THE STUDY THE RELATIONSHIP BETWEEN EXECUTIVE FUNCTIONS OF THE BRAIN AND LANGUAGE PERFORMANCES IN PATIENTS SUFFERING FROM APHASIA

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Abstract
Introduction*: In patients with aphasia, aside from impairments in language functions, deficits in non-linguistic cognitive skills may also affect their potential success in aphasia treatment. Therefore, the current study was conducted to determine the relationship between executive functions of the brain and language performances in patients suffering from aphasia.*
Method*: The research method employed was descriptive correlation. The Statistical population consisted of patients with aphasia referred to the Speech Therapy Unit at Razi Educational, Research, and Treatment Center in Tabriz in the year 2023. A sample of 50 participants was selected using purposive sampling method. In order to collect data, the Delis-Kaplan Executive Function System (2001) questionnaire and the Persian Aphasia Battery Test developed by Nilipour et al. (2016) were employed. Data analysis was conducted using the Pearson correlation coefficient method with SPSS version 24.*
Findings*: The findings revealed a significant and positive correlation between executive functions of the brain, including mental flexibility, problem-solving, verbal fluency, working memory, reasoning, and inhibitory control, with language performances such as oral expression, listening comprehension, reading, and writing ($p < 0.05$). Furthermore, the highest correlation was found between inhibitory control function and listening comprehension skill ($r = 0.51$), while the lowest correlation was observed between working memory function and writing skill ($r = 0.24$).*
Conclusion*: Based on the findings of the study, it appears that executive functions are involved in linguistic representations, suggesting that attention to cognition alongside language is recommended in the process of aphasia patient treatment.*
Keywords*: Executive Function, Brain, Language Performance, Aphasia*

INTRODUCTION:

Language is a tool that helps people communicate more easily with each other. Many different definitions of language have been suggested, but their common feature is that language serves as a means of communication (Bullier et al., 2020). However, speech disorders can occur when there's damage to the speech areas of the brain, with aphasia being one of them. Based on the location and anterior or posterior nature of the brain lesion (Cavanaugh & Haley, 2020), as well as other factors, different types of aphasia are classified, including Broca's, Wernicke's, Global, Conduction, Anomic, Trans Cortical- Sensory, Trans Cortical- Motor, and Trans Cortical- Mixed aphasia (Lahiri et al., 2020). The traditional classification of aphasia is rooted in the belief that the anterior half of the brain controls motor and executive functions, whereas the posterior half is responsible for sensory and perceptual functions(Adams Et al.,2001). In classical terms, damage to the frontal lobe is associated with motor aphasia or Broca's aphasia, while damage to the posterior part of the temporal lobe is linked to sensory aphasia or Wernicke's aphasia. In cases where both areas are affected, global aphasia occurs (Fromm et al.,2022). Furthermore, lesions that disrupt the connection between the frontal lobes and posterior brain regions are known to cause conductive aphasia. The Broca's area is located in the inferior frontal gyrus of the third frontal convolution, recognized as the region responsible for speech production. On the other hand, the Wernicke's area is situated in the posterior third of the superior temporal gyrus of the temporal lobe, identified as the region responsible for speech comprehension (Lahiri et al., 2020). Aphasia is an acquired disorder with a neurocognitive origin and does not cause sensory or intellectual impairments (Wang

et al.,2020). Broca's aphasia is considered one of the most important types of aphasia, often accompanied by slow, difficult, and non-fluent speech. Patients' speech is termed 'telegraphic speech' because it's made up of brief and essential nouns, verbs, and adjectives, without the use of conjunctions, prepositions, or other grammatical words (Bonilha et al.,2024). One of the functions that is impaired by aphasia is language function.

Individuals suffering from aphasia may experience difficulties in one or more modalities of language output and input, including oral expression, listening comprehension, written expression, and gestural communication (Kuzmina & Weekes,2017). Due to language impairments caused by stroke or accident, these individuals may attend speech therapy sessions for several months. While aphasia therapy is effective in improving the condition for many individuals, unfortunately, some others do not show significant progress in their treatment. In some patients, damage resulting from stroke to non-linguistic cognitive skills such as attention, memory, processing speed, and executive functions may impact their potential success in aphasia rehabilitation (Mikola,2010). In a study carried out by Raithel (2005) on individuals with Broca's and Wernicke's aphasia in the German language, their performance was assessed by examining their ability to recognize the contours of declarative and emphatic sentence melodies. In a test where the content and structure of sentences were neutral, it was found that aphasic individuals performed similarly to healthy individuals, although healthy individuals performed better in this test. Raithel suggested that the observed performance deficits in aphasic individuals could be attributed to the interference of semantic and syntactic factors as well. There are very few and scattered studies that have investigated and examined the relationship between aphasia and executive functions. The few studies examining the relationship between aphasia and executive functions have revealed that deficiencies in initiation, planning, and generalization typically result in a weak response to treatment (Kuzmina & Weekes,2017; Simic et al.,2019).

Executive function involves a range of abilities necessary for effective and appropriate cognitive performance, including abstract thinking, planning, sequencing, monitoring, and controlling complex and purposeful behaviors. Executive function refers to a set of cognitive processes that allow individuals to behave independently of their environment, serves as an intermediary for connecting the inner world and the external environment (Bialystok,2017). In other words, executive function involves controlled and coordinated mental processes required for daily tasks such as planning and attention control (Arizmendi, Alt, Gray, Hogan, Green & Cowan,2018). The executive function system is a broad cognitive system essential for flexibility and regulation of cognition and purposeful behavior (Best & Miller,2010). It's often referred to as the most important cognitive achievement of childhood (Del Maschio, Sulpizio, Fedeli, Ramanujan, Ding & al.2019). Inhibitory control consists of two domains: cold control and hot control. Cold control, known as attentional inhibition, refers to the ability to suppress attentional shifts towards external stimuli (Arizmendi et al., 2018). It is typically measured using tasks involving conflict, requiring participants to inhibit distracting stimuli to successfully complete the task (Lowe, Cho, Goldsmith & Morton, 2021). Another method is hot control, which is usually measured using delayed tasks such as delay in task performance (Mischel, Shoda & Rodriguez,1989). In general, a wide area of the frontal lobe, including all regions of the prefrontal cortex, particularly the middle frontal gyrus and the amygdala, are involved in executive functions (Del Maschioet al.,2018).

According to the report by Helm-Estabrooks (2002), executive functions are the cognitive abilities most likely to be impaired as a result of brain damage associated with aphasia. Knowing about the non-linguistic cognitive impairments in individuals who suffer from aphasia allows speech and language therapists to develop an appropriate treatment plan targeting both aphasia and executive function deficits simultaneously. This approach can have a significantly positive impact on the communicative skills and functional performance of individuals with aphasia. Different research studies have demonstrated that patients suffering from aphasia not only struggle with language impairments but also experience cognitive deficits and difficulties with executive functions like planning and utilizing strategies, which can affect their communication skills. Furthermore, individuals with aphasia typically demonstrate milder performance on executive function tests

compared to unimpaired individuals (Tessaro et al., 2023; Simic et al., 2019; Thompson et al., 2018; Kuzmina & Weekes, 2017). Based on clinical experiences, it is believed that post-stroke rehabilitation necessitates the engagement of all the patient's emotional, cognitive, and executive capacities. Having impairments in any of these areas can not only hinder the rehabilitation of language functions but also, more broadly, obstruct the patient's ability to compensate for their disabilities and achieve independence (Tessaro et al., 2023; Seniów et al., 2009).

Therefore, in individuals with aphasia, besides language problems, there may also be degrees of cognitive impairment. Determining the impairment in executive brain functions may be crucial for developing an appropriate treatment plan. Therefore, conducting the current research seems necessary. Furthermore, the effects of these executive dysfunctions on daily activities may interact with the limitations resulting from their language disorder, either exacerbating them or intensifying their impact. Based on this idea, the current study aimed to determine the relationship between executive functions of the brain and language performances in patients suffering from aphasia.

Research Methodology

The present research employed a descriptive-correlational method. The Statistical population consisted of patients with aphasia referred to the Speech Therapy Unit at Razi Educational, Research, and Treatment Center in Tabriz in the year 2023. A sample of 50 participants was selected using purposive sampling method. The patients ranged in age from 35 to 59 years old. The location and extent of the lesion were determined by a neurologist based on reports from CT scans and MRI. Each patient's family had provided consent for their participation in this study. Initially, patients were briefed on the methodology, procedures, and objectives of the research. The study inclusion criteria included being diagnosed with aphasia, proficiency in understanding and speaking Persian before the brain injury, absence of severe sensory impairments or other neurological disorders affecting language and speech, no history of psychiatric disorders, and no prior traumatic brain injury. Participants were excluded from the study if they were not fluent in Persian, had a history of stuttering, or had other psychiatric disorders before the onset of the illness. Some ethical considerations observed in the current study included: voluntary participation of the participants and obtaining full consent from each patient's family to participate in the research, maintaining confidentiality of information and the identity of individuals in the study, informing participants of their right to withdraw from the study at any stage without consequences, and committing to preserving the confidentiality of participants and adhering to this commitment. The data analysis was conducted using Pearson correlation coefficient through SPSS software version 24. The following questionnaires were used for data collection.

Delis Kaplan Executive Function System Questionnaire:

Delis, Kaplan, and Kramer developed a reliable tool in 2001 to measure important aspects of executive functions in both children and adults. This test is a neuropsychological assessment used to evaluate both verbal and non-verbal executive functions in children and adults aged 9 to 90 years old. This test is used to measure variables such as mental flexibility, problem-solving, verbal fluency, working memory, reasoning, and inhibitory control. The test comprises nine subtests, each designed to measure different components of executive function. The first subtest, known as the Sequential Order subtest, which consists of five questions, is used to measure mental flexibility, while the fifth subtest, known as the Card Sorting subtest, includes four questions and is employed to evaluate working memory. Additionally, the fourth subtest, known as the Stroop Color subtest, comprises four questions and is used to measure inhibitory control. This scale is scored based on a 3-point Likert scale ranging from Never (0), Sometimes (1), to Always (2). This tool demonstrates good reliability and validity, with its test manual reporting a reliability coefficient between 0.84 and 0.98. Karr et al. (2018) reported the reliability of this scale to be 0.86 using Cronbach's alpha method. In Iran, Ghavami et al. (2016) employed the Persian version of the test and reported its Cronbach's alpha reliability as 0.95.

Niliapour et al. (2016) Persian Aphasia Battery Test

This test, originally developed by Michel Paradis from McGill University in Canada for various languages, was translated and standardized into Persian by Nilipour in Iran in 1989. In 1999, under the guidance of Paradis, Paribakht and Nilipour revised and standardized the test, and it has been translated into 65 common languages worldwide. In this study, the short version of this test was utilized, which consists of 217 items. With this version, four important aspects related to aphasic patients are examined: the four main language skills (oral expression, listening comprehension, reading, and writing), which are further divided into subskills and measured within the framework of the test. The scoring method of the test is as follows: for each item, a score of "0" is assigned for no response, "1" for a correct answer, and a "negative" score for an incorrect response. Therefore, a quantitative language profile is drawn using the patient's correct responses, serving as a diagnostic tool for identifying aphasia symptoms and evaluating the extent of impairment in different language skills. This test has been normalized in Iran, and its overall validity and internal consistency of its subtests were confirmed through calculating a Cronbach's alpha coefficient of 0.93. The findings of the construct validity assessment also revealed that there was a correlation between the subtests of oral comprehension ranging from 0.82 to 0.36, a correlation between the subtests of oral expression ranging from 0.67 to 0.43, a correlation between the reading subtests ranging from 0.83 to 0.48, and a correlation between the writing subtests ranging from 0.71 to 0.40 (Nilipour at el.,2016).

Findings

Table 1 presents the demographic characteristics of the research sample, including age, gender, education level, duration of injury, and type of aphasia.

Table 1. Demographic Characteristics of Patients and Frequency Distribution of Features

Variable		Frequency (Percentage)	Mean (Standard Deviation)
Age		**-**	**13/47 (69/5)**
Gender	**Female**	57 (5/47)	-
	Male	63 (5/52)	-
Education Level	**Middle School Diploma**	(30) 36	-
	Under diploma	(26/6) 32	-
	Diploma	(24/1) 29	-
	Bachelor's degree	(14/1) 17	-
	Master's degree and higher	(5) 6	-
duration of injury		-	12/4 (02/1)
Type of Aphasia	**Broca's**	(34/1) 41	-
	Wernicke's	(30/8) 37	-
	Global	(24/1) 29	-
	Conductive	(6/6) 8	-
	Anomic	(4/1) 5	-

The findings from Table 1 reveal that the average age of the research sample was 47.13 years with a standard deviation of 5.69. In terms of gender, the majority of the sample were male (52.5%). Regarding education level, most participants had completed middle school diploma (30%). The average duration of injury was 4.12 years. Moreover, Broca's aphasia was the most prevalent type among participants (34.1%).

In Table 2, the mean and standard deviation of the research variables are presented.

Table 2. Descriptive Statistics of Executive Function Variables and Language Skills

Variable	Components	SD±M
Executive Functions	**Mental Flexibility**	25/66±4/60
	Problem Solving	24/62±1/85
	Verbal Fluency	19/30±2/01
	Working Memory	18/87±1/08
	Reasoning	15/71±6/21
	Inhibitory Control	19/51±7/95
Language Skills	**Oral Expression**	46/04±8/02
	Listening Comprehension	45/12±5/18
	Reading	47/61±6/14
	Writing	51/84±5/18

According to the findings presented in Table 2, among the executive functions, the highest mean was related to mental flexibility (M = 25.66), while the lowest mean was associated with reasoning skills (M = 15.71). The language skill with the highest average score was writing (51.84), while the skill with the lowest average score was listening comprehension (45.12). Table 3 displays the correlation matrix of the research variables.

Table 3. Correlation Matrix of Predictor and Criterion Variables

Variable	1	2	3	4	5	6	7	8	9	10
Mental Flexibility	**1**									
Problem Solving	***0/34**	**1**								
Verbal Fluency	***0/36**	****0/32**	**1**							
Working Memory	***0/41**	***0/45**	****0/39**	**1**						
Reasoning	***0/42**	****0/45**	***0/41**	****0/38**	**1**					
Inhibitory Control	***0/39**	****0/41**	***0/35**	***0/32**	**0/29**	**1**				
Oral Expression	***0/41**	****0/44**	****0/39**	***0/36**	****0/49**	***0/47**	**1**			
Listening Comprehension	****0/38**	***0/41**	****0/45**	****0/44**	***0/41**	****0/51**	****0/42**	**1**		
Reading	***0/29**	****0/32**	****0/41**	****0/39**	****0/28**	***0/31**	****0/39**	****0/27**	**1**	
Writing	****0/38**	***0/31**	***0/29**	***0/24**	***0/31**	****0/43**	***0/25**	****0/36**	****0/33**	1

**** P<0/01 ،*P<0/05**

According to the findings in Table 3, there is a significant positive correlation between all brain executive functions, including mental flexibility, problem-solving, verbal fluency, working memory,

reasoning, and inhibitory control, with the four language skills, including oral expression, listening comprehension, reading, and writing ($p < 0.05$). Among these, the highest correlation was found between inhibitory control function and listening comprehension skill ($r = 0.51$), while the lowest correlation was observed between working memory function and writing skill ($r = 0.24$).

Discussion and Conclusion

The current study was conducted to determine the relationship between executive functions of the brain and language performances in patients suffering from aphasia. The research findings indicated that there is a significant and positive correlation between executive functions of the brain, including mental flexibility, problem-solving, verbal fluency, working memory, reasoning, inhibitory control, and the four language skills, including oral expression, listening comprehension, reading, and writing. In other words, it can be said that deficits in executive functions lead to difficulties in the language skills of oral expression, listening comprehension, reading, and writing in patients with aphasia. The findings of this study suggest that individuals suffering from aphasia, despite reduced linguistic demands in executive function tests, still face cognitive impairments in addition to language deficits. These results support the hypothesis that individuals suffering from aphasia demonstrate deficits in executive functions. This finding aligns with previous research findings (Spitzer et al., 2020; Simic et al.,2019; Olsson et al.,2019; (Kuzmina & Weekes,2017; Cahana-Amitay& Albert, 2015; Fucetola & Tabor Connor,2015).

In explaining these findings, it's commonly understood among aphasia therapists that variable responses from some patients with similar severity levels to a specific treatment program may be due to impairments in certain cognitive aspects, in addition to language. Moreover, differences in communicative skills performance among some patients with similar severity of aphasia are attributed to their high-order cognitive abilities. These high-order cognitive abilities refer to the skills that enable us to plan intentional activities according to situational changes. These intentional activities are executive functions (Spitzer et al.,2020).

Card sorting, a task used in assessing executive functions, evaluates individuals' abilities in shaping abstract concepts, adapting and retaining sets, maintaining active memory, and feedback utilization. Furthermore, it serves as a useful tool for measuring problem-solving ability across different scenarios (Kopp et al.,2021). Effective performance in this area requires mental flexibility and problem-solving skills. However, individuals with aphasia, due to brain damage, are unable to perform these tasks as efficiently as normal individuals. Over time, this leads to deficits in their expressive abilities, impacting both speech comprehension and the processing and expression of speech. The evidence indicates that the segment of language related to vocabulary and nouns is situated within the middle portion of the temporal lobe and originates from a ventral-anterior expressive system. Furthermore, grammatical rules are processed by a section of the frontal lobe and basal ganglia (Kuzmina & Weekes,2017). Patients suffering from aphasia, particularly those with lesions in the frontal region of the brain, or frontal lobe damage, may struggle with grammar and sentence structure. This can result in the omission or misuse of function words. While access to lexical content such as nouns is less impaired. Dogil et al. (2014) used functional magnetic resonance imaging to investigate how the brains of several healthy individuals functioned when producing prosody. The findings of this study indicated that both the left and right hemispheres of the brain are involved in processing prosody, and this processing occurs in the superior temporal gyrus. Furthermore, these researchers demonstrated that lateralization in distinguishing between the linguistic and emotional roles of prosody is not present. Instead, it is the foundation of prosody that underlies lateralization, rather than its linguistic-emotional role.

Another clarification regarding the correlation between executive function and language ability in the current study is that there is a close neuroanatomical similarity between these two functions. This is evidenced by the fact that massive strokes result in more significant impairments, both in language and cognition (Kahana-Amitay & Albert,2015). Furthermore, some researchers consider aphasia symptoms to some extent as executive dysfunction effects (Kahana-Amitay & Albert,2015). While others argue that the severely impaired language function has adverse effects on executive

functions (Baldo et al.,2005). Both of these hypotheses anticipate correlations similar to what we observed in our results, and the findings of this study support the relationship between executive function and language ability. For most participants in this study, the card sorting task proved to be quite challenging because they had difficulty identifying the rule for each category, leading to increased perseveration errors due to difficulties in behavior change. Particularly when the categorization rule changed and the task appeared more complex, patients struggled with changing the cards, suggesting a potential impairment in their working memory. In conclusion, aphasia is a language disorder caused by brain injury, which manifests as irregularities in both language perception and expression, and appears as impairments in the four language modalities: speaking, listening, reading, and writing. It can also impact the executive functions and cognitive abilities of affected individuals. The findings of this study indicate that individuals suffering from aphasia may experience deficits in executive functions. This issue can influence their linguistic representations, resulting in challenges in listening comprehension, oral expression, reading, and writing. One of the drawbacks of this research is the restriction to Persian-speaking participants, which was due to limited access to fewer patients and the utilization of non-random sampling methods. Therefore, caution should be exercised when generalizing the findings to other bilingual and multilingual individuals with aphasia, as well as to other cultures. Future researchers are recommended to address these limitations by examining executive functions separately according to the type of aphasia, and then explore their relationship with linguistic abilities. Moreover, rehabilitation and health and medical centers are suggested to consider the role of executive functions in the rehabilitation programs of these patients, aiming to improve their language skills.

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