants with cerebellar lesions and right hemisphere lesions. The inclusion criteria for the control group right hemisphere damage individuals were as follows: Montreal Cognitive Assessment Scale (MoCA-TR) score of at least 21 (Selekler et al., 2010), not having major neurological diseases (e.g., Alzheimer's disease, Parkinson's disease, epilepsy, etc.), not having major psychiatric diseases. During the study, language and neuropsychological tests were administered to the participants. The language assessment test for aphasia (ADD) was

Table 1. Lesion locations of participants with CL and RHL.

	CEREBELLAR GROUP		RIGHT HEMISPHERE GROUP	
	Lesion Localization	Onset Time (months)	Lesion Localization	Onset Time (months)
1	Left posterior inferior cerebellar infarction	36	Right frontal, right parietal partial vascular lesion	18
2	Right posterior cerebellar hemorrhage	12	Right frontal, right cortical and centrum semiovale vascular lesion	24
3	Right posterior inferior cerebellar infarction	8	Right insula, right frontal operculum, right anterior frontal vascular lesion	6
4	Large right inferior cerebellum, left cerebellar punctate infarct	3	Vascular lesion in the right putamen and right corona radiata	48
5	Bilateral superior cerebellar infarction	12	Vascular lesion in the right posterior temporal parietal, insula and corona radiata	12
6	Anterior medullary- medulla cervical junction	60	Right pericallosal and centrum semiovale vascular lesion	8
7	Right posterior inferior cerebellar infarction	24	Right temporaparietal vascular lesion	12
8	Left cerebellar hematoma	12	Vascular lesion in the right insula, capsula externa, right corona radiata	11
9	Right posterior inferior cerebellar infarction	1	Right frontal, parietal and right middle cerebral artery deep vascular lesion	36
10	Left posterior inferior cerebellar infarction	18	Right frontal, parietal and right middle cerebral artery deep vascular lesion	15
11	Left lateral cerebellar infarction	24	Right frontaparietal vascular lesion	12
12	Left cerebellar infarction and left thalamic infarction	36	Right occipital and right lateral temporal vascular lesion	7
13	Large right cerebellar, left cerebellar and both occipital partial infarcts	1	Vascular lesion in the right putamen and right corona radiata	24
14	Left posterior inferior cerebellar infarction	6	Vascular lesion in the right insula, perisylvian, caudate nucleus and corona radiata	12
15	Right posterior inferior cerebellar infarct (small and fragmented)	1	Right frontal, right parietal partial vascular lesion	39

administered to assess language (Toğram & Maviş, 2012). In the narration section of the ADD, "Accident Scene" picture was used and the participants' spoken were recorded. Narrative samples were analyzed with SALT-TR (Acarlar et al., 2006). Benton Line Orientation Test, Benton Face Recognition Test and Single Letter Cansellation Test were applied for visuospatial function assesment.

Data collection tools

The language assessment test for aphasia (ADD)

The main purpose of ADD is to measure and evaluate Turkish language performance of individuals with left brain damage. The test was developed to (a) determine performances in all language domains, (b) diagnose aphasia, and (c) help select appropriate therapy targets (Toğram & Maviş, 2012). The test consists of 8 sub-sections that contribute to a total score; speech fluency, auditory comprehension, repetition, naming, reading, grammar, speech acts and writing.

The subtests are briefly introduced: speech fluency (maximum score, 32); spontaneous assessment of language, speech and cognition ("How many children do you have?" "Where are you from?", etc.) and automatic speech ("Count from 1 to 10", "Count the days of the week", etc.). Auditory comprehension (maximum score, 66); comprehension of commands ("Show me the window"., "Close your eyes, open your mouth"., etc.), comprehension of yes-no questions ("Is boiling water hot?", "Do dogs meow?", etc.), comprehension of objects ("We lock the door to the house with it [key]". "We wear [glasses] to see better", etc.), comprehension at the category level [comprehension of categories [[fruits, letters, sitting, etc.]], [comprehension of detail within a category [[red apple, "The girl is sitting", etc.]] sentence variety comprehension ("The careless drivers of two cars collided"., "Someone broke the third wooden chair". "The child was naughty and broke his mother's most precious vase"., etc.). Repetition (maximum score, 20) has a hierarchy from phoneme level to sentence repetition and the patient is asked to repeat what they hear. Naming (maximum score, 44); categorical ("Name the household items you can think of".) by looking at the picture, responding ("Where do you wear socks?", "What do you do with a knife?", etc.). Reading (maximum score, 50); reading and command execution, letter-number reading, word reading, word-picture matching, paragraph reading. Grammar (maximum score, 20); completing the sentence heard ("Babies ………… [do not smoke]"., "My mother's husband is my ……… [father]"., etc.). Speech acts (maximum score, 20); forming an appropriate response to the heard sentence ("The doorbell rings, what do you ask before answering?", "What do you say if someone sneezes?", "You want to buy a pair of shoes. There is no price tag; What do you ask the seller?", etc.). Writing (maximum score, 40); spontaneous writing, letter/number writing by dictation, word writing by dictation, looking writing.

In scoring the ADD, a correct response is scored as 2 points, an incomplete response is scored as 1 point and an incorrect or no response is scored as 0 points. In the ADD, two types of scores are calculated: test score and language score. In the evaluation of this calculation, the highest total score is 292. Individuals with the highest score in the test results are classified as individuals who use language and speaking skills effectively (Maviş & Toğram, 2009). The result of the test varies according to the age and education level of the participant; between the ages of 23–59, individuals with 1–5 years of education and scored lower than 152, between the ages of 23–59, individuals with 6 years of education or more and scored lower than 155, between the ages of 60–74, individuals who are illiterate and scored lower than 127, between the ages of 60–74, individuals with 1–5 years of education and scored lower than 145, Individuals aged 60–74 years, with 6 years or more of education and a score lower than 152, individuals aged 75 years or older, illiterate and a score lower than 63, individuals aged 75 years or older, with 1–5 years of education and a score lower than 118 are diagnosed with "aphasia due to left brain lesion"(Toğram & Maviş, 2012).

Narrative analysis of the "accident scene"

Participants' narratives were elicited using the "Accident Scene" picture (part of the ADD). During the narrative, participants were encouraged to provide further elaboration. The narratives were analyzed with the Systematic Analysis of Language Transcripts-Turkish (SALT-TR Research V9) program. SALT-TR Research V9 is a program that includes micro-structural codes (Acarlar et al., 2006). Effort utterances were coded by the researchers on the transcripts and the number of uses was calculated utilizing SALT-TR. Effort (Maze), gap fillers during the narration such as, well, um, etc. use of words, false starts, repetitions and rearrangement behaviour as endeavouring. Examples obtained from the participants: Gap

Filling Words: (i.e., eee) an accident in traffic. False Starts: (Li*) an accident at the lights. Repetitions: this car (this car) was also smashed. Rearrangements: there are lights (lamp la*) lamps.

The manual scoring was conducted by three different scorers, and the parameters with 100% agreement were included in the study. Subsequently, the transcripts were uploaded to the SALT-TR, where the measurement was performed.

Microstructural parameters

Microstructural parameters consisted of: total number of utterances, mean legnth of utterance (MLU), type-token ratio (TTR), number of subordination clauses with inflected verbs (SUB), number of subordinations [S], the number of simple sentences, number of complex sentences, ratio of total subordinations to complex sentences (clausal density), ratio of complex sentences to total sentences, pause duration (in two different forms as between and within sentences), number of omissions and number of errors.

We also examined frequency of effort behaviors (i.e., number of reorganization, repetition and gap-fillers). Effort behaviors are enclosed in parentheses. The subheadings we examined consist of three parts. "Gap Filling: It is a discourse that is not connected to the context, is not meaningful and does not have the quality of a word." Example:-(uhh) there are two cars. -(well) there was an accident. The ambulance is coming (you know). Reorganization: It is the expression of a word or phrase in a different way by moving it to the beginning or rearranging it in the middle. A '*' sign is placed at the end of words that are obviously going to continue." Example:-(car) the ambulance has arrived. -The patient(s) were taken away (tak*). Repetition: Repetition of the whole or part of a word or phrase. Example:-(ca*) the car(s) were damaged. -(doctor) The doctor is treating the patient(s). Evidence of word finding difficulties were also coded. For example; *"What was the name of that thing (stretcher)? He is carrying the patient on it*."

Macrostructural parameters

Inferences are judgments that are not directly included in the picture of the scene but can be determined through reasoning (Karaduman et al., 2017). Statements containing inferences were coded as (Inference). For example: *"The police are trying to calm the people around"*. Filler phrases are compensatory and are not directly related to the content of the narrative but serve to maintain the continuity of communication (Karaduman et al., 2017). Filler phrases indicate an attempt to maintain communicative reciprocity and that a thought is about to be uttered. It corresponds to roles such as formulating thoughts, giving the listener a waiting period as a matter of courtesy, avoiding the necessity to turn unsure thoughts into statements, softening the statement to fit the context, approving or minimizing statements. The use of filler expressions, which is seen in all languages, has a universal feature as it ensures the continuity of the conversation (Schegloff, 2000). For example; *"That's all I have to say, I can't think of anything else"*.

Benton judgment of line orientation test (JLO)

The JLO is frequently used in individuals with various brain injuries because it can measure visuospatial skills and spatial thinking, since language-related abilities are not required (Benton et al., 1978). Because it measures a relatively basic level of visuospatial ability, the JLO can be useful when interpreting a patient's performance on more complex tasks of visual reasoning and visuoconstruction. Limitations exist in the evidence supporting the notion that the JLO performance in patients with cerebellar lesions is not impaired (Molinari et al., 2004). However, in healthy subjects, cerebellar regions, hemispheres Lobules IV, VI and Crus I were activated while performing the experimental task of line orientation (Lee et al., 2005). Two partial line segments are presented together on a page and the participant is asked to match their orientation to those on a multiple-choice response card. The response options consist of 11 complete lines, all 18 degrees apart, arranged in a semicircle. The participant is presented with five sample items where erroneous responses are corrected and then 30 test items are presented without feedback. The test items consist of a bundle of lines 3.8 cm long, numbered from 1 to 11 and drawn based on the center. Each item asks to find the number to which two lines of the same length correspond. There are 30 items in total and below 14 points are considered pathological (Karakaş, 2006).

Benton facial recognition test

This test consists of photographs of faces. Individuals are asked to recognize and match the faces (Benton et al., 1983). Face recognition tests assess an individual's ability to recognize faces and understand emotional expressions. Lesion to the cerebellum can lead to difficulties with such tests (Erdal et al., 2021).

Single letter cancellation test

The Single Letter Cancellation Task is a paper-and-pencil test used to assess whether a visual scanning deficit is present and if so, the severity of it (Diller et al., 1974). In this test, target stimuli must be scanned, recognized and cued, thereby integrating visual perception with motor action (Uttl & Pilkenton-Taylor, 2001).

The basic task consists of six lines of 52 letters with the target letter randomly interspersed 18 times in each line. 104 targets (letter H) and 208 other letters are arranged in six horizontal lines. Within the scope of this test; A4 format test papers with 52 capital letters are presented to the participants by asking them to mark the specified shapes or draw the specified letters. The highest score is 53 on the left and 51 on the right. H's omitted without a cross are summed and subtracted from the left and right sums. If 70% of the responses are on the same side as the hemiplegic limb or collected on one side of the midline, this is considered in favor of visual semifield neglect (Karatas, 2002). In healthy individuals, cerebellar activation was observed along with various cortical areas during the performance of Single Letter Cancellation Tests (Deng et al., 2019).

Statistical analysis

SPSS (version 25) package program was used for data analysis. Number, percentage, minimum and maximum values, mean, standard deviation values were used to analyze descriptive data. Normality distribution analysis of the data groups was performed with the Shapiro-Wilk Test ($p > 0.05$). The accuracy of the test was checked by looking at the kurtosis and skewness values. Since most of the data did not show normal distribution,

Table 2. Demographics of the groups.

Group		CL		RHL		HC		Difference	
		N	%	N	%	N	%	χ^2	p
Sex	Female	5	33.3	5	33.3	5	33.3	0.000	1.000
	Male	10	66.7	10	66.7	10	66.7		
Education	Primary School	11	73.3	11	73.3	11	73.3	0.000	1.000
	High School	3	20	3	20	3	20		
	University	1	6.7	1	6.7	1	6.7		
Age		X	SD	X	SD	X	SD	U	P
		58.93	16.355	57.62	15.678	57.87	16.115	106	0.787

CL: Cerebellar lesion, RHL: Right Hemisphere Lesion, HC: Healthy Control.

non-parametric tests were utilized. The Kruskal Wallis-H test was used for the comparison of three groups and the Mann-Whitney U test was used for the comparisonof two groups and also for the post-hoc test. In the analyses, $p < 0.05$ was considered as significance value and bonferroni correction was applied.

Results

In Table 2, demographic information about the participant groups is shown.

There was no significant difference between the groups according to gender ($\chi^2 = 0.000$, $p > 0.05$), educational status ($\chi^2 = 0.000$, $p > 0.05$) and ages (Kruskal Wallis-H Test, $p > 0.05$). Comparison findings of narrative analysis scores between the three groups are presented in Table 3.

Comparison findings of nonverbal cognitive test scores between the three groups are presented in Table 4.

Comparison findings of ADD total and subtest scores between the three groups are presented in Table 5.

A significant difference was found for effort ratio, error morpheme, inference, Benton Facial Recognition, Benton Judgment of Line Orientation, total score of ADD, speech fluency, naming, reading, grammar and writing variables in the comparison between groups. Post-hoc test findings, i.e., pairwise group comparisons, are given in Table 6.

Among the microstructural parameters of the narrative language analysis, effort ratio was significantly higher in the cerebellum lesion group compared to the healthy control group. Among the nonverbal cognitive tests, the Benton Facial Recognition Test score was significantly lower in the cerebellum lesion group compared to the healthy control group. Total score, naming and grammar scores in the ADD test were significantly lower in the cerebellum lesion group compared to the healthy control group.

Discussion

In the present study, although aphasia was not detected in individuals with cerebellar damage according to a standard language assessment tool (ADD), it was observed that participants achieved lower performance in total ADD score; naming and grammer subtests of the tool compared to the healthy control group. When compared with patients with right hemisphere lesions, no significant difference was observed.

Table 3. Comparison of narrative analysis scores (CL/RHL/HC).

		Group	N	Min	Max	Mean	SD	p
Micro Analysis	Number of total utterances	CL[1]	15	6	31	16.93	7.68	0.045
		RHL[2]	15	7	26	13.93	5.75	
		HC[3]	15	6	25	10.87	5.6	
	MLU	CL[1]	15	3.38	6.77	4.96	1.02	0.054
		RHL[2]	15	2.98	9.98	6.08	1.87	
		HC[3]	15	2.67	14.67	7.66	3.83	
	TTR	CL[1]	15	0.58	1	0.75	0.12	0.059
		RHL[2]	15	0.54	0.94	0.7	0.14	
		HC[3]	15	0,54	0.94	0.78	0.1	
	SUB	CL[1]	15	0	5	0.47	1.3	0.120
		RHL[2]	15	0	3	0.40	0.828	
		HC[3]	15	0	0	0	0	
	S	CL[1]	15	0	8	1.8	2.04	0.614
		RHL[2]	15	0	7	2.07	2.463	
		HC[3]	15	0	5	2.33	1.84	
	Simple Sentences	CL[1]	15	3	18	9.47	4.34	0.032
		RHL[2]	15	2	13	7.40	3.019	
		HC[3]	15	2	16	5.93	3.56	
	Complex sentences	CL[1]	15	0	6	1.73	1.62	0.734
		RHL[2]	15	0	5	1.73	2.086	
		HC[3]	15	0	5	1.93	1.58	
	Total sentences	CL[1]	15	4	24	11.2	5.41	0.138
		RHL[2]	15	2	20	9.33	4.639	
		HC[3]	15	0	4	1.06	0,93	
	Clausal density	CL[1]	15	0	1.33	0.79	0.44	0.376
		RHL[2]	15	0	3	0.72	0.85	
		HC[3]	15	0	4	1.06	0,93	

(Continued)

Table 3. (Continued).

		Group	N	Min	Max	Mean	SD	p
	Complex sentences/total sentences	CL[1]	15	0	0.44	0.16	0.12	0.195
		RHL[2]	15	0	0.5	0.15	0.18	
		HC[3]	15	0	0.66	0.26	0.21	
Effort (Reorganization)	Partial	CL[1]	15	0	1	0.13	0.35	0.842
		RHL[2]	15	0	5	0.47	1.302	
		HC[3]	15	0	1	0.2	0.41	
	Word	CL[1]	15	0	10	2.6	2.44	0.007
		RHL[2]	15	0	5	2.00	1.852	
		HC[3]	15	0	5	0.67	1.35	
	Phrase	CL[1]	15	0	7	2.27	2.05	0.013
		RHL[2]	15	0	5	1.47	1.552	
		HC[3]	15	0	3	0.6	1.06	
Effort (Repetition)	Partial	CL[1]	15	0	4	0.8	1.15	0.022
		RHL[2]	15	0	3	0.20	0.775	
		HC[3]	15	0	1	0.13	0.35	
	Word	CL[1]	15	0	2	0.27	0.59	0.186
		RHL[2]	15	0	2	0.26	0.57	
		HC[3]	15	0	0	0	0	
	Phrase	CL[1]	15	0	0	0	0	0.368
		RHL[2]	15	0	1	0.07	0.258	
		HC[3]	15	0	0	0	0	
Effort (Gap filler)	Single Word	CL[1]	15	1	6	2.53	1.3	0.372
		RHL[2]	15	0	6	1.80	1.781	
		HC[3]	15	0	6	2.13	2.1	
	More than one Word	CL[1]	15	0	0	0	0	1.000
		RHL[2]	15	0	0	0	0	
		HC[3]	15	0	0	0	0	

(*Continued*)

Table 3. (Continued).

			Group	N	Min	Max	Mean	SD	p
	Total Effort	Effort ratio	CL[1]	15	11.4	42.9	27.92	9.94	**0.000***
			RHL[2]	15	1	31	12.43	9	
			HC[3]	15	0	23.4	8.97	8.43	
	Pause	Within-utterance	CL[1]	15	0	7	1.4	1.96	0.497
			RHL[2]	15	0	7	1.13	2.416	
			HC[3]	15	0	18	1.73	4.64	
		Between-utterance	CL[1]	15	0	40	14.13	12.17	0.032
			RHL[2]	15	0	30	6.93	9.706	
			HC[3]	15	0	27	6	8.38	
	Omission	Morpheme	CL[1]	15	0	0	0	0	0.351
			RHL[2]	15	0	1	0.07	0.258	
			HC[3]	15	0	0	0	0	
		Word	CL[1]	15	0	2	0.27	0.7	0.335
			RHL[2]	15	0	1	0.07	0.25	
			HC[3]	15	0	0	0	0	
	Error	Morpheme	CL[1]	15	0	0	0	0	**0.001***
			RHL[2]	15	0	2	0.47	0.640	
			HC[3]	15	0	0	0	0	
		Word	CL[1]	15	0	4	0.8	1.08	0.001
			RHL[2]	15	0	7	1.60	1.639	
			HC[3]	15	0	1	0.27	0.46	
	Anomia		CL[1]	15	0	7	2.93	2.58	0.006
			RHL[2]	15	0	8	2.40	2.694	
			HC[3]	15	0	3	0.53	0.92	
Macro Analysis		Inferention	CL[1]	15	1	16	4.53	4.32	**0.000***
			RHL[2]	15	0	9	4.20	2.484	
			HC[3]	15	0	9	4.47	2.53	
		Filler phrases	CL[1]	15	0	7	2.4	2.1	0.007
			RHL[2]	15	0	8	1.93	2.017	
			HC[3]	15	0	2	0.53	0.64	

CL: Cerebellar lesion, RHL: Right Hemisphere Lesion, HC: Healthy Control. SUB: subordination clauses with inflected verbs. S: subordination. The results were determined to be significant if the p-value < 0.05/41, i.e., 0.0012, according to Bonferroni correction.*$p < 0.0012$.

Table 4. Comparison of nonverbal cognitive tests (CL/RHL/HC).

	Group	N	Min	Max	Mean	SD	p
Single Letter Cancellation (Right)	CL[1]	15	5	51	42.07	15.22	0.133
	RHL[2]	15	10	53	44.27	13.81	
	HC[3]	15	50	51	50.8	0.41	
Single Letter Cancellation (Left)	CL[1]	15	13	53	42.2	15.85	0.034
	RHL[2]	15	12	54	45.13	13.6	
	HC[3]	15	47	53	52.6	1.54	
Benton Facial Recognition	CL[1]	15	26	38	33.46	3.42	**0.000***
	RHL[2]	15	32	52	33.07	3.31	
	HC[3]	15	32	52	42.53	4.58	
Benton Judgment of Line Orientation	CL[1]	15	4	27	12.47	6.68	**0.000***
	RHL[2]	15	16	24	12.47	6.63	
	HC[3]	15	16	24	20.8	2.48	

CL: Cerebellar lesion, RHL: Right Hemisphere Lesion, HC: Healthy Control. The results were determined to be significant if the p-value < 0.05/41, i.e., 0.0012, according to Bonferroni correction.*$p < 0.0012$.

Table 5. Comparison of ADD total score and subtests scores (CL/RHL/HC).

	Group	N	Min	Max	Mean	SD	p
Total Score	CL[1]	15	181	292	258.67	31.55	**0.000***
	RHL[2]	15	152	287	252,46	41,66	
	HC[3]	15	277	292	287.87	4.941	
Speech Fluency	CL[1]	15	25	32	29.73	2.314	**0.000***
	RHL[2]	15	23	31	27.8	2.756	
	HC[3]	15	30	32	31.60	0.737	
Auditory Comprehension	CL[1]	15	41	66	59.33	7.316	0.020
	RHL[2]	15	34	66	59	9.227	
	HC[3]	15	60	66	64.27	2.251	
Repetition	CL[1]	15	17	20	19.20	1.146	0.001
	RHL[2]	15	16	20	18.6	1.183	
	HC[3]	15	19	20	19.93	0.258	
Naming	CL[1]	15	29	44	40.07	4.2	**0.001***
	RHL[2]	15	38	44	42.9	1.884	
	HC[3]	15	41	44	43.67	0.9	
Reading	CL[1]	15	29	50	41.87	7.14	**0.000***
	RHL[2]	15	0	48	37.26	16.3	
	HC[3]	15	42	50	48.87	2.475	
Grammar	CL[1]	15	8	20	16.33	3.677	**0.000***
	RHL[2]	15	14	20	17.53	1.767	
	HC[3]	15	19	20	19.8	0.414	
Speech Acts	CL[1]	15	16	20	19.07	1.387	0.054
	RHL[2]	15	15	20	19.06	1.39	
	HC[3]	15	18	20	19.87	0.516	
Writing	CL[1]	15	5	40	33.06	11.12	**0.000***
	RHL[2]	15	0	40	30	12.37	
	HC[3]	15	30	40	39.33	2.582	

CL: Cerebellar lesion, RHL: Right Hemisphere Lesion, HC: Healthy Control. The results were determined to be significant if the p-value < 0.05/41, i.e., 0.0012, according to Bonferroni correction.*$p < 0.0012$.

Table 6. Post-hoc pairwise comparisons.

Parameters	Groups	Adj. Sig.	Significant Difference
Effort Ratio	CL-RHL	0.003	No
	RHL-HC	1.000	No
	CL-HC	0.000	Yes
Error Morpheme	CL-RHL	0.004	No
	RHL-HC	0.004	No
	CL-HC	1.000	No
Inferention	CL-RHL	0.007	No
	RHL-HC	0.000	Yes
	CL-HC	0.378	No
Benton Facial Recognition	CL-RHL	1.000	No
	RHL-HC	0.000	Yes
	CL-HC	0.000	Yes
Benton Judgment of Line Orientation	CL-RHL	1.000	No
	RHL-HC	0.002	No
	CL-HC	0.001	No
ADD Total Score	CL-RHL	1.000	No
	RHL-HC	0.000	Yes
	CL-HC	0.000	Yes
Speech Fluency	CL-RHL	0.143	No
	RHL-HC	0.000	Yes
	CL-HC	0.040	No
Naming	CL-RHL	0.037	No
	RHL-HC	0.833	No
	CL-HC	0.001	Yes
Reading	CL-RHL	1.000	No
	RHL-HC	0.000	Yes
	CL-HC	0.002	No
Grammar	CL-RHL	1.000	No
	RHL-HC	0.001	No
	CL-HC	0.000	Yes
Writing	CL-RHL	0.179	No
	RHL-HC	0.000	Yes
	CL-HC	0.084	No

CL:Cerebellar lesion, RHL: Right Hemisphere Lesion, HC: Healthy Control. The results were determined to be significant if the p-value <0.0012/3, i.e., 0.0004, according to post hoc multiple comparisons with Bonferroni correction, using the Mann-Whitney U test. Adjusted *p* value (0.0004*3=<0.0012/3) was recorded in the table.

Studies showing that individuals with cerebellar lesions may differ from healthy individuals at various linguistic tasks such as comprehension, production and grammaticality judgments have drawn attention to the role of the cerebellum in grammatical processing (Justus, 2004). In the grammatical subtest of ADD, aurally presented incomplete sentences had to be completed in morphosyntactically and semantically correct sentences. The biologically-constrained artificial intelligence model, which focuses on understanding the role of the cerebellum in linguistic processing, posits that cerebellum-specific anatomo-physiological circuits help predict the word sequences that appear in a grammatical string and inferring the rule of syntactic sequences (Ohmae & Ohmae, 2024). Consistent with these studies, the ability of Turkish-speaking individuals with cerebellar lesions to complete incomplete sentences with appropriate morphemes and words was impaired compared to healthy individuals. Another subtest in which the cerebellar lesion group differed from healthy participants was naming. The naming subtest of ADD includes noun and verb naming tasks elicited by categorical, picture and question elicitation. Lesion studies supporting the role of the cerebellum in naming performance emphasized the role of cerebello-cerebral connectivity in naming skills in post-stroke aphasia recovery (Keser et al., 2023) and suggest that neuromodulatory stimulation of the right part of the cerebellum improves naming performance in post-stroke aphasia patients (Sebastian et al., 2020).

In the light of these data, although it is doubtful that the low ADD performance without aphasia can be directly attributed to the cerebellum, it can be said that brain damage leads to differentiation from neurotypical performance in various levels of language. The definition of aphasia has been re-discussed in recent years and the need to consider aphasia as a communicative difficulty rather than a language disorder. According to standard aphasia assessments, language impairment may be masked in patients who are not diagnosed with aphasia with standard aphasia assessments. Therefore, interactive conversation and quality of life measures should be used to assess functional communication rather than simple picture description (Berg et al., 2020; Doedens & Meteyard, 2020). Thus, discourse analysis can be employed as a methodology.

In this study, the "Accident Scene" picture in ADD was used to obtain narrative samples from individuals with acquired brain injury. Turkish is an agglutinative language in which morphemes are attached to word roots in a specific hierarchy and order (Slobin, 1985). The Accident Scene can elicit production of subordinate clauses, verbs, inflectional suffixes, passive voice constructions, and past tense suffixes in Turkish-speaking healthy individuals (Seçkin & Savaş, 2023). Narrative analysis also allows for the measurement of parameters of verbal fluency (number of words produced per minute, time spoken, rate of speech) and effortful behaviors such as word or phrase repetition/revision (Fiestas et al., 2005; Wardle et al., 2011). Efforts that disrupt speech fluency such as gap-filling expressions, repetition and rearrangement of syllables or words and are defined as maze/effort behaviors (Shadden, 1997). In this study, it was found that individuals with cerebellar lesions produced such effort behaviors at a higher rate than healthy controls. The organization of the morphosyntactic and lexicosemantic dimensions of verbal messages in speech production requires the involvement of executive functions such as working memory, attentional modulation and inhibition. It is a widely accepted assumption that verbal production reflects the simultaneous integration of cognitive, linguistic and motor functions. Verbal production is controlled online in the planning, programming and execution stages by feed-forward and feedback mechanisms that are considered to be regulated by the cerebellum in other motor systems (Callan et al., 2000; Guenther, 2006). Therefore, effort behaviors are considered as strategies to cope with the planning and processing load of speech (Arslan & Göksun, 2022). While repetition and reorganization-type efforts reflect syntactic processing difficulties, gap-filling expressions such as "aaa" and "ımm" are interpreted as efforts to maintain the reciprocity of communication and may indicate lexical access difficulties (Braver et al., 2007). Silent pauses are temporary discontinuities in which there is a silent break often within or between sentences (Bortfeld et al., 2001). Pauses in monologic discourse are caused by delays in utterance production, in the selection and execution of motor programs necessary for articulation, or in other information processing problems, resulting in marked reduction in fluency. Between-utterance pauses occur at the beginning of a sentence and are interpreted as difficulties in the simultaneous integration of linguistic, cognitive and motor resources of the verbal message (Roberts et al., 2009; Tannen, 1982). The fact that individuals with cerebellar lesions showed efforts at a higher frequency than the healthy control group in the study suggests that their awareness of the disruptions in communication was preserved and that they made efforts to repair these disruptions.

The mental representations created with visual stimuli in picture interpretation processes cause various inferences to be made through associations with past experiences (Pike et al., 2010). The interpretation of the elements in the Accident Scene in this study, their expression on a logical and causal plane (*"The police tell pedestrians not to cross here".)*, and the production of predictive discourse structures (*"One of the bus or taxi drivers is probably at fault"*.) were interpreted as inferences. Since patients with right hemisphere lesions made inferences at a lower rate than healthy controls may be consistent with well-documented inferential difficulties after right hemisphere lesions (Myers, 1991). On the other hand, patients with right hemisphere lesions are known to make local coherence-type inferences that require linking new information to the previous context (Tompkins et al., 1994). Therefore, it may be useful to examine the simple and complex level inference performance of patients with right hemisphere lesions in more detail in future studies.

Furthermore, patients with right hemisphere lesions had lower total ADD scores than the healthy control group as well as other ADD subtests in which they differed in terms of fluency, reading and writing skills. Although these patients did not have a diagnosis of aphasia, they differed from healthy controls in several components of language. The ADD fluency subtest consists of responses to everyday conversation topics such as marital status, occupation, number of children, and automatic language tasks such as counting. The reading subtest includes tasks such as single word reading and text comprehension. The arcuate fasciculus of the right hemisphere was found to be significantly involved in reading comprehension in healthy individuals (Horowitz-Kraus et al., 2014).

Although the role of the right hemisphere in writing is not clear (Landis et al., 1982), in this study it was observed that patients with right hemisphere lesions had low writing performance despite the absence of hemispatial neglect.

None of the patients with cerebellar and right hemisphere lesions included in the study had hemispatial neglect. However, they showed significantly lower performance in the facial recognition test compared to the healthy control group. The limited number of studies on the relationship between visual and verbal skills, suggest that verbal creativity partially relies on visual skills (Palmiero et al., 2010) and individuals who confabulate tend to have poor visual memory and relatively poor executive functioning (Cunningham et al., 1997).

Limitations of the study

The small sample size of the groups is a limitation of the present study. The fact that the narrative samples elicited from the participants were based on a single picture is a further limitation. Considering life experiences and individual differences, the of use more than one narrative tool should be used in future studies. Different narrative tools and contexts should be used to further analyze the difficulties that language disorders cause in social interactions. Patients with cerebellar lesions should be evaluated for other cognitive function problems and such assessment results should be incorporated into the patient's treatment plan.

Conclusions

It was found that cerebellar damage caused impairments in naming and grammar subfields. When patients' narrative productions were analyzed, it was observed that verbal fluency was disrupted by pauses and other interruptions. There was no difference in ADD score, ADD subtests and narrative parameters between patients with right hemisphere lesion and cerebellar lesion patients. However, both stroke groups showed lower performance compared to healthy subjects. This suggests that brain damage of ischemic aetiology may have a negative impact on language skills, regardless of lesion location. In addition, ischemic lesions may cause differences in face recognition.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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