

The relationship between working memory and sentence processing in individuals with Broca's aphasia

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Abstract:

The aim of this study was to investigate the relationship between working memory and sentence processing in individuals with Broca's aphasia. To this end, the study was conducted on a sample of twenty (20) purposively selected individuals diagnosed with Broca's aphasia. A descriptive approach was adopted and two tests were used for data collection: the Baddeley Working Memory Test and the Sentence Processing Test. After data collection and statistical analysis, the results indicated a relationship between working memory and sentence processing in individuals with Broca's aphasia.

Keywords: Working memory, Sentence processing, Broca's aphasia.

Introduction:

Since its inception in the 1950s and 1960s, research in cognitive science has emphasised the need for cognitive studies for a scientific understanding of human behaviour. As humans are information processing systems, the analysis of cognitive processes has been of interest to experts in cognitive psychology and linguistic studies, which revolve around two fundamental elements: memory and language.

Language is a behaviour based on neural, cognitive and psychological foundations. Like other mental processes, it uses bottom-up processing based on linguistic sensation and top-down processing based on linguistic perception and its interaction with knowledge stored in long-term memory. Thus, as an open system, language is a product of the interaction between linguistic sensation, which is determined by genetic and neural factors, and linguistic perception. This interaction also involves cognitive structures and representations (Mahmoud Bani Younis, 2009, p. 290).

Human beings are social by nature, and to maintain this characteristic, they constantly strive to communicate with others through various means, including writing, symbols, drawing, sign language and, most importantly, oral expression. However, this communication can be disrupted if the specific area of the central nervous system responsible for it is affected. Stuttering, known as a language disorder resulting from brain damage to the central nervous system, occurs in individuals who previously acquired language skills (J.A. Rondal, 1988, p. 354).

There are different types of stuttering, each with a specific clinical profile. The most common type is Broca's stuttering, which results from damage to the third convolution of the frontal lobe. People with this type remain aware of their speech disorder, while their comprehension skills are relatively normal. However, their speech production is severely restricted. Other symptoms observed in affected individuals may include dysarthria, reduced compound words and non-grammatical speech patterns leading to telegraphic speech (télégraphique).

The linguistic sign extends in time through pronunciation and in space through writing. It occupies a space on the page and lasts a few seconds when spoken. All of this is based on cognitive processing, so we find a strong relationship between language and cognitive skills, especially working memory. Working memory plays a role in oral and written comprehension, oral and written production. We observe that the complex processing of sentences, i.e. the morphosyntactic level, depends on the capacity and efficiency of working memory. The strength and efficiency of working memory are reflected in a person's ability to use a language, i.e. linguistic ability and performance.

MAZEAU and colleagues (2005) have shown through research on neurological disorders in children (such as epilepsy, brain injury and specific language impairment) that there is a decline in the ability to understand spoken and relatively long texts.

This decline is attributed to a severe impairment of the phonological loop, which is part of working memory.

In addition, McCarthy and WARRINGTON (1987) pointed out that people with short-term memory impairment find it difficult to assign appropriate interpretations in tests involving ambiguous sentences because the process requires the retrieval of previously uttered information from the phonological store to determine ambiguity.

These studies confirm the relationship between working memory and sentence processing, and that language impairments resulting from brain damage in language areas can affect both working memory and sentence processing.

1- Problem statement: Working memory is a cognitive process responsible for interpreting cognitive concepts and stimuli that activate information in human memory for retrieval in various cognitive tasks related to learning, thinking, and understanding. It also enables the efficient use of available resources. (Baddeley and Hitch) were among the first to emphasise the importance of this process, and the Baddeley model is the most widely used model in the field of cognitive psychology. According to this model, Baddeley's working memory consists of three components: the central executive, the phonological loop and the visuospatial sketchpad.

In 1974, Baddeley and Hitch proposed that the phonological loop is responsible for verbal information, while the visuospatial sketchpad stores visual and spatial information for a short period of time. The role of the central executive is to coordinate different activities and integrate information in the primary subsystems. In addition to the above model, Baddeley and Hitch added a fourth component to the original model, called the episodic buffer. It is thought to link information from long-term memory with incoming information from working memory stores and relies on the central executive.

Recent research in the United States has highlighted the importance of working memory as one of the most important cognitive skills. As a result, most studies focus on the relationship between working memory and learning difficulties. For example, Huijts' study found that children with learning difficulties have deficits in the working memory needed for comprehension, language, sentence formation and problem solving.

Working memory plays a crucial role in language processing, including comprehension, inference and other processes.

As the brain is responsible for a range of cognitive and motor functions, language has specific neural centres, predominantly in the left hemisphere of the brain in most people. Language has two aspects: production (expressive) and comprehension (receptive), each with its own specific neural areas. Broca's area, located in the frontal lobe, is responsible for expressive language, while Wernicke's area, located in the temporal lobe, is responsible for comprehension. A study by Louzaoui Raziqa (2006) found that people with frontal lobe damage have more dysfunction in the central executive than in the phonological loop and visuospatial sketchpad. This finding supports the relationship between the central executive and selective attention. Van der Linden also emphasised the relationship between the frontal systems and working memory, selective attention, language, movement, memory, thinking, executive functions and emotional behavioural changes.

According to researchers, the production of spoken or written language is a highly complex process involving several areas of the brain that work in concert with each other. Any disruption in any of these areas can lead to language disorders. These language disorders, known clinically as aphasia or dysphasia, manifest as impairments in language comprehension, production, reading and writing. Scientists have categorised aphasia into different types.

Some types are non-fluent aphasia, such as Broca's aphasia, transcortical motor aphasia and global aphasia. Other types are fluent aphasia, such as Wernicke's aphasia, conduction aphasia and transcortical sensory aphasia. The specific type of aphasia depends on the location of the brain injury.

Temple has mentioned that patients with Broca's aphasia have varying degrees of language impairment. Some people are unable to produce the desired vocabulary, while others experience the opposite. This type of aphasia is often associated with certain levels of language analysis impairment,

starting at the phonological level. People with Broca's aphasia have difficulty articulating certain phonemes and linking them together to form words and meaningful sentences.

At the morphosyntactic level, which relates to sentence structure, people with Broca's aphasia have difficulty or inability in constructing sentences. They struggle to connect words using connectors and cannot control the rules of sentence formation. As a result, they cannot form sentences that are meaningful to the listener.

At the semantic level, people with Broca's aphasia have difficulty grasping the meaning of language structures. They have what is called semantic paraphasia, where they use a word that is related in meaning but different in form. For example, writing 'pen' instead of 'pencil'. They also struggle with naming objects and pictures. Most people have difficulty naming close relatives.

The current research aims to investigate the relationship between working memory and sentence processing in individuals with Broca's aphasia, focusing on the following research question:

- Is there a relationship between working memory and sentence processing in individuals with Broca's aphasia?

The subquestions are:

- Is there a relationship between working memory and word retrieval deficits in individuals with Broca's aphasia?

- Is there a relationship between working memory and sentence formation in individuals with Broca's aphasia?

2- Based on the theoretical framework and previous research findings, the research hypotheses are formulated as follows:

General hypothesis:

-There is a relationship between working memory and sentence processing in individuals with Broca's aphasia.

Specific hypotheses:

-There is a relationship between working memory and word retrieval deficits in individuals with Broca's aphasia.

-There is a relationship between working memory and sentence formation in individuals with Broca's aphasia.

3- The aims of the study are:

- To explain how sentence processing occurs in individuals with Broca's aphasia and to develop a comprehensive assessment tool for sentence processing disorders.

- To explain the existing impairments in sentence formation.

- To explain semantic comprehension at the sentence level.

- To explain the relationship between working memory and sentence processing disorders.

- To understand the role of the phonological loop in the processing of verbal information.

- Understand the role of the visuospatial sketchpad in the processing of written information.

4- Importance of the research:

4-1 Theoretical significance:

The theoretical significance of this research lies in its ability to open up new perspectives and enrich the knowledge base in the field of Broca's aphasia, particularly in terms of linking neural structures to cognitive abilities. This research examines the relationship between working memory and language processing (comprehension and production) at the sentence level in individuals with Broca's aphasia.

4-2 Practical implications:

The practical significance lies in understanding the impact of working memory, specifically the phonological loop, on the linguistic processing of word structure as part of a sentence. Individuals with Broca's aphasia have difficulty retrieving words from the mental lexicon, resulting in word retrieval deficits and other difficulties with sentence comprehension and construction.

5- Definition of terms:

5-1 Working memory:

a. Conceptual: It refers to the storage system that holds a limited amount of information in an active state and includes the processes of selecting and retrieving relevant information. It consists of the central executive, the phonological loop and the visuospatial sketchpad.

b. Operational: This is the ability to achieve appropriate language comprehension and production in context. This can be assessed by tests that measure deficits in word retrieval and sentence processing.

5-2 Broca's aphasia:

a. Conceptual: It is a language disorder that affects either expressive or receptive language, depending on the region of the brain affected.

b. Operative: It is an acquired language disorder resulting from a brain injury that affects the dominant hemisphere, specifically the language systems involved in word production and sentence formation.

5-3 Broca's aphasia (specific):

a. Conceptual: This is the most common type of aphasia and typically results from damage to the third frontal cortex in the left hemisphere (based on the individual's cerebral dominance). Symptoms include phonemic disintegration and mutism, followed by word retrieval deficits and difficulties with sentence construction.

b. Operational: It is a language disorder primarily affecting language production, characterised by initial mutism and a marked difficulty in word retrieval due to impaired mental word retrieval processes, resulting in difficulties in sentence construction.

5-4 Sentence processing:

a. Conceptual: It refers to the linguistic and cognitive processes involved in the oral or verbal processing of words and verbs to form meaningful sentences that can be understood by the recipient.

b. Operational: It is the ability to formulate a sentence in accordance with the rules of the language.

5-5 Broca's aphasic behaviour in sentence processing:

People with Broca's aphasia have clear difficulties in retrieving words from the mental lexicon. They also struggle with word order, the use of linking mechanisms and verb inflection within the context of a sentence.

4- Research methodology:

4-1 Research method used: The methodology used in this research is descriptive, which is considered to be the most appropriate for such studies. The current research aims to explore the relationship between the research variables.

4-2 Research population: The term "research population" refers to the methodological concept that denotes the phenomenon to which the study findings are generalised. In our study, the research population consists of cases affected by a specific language disorder known as Broca's aphasia.

4-3 Research sample: The research sample consists of twenty (20) cases diagnosed with Broca's aphasia, selected through purposive sampling.

4-3-1 We clarify the spatial and human scope in the following table:

Institution Name	Research Sample	The selected sample.
Public Hospital Establishment Chi Qay Fara	10	04
University Hospital Establishment 1st November 1954	15	10
Public Hospital Establishment Hamadou Hussein	07	06

Table (13): Research Sample

4-3-2 Sample selection criteria: Cases diagnosed with Broca's aphasia were selected on the basis of the following criteria:

- Age: Cases must be adults.
- Cases receiving aphasia care support were selected.
- Language used: Either Modern Standard Arabic or French.
- Gender: Both genders were included in the selection.

4-3-3 Presentation of cases:

Name and family name	Age	Gender	Occupation	Type of Injury
L.M	38years	Female	Doesn't work	AVC(I)
M.M	41years	Female	Doesn't work	AVC(I)
CH.D	47years	Female	Doesn't work	AVC(H)

A.F	40years	Female	Doesn't work	AVC(I)
A.Y	61 years	Female	Doesn't work	AVC(H)
B.D	79 years	Male	Doesn't work	AVC(H)
B.A	32 years	Female	English teacher	AVC(H)
M.A	36 years	Male	English teacher	AVC(I)
L.F	62years	Male	Teacher	AVC(I)
K.M	57years	Male	Mechanic	AVC(I)
M.S	50years	Male	Mechanic	AVC(I)
CH.I	68 years	Male	Farmer	tumor
K.M	86 years	Male	Farmer	AVC(I)
M.Ch	60 years	Male	Merchant	AVC(I)
A.M	54 years	Male	Merchant	AVC(I)
L.F	39 years	Male	Employee	AVC(H)
M.T	34years	Male	Employee	AVC(I)
H.S	51 years	Female	Nurse	AVC(H)
R.A	70years	Male	Officer (Gendarme)	AVC(I)
H.A	25 years	Male	Student	AVC(I)

Table (14): Presentation of research sample cases

4-3-4 Time Frame: The primary study started from 1 January 2019 to 10 March 2019.

5- Instruments used in the research:

5-1 Working Memory Test: A test developed by Dr Maryam Draqini in her Ph.D. thesis and applied to Arabic-speaking children. The test has three dimensions:

- Clown Scale: Relates to spatial visual memory
- Sentence Scale: Relates to the phonological loop
- (AB) scale: Relates to central executive function

5-2 Sentence Processing Test: A test designed by researchers to diagnose sentence processing disorders in people with Broca's aphasia. This test measures comprehension and sentence construction and includes dimensions such as word recall, sentence formation, event sequencing and picture sequencing.

1-2 The results of the Sentence Processing Test for the whole sample are presented below.

Name and family name	Word Deficiency/10	Sentence Structure/10	Sequence of Events/8	Sequence of Images/3	Sequence of Events/8	Sequence of Images/3
L.M	04	05	00	03	00	03
M.M	10	10	08	03	08	03
CH.D	9.5	8.5	1.5	03	00	2.5
A.F	05	05	00	03	00	03
A.Y	09	8.5	03	03	1.5	03
B.D	09	6.5	00	03	2.5	03
B.A	08	10	08	03	08	03
M.A	10	10	5.5	03	07	07
L.F	10	08	00	2.5	00	03
K.M	08	04	00	03	4.5	03
M.S	07	05	00	03	2.5	03
CH.I	08	4.5	2.5	03	4.5	03
K.M	7.5	3.5	00	03	00	03
M.Ch	3.5	10	06	03	2.5	03
A.M	09	07	01	03	02	03
L.F	10	8.5	03	03	04	03
M.T	08	07	02	03	03	03
H.S	09	08	04	03	05	03
R.A	09	08	1.5	03	4.5	03
H.A	05	03	00	03	00	03

Table (15): Presentation of sentence processing test results for all cases

Table comment: The results of the sentence processing test in each dimension show that the responses were limited to the word recall dimension, ranging from (3.5-10) out of a total score of (10). It is noteworthy that the majority of cases scored full marks in this dimension. In the Sentence Formation dimension, cases scored (3-10) out of a total of (10). In the event sequencing dimension, marks ranged between (0-8) out of a total of (08, and in the picture sequencing dimension, marks ranged between (2.5-3) out of a total of (3). It was observed that the majority of the sample gave correct answers and scored full marks in these dimensions. The results suggest that the research sample has difficulties with sentence processing as indicated by the test dimensions. The severity of the disorder varies according to the nature and environment of the individual, in addition to the sponsorship of aphasia care.

1-3 Presentation of working memory test results: We applied the Working Memory Test to our research sample and the results were as follows:

Name and family name	Clown Test/25	Sentence Test/42	Father Test/30	Total
L.M	10	10	07	27
M.M	11	18	10	28
CH.D	11	11	07	31
A.F	11	10	07	31
A.Y	11	10	09	30
B.D	13	11	09	36
B.A	13	12	10	35
M.A	09	10	07	26
L.F	10	10	08	28
K.M	10	09	07	26
M.S	10	11	08	29
CH.I	10	10	10	27
K.M	10	12	07	35
M.Ch	13	11	10	29
A.M	10	11	08	30
L.F	11	10	09	30
M.T	11	10	09	33
H.S	12	12	03	33
R.A	11	13	09	32
H.A	10	10	07	27

Table 16: Shows the results of the Baddeley Working Memory Test for the research sample.

- Comment on the table: Based on the obtained results of the Working Memory Test, which indicate the degree of response of the cases ranging from 26 to 37 out of a total test score of 97, it can be observed that in the Spatial Visual Sketchpad Test, the response scores ranged from 9 to 14. In the Phonological Loop Test, the response scores ranged from 9 to 13. In the Phonological Loop test the response scores ranged from 9 to 13. On the Central Executive test, response scores ranged from 7 to 11. These results indicate that all scores were below average. It can therefore be concluded that the research sample has working memory impairments in all its components (Phonological Loop, Spatial Visual Sketchpad and Central Executive).

2- Discussion of hypotheses in the light of the results with regard to the relationship between working memory and test items:

The working memory's relationship with	the correlation coefficient	value (sig)	significance level (p)
word deficit	,0.59**	0.001	significance at 0.01

Table 17: Results of the correlation coefficients between working memory test scores and word deficit scores in the main sample.

** Correlation coefficients are statistically significant at the 0.01 level.

* Correlation coefficients are statistically significant at the 0.05 level.

The results presented in Table 17 above indicate that the Pearson correlation coefficient between the scores of the individuals in the research sample on the dimensions of the Working Memory Test and their scores on the word deficit from the Sentence Comprehension Test in the current research is 0.59. This value is statistically significant because the p-value (sig) is 0.001, which is less than the significance level of 0.01. This confirms that there is a significant relationship between working memory and word deficit in the people in the research sample. Therefore, we accept the hypothesis that there is a relationship between working memory and word deficit in individuals with Broca's aphasia.

The working memory's relationship with	the correlation coefficient	value (sig)	significance level (p)
The sentence structure	,72**	0.000	Significant

Table 18: Results of the correlation coefficients between working memory test scores and sentence formation scores.

-**Correlation coefficients are statistically significant at the 0.01 level.

-*Correlation coefficients are statistically significant at the 0.05 level.

-The results presented in Table 18 above indicate that the Pearson correlation coefficient between the scores of the research sample individuals on the dimensions of the working memory test and their scores on sentence formation from the sentence comprehension test in the current research is 0.72. This value is statistically significant because the p-value (sig) is 0.001, which is less than the significance level of 0.01. This confirms that there is a significant relationship between working memory and sentence formation in the people in the research sample. Therefore, we accept the hypothesis that there is a relationship between working memory and sentence formation in individuals with Broca's aphasia.

-General discussion of hypotheses: Broca's aphasia is considered to be one of the most important topics that has received considerable attention in various fields. It is a complex language disorder resulting from damage to brain regions involved in language processing. Its study involves extensive research in linguistic, social, neuropsychological and cognitive areas. Studies focusing specifically on language and its relationship to memory in individuals with Broca's aphasia are rare in the field of neuropsychology. Therefore, our research aims to make a modest contribution to this field under the title "The Relationship between Working Memory and Sentence Processing in Individuals with Broca's Aphasia". The first hypothesis is that there is a relationship between working memory and the word deficit in individuals with Broca's aphasia. The researchers attribute this finding to dysfunction at the level of the phonological loop, which is responsible for the necessary processes of encoding, storing and retrieving verbal information, whether temporarily in short-term memory or permanently in long-term memory. Its functioning is influenced by various factors such as word length, phonological suppression effects and others. Therefore, brain damage affects cognitive abilities, including working memory and its various components. Some researchers have suggested that people with Broca's aphasia have difficulty retrieving information and remembering words. Trousseau (1864) also mentioned that the primary loss of words results from forgetting both the words and the basic movements of speech, accompanied by a decline in intelligence. Similarly, Broca (1865) stated that people with Broca's aphasia struggle with sentence formation and verbal expression.

As shown by Bouridah Nafissa (2013), people with Broca's aphasia have difficulty finding the target word, which is accompanied by different linguistic behaviours. The researchers attribute this result to the impairment of working memory, particularly the phonological loop responsible for processing sentences. This was confirmed by Baddelley (1993), who emphasised the role of the phonological loop in understanding spoken and written sentences, especially when they are long and complex. Our study is consistent with Delage's (2012) study, which highlighted the involvement of working memory in sentence processing in terms of grammar, structure, comprehension and production.

Furthermore, our findings are consistent with Louzani Raziqa's (2006) study of frontal lobe representation as a neural study of working memory and selective attention. The study found that frontal lobe presentation negatively affects the performance of working memory components,

particularly the phonological loop, in the retrieval process. It also leads to a significant reduction in visuospatial sketchpad capacity.

A study by Christian et al. (2004) entitled "Working Memory Capacity" showed that individuals with low working memory capacity have difficulties with sentence comprehension compared to children with high working memory capacity. Sentence comprehension is also influenced by sentence length and clarity. Our study found a strong statistical correlation ($r = 0.59$, $p < 0.01$) between working memory and word deficit. We can therefore conclude that the first hypothesis of our research was confirmed.

The third hypothesis, which suggests a relationship between working memory and sentence formation in individuals with Broca's aphasia, is supported by our findings. We observe that there is a relationship between working memory and sentence formation, which is attributed to the linguistic and cognitive difficulties that people with Broca's aphasia face as a result of their brain injury. The researchers attribute this finding to the negative impact of working memory impairment, specifically working memory, on oral language at the sentence level, both in terms of structure and comprehension.

Our study is consistent with the research conducted by Ludivine (2012) Quertaimont, who demonstrated the effectiveness of the proposed programme in improving working memory and, consequently, oral language skills.

The Jashatalite theory and Nacira Zallal (2009) indicated that individuals with Broca's aphasia have cognitive perception problems.

Our study is consistent with Karima Mejah's (2010) study entitled "Neuropsychological Assessment of Working Memory and Mental Flexibility Disorders", which found extensive impairment in the components of working memory in individuals with mild and severe brain trauma. In addition, a study by Salmon (1917) highlighted the language and sentence-related disorders experienced by people with aphasia. Schwartz and Coll (1980) constructed a test to measure sentence disorders and their results indicated that individuals with Broca's aphasia have difficulties in processing sentences. Similarly, the study by Goodglasse and Caplen (1972) confirmed that people with Broca's aphasia have problems with sentence production.

In addition, the study by Saida Brahimi (2003) linked dysphasia and Broca's aphasia by administering the Goodglass Battery (Algerian version) to children with dysphasia in the Algerian clinical setting. The study found a lack of ability to link sentence components and incorrect linking of these components, as well as confusion in the use of gender and number concepts. The same conclusion was reached when the same clinical tool was applied to adult individuals with Broca's aphasia. The correlation coefficient between working memory and sentence formation was calculated to be 0.72, indicating statistical significance at the level of $p < 0.01$. We can therefore conclude that the second hypothesis of the research was confirmed.

General conclusion: The process of memory retrieval is one of the most important cognitive functions in humans. It involves the retrieval of past experiences through the recall of previously acquired information and knowledge. Memory plays a crucial role in various aspects of human behaviour such as speaking, writing and reading. It is on this premise that our research topic was chosen: "The relationship between working memory and sentence processing in individuals with Broca's aphasia". After conducting the field study and administering both Baddeley's Working Memory Test, adapted by Darqini Maryam for the Algerian context, and the Sentence Processing Test, designed by the researchers, using Pearson's correlation coefficient, we found that the first and second hypotheses of the research were confirmed. The aim was to investigate the relationship between working memory and sentence processing in individuals with Broca's aphasia, using the Baddeley model as a framework for processing linguistic information. Working memory, as an active cognitive capacity in various cognitive tasks, serves as a mediator between other types of memory. The development of research has provided several models of working memory, the most widely used being the Baddeley model, which recognises that working memory consists of the phonological loop, the visuospatial sketchpad and the central executive.

Working memory and language are two related cognitive abilities, as can be seen in children's language development. Language development progresses from simple to complex (babbling, first words, first sentences, etc.) as a result of the development of cognitive skills, particularly working

memory skills. Working memory serves as the basis for sentence processing, including the phonological processing of words, the syntactic and grammatical rules of sentence formation, and the retrieval of words from the mental lexicon. Through its specialised components, working memory carries out the actual processing of sentences, whether in comprehension or in production.

Recent studies on working memory emphasise its crucial role in the processing of linguistic information, both oral and written. For example, a study by Zaghboush on "Memory and Language" confirms the general role of memory and the specific role of working memory in the processing of oral information, including oral comprehension and production, involving the retrieval and activation of words from the mental lexicon and the use of syntactic and grammatical rules for sentence formation. Another study by Baddeley (1993) highlights the role of the phonological loop in sentence processing in terms of structure, grammar and complexity.

Based on these studies and the statistical results of this research, we can conclude that working memory, as an active cognitive capacity in different tasks, is related to sentence processing in terms of word retrieval, sentence formation and event sequencing.

Conclusion:

In conclusion, in this research, we aimed to investigate the relationship between working memory and sentence processing. We selected a sample of individuals with Broca's aphasia, specifically 20 adult cases, purposively selected from different locations: the University Hospital of Oran, the General Hospital of Mostaganem and the General Hospital of Sidi Ali. We used a descriptive correlational approach, which aims to describe the existing relationship between two variables.

Due to the lack of specialised diagnostic tests for sentence processing in this population, we attempted to develop a sentence processing test. The test aimed to diagnose the processing of verbal and written information in sentences in individuals with Broca's aphasia. The results were analysed using Pearson's correlation coefficient. However, the test had good psychometric properties and was suitable for measuring the intended constructs, with the exception of the picture sequencing task, which had a difficulty level of 1 out of 1. This was because all the participants in the standardisation sample answered all the questions easily and with a 100% success rate.

Based on the results obtained, the current research concludes that:

- The proposed Sentence Processing Test has a role in the diagnosis of verbal and written information processing in sentences in individuals with Broca's aphasia.
- There is a relationship between working memory and word retrieval deficits in individuals with Broca's aphasia.
- There is a relationship between working memory and sentence formation in people with Broca's aphasia.

Having carried out this valuable research, which has enabled the researcher to gain new knowledge about people with Broca's aphasia, certain limitations have been identified. These include the paucity of studies on sentence processing in individuals with Broca's aphasia and the need for further research on sentence processing in Arabic-speaking individuals with Broca's aphasia.

Therefore, it is proposed to:

- Broaden the scope of research across different scientific disciplines related to the topic.
- Further investigate sentence processing in Arabic-speaking individuals with Broca's aphasia.
- Develop additional diagnostic tools for this population.
- Increase awareness and establish specialised centres for people with Broca's aphasia.
- Propose studies focusing on Broca's aphasia in different linguistic contexts.
- Promote research in cognitive and neuropsychology.

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