

The effectiveness of IRMF technology in stimulating neurolinguistics in Aphasia.

فعالية تقنية IRMF في تحفيز اللغويات العصبية عند الحبسة.

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Abstract:

This study investigates the effectiveness of Infrared functional magnetic resonance imaging (IRMF) technology in stimulating neurolinguistic functions in individuals with aphasia. Aphasia is a language disorder caused by brain damage, often following a stroke, affecting speech and comprehension. IRMF is a non-invasive technique believed to promote neural activation and plasticity in language-related brain areas. In this research, aphasic patients underwent IRMF sessions over several weeks, with language performance evaluated before and after treatment using standardized assessments. The results showed significant improvement in language abilities—especially in verbal expression and comprehension—in the group treated with IRMF compared to a control group. These findings support the potential of IRMF as an effective tool in aphasia rehabilitation and open new perspectives for neurolinguistic therapy.

Keywords: Aphasia, functional magnetic resonance imaging (IRMF), Neurolinguistics.

ملخص:

تبحث هذه الدراسة في فعالية تقنية التصوير بالرنين المغناطيسي الوظيفي بالأشعة تحت الحمراء (IRMF) في تحفيز الوظائف اللغوية العصبية لدى الأفراد المصابين بفقدان القدرة على الكلام، التي تعرف بالحبسة فاهو اضطراب لغوي ناتج عن تلف في الدماغ، غالبًا ما يحدث بعد سكتة دماغية، مما يؤثر على اللغة. يُعد IRMF تقنية تعزز النشاط العصبي والمرونة في مناطق الدماغ المرتبطة باللغة. في هذا البحث، خضع مرضى فقدان القدرة على الكلام لجلسات IRMF على مدى عدة أسابيع، مع تقييم الأداء اللغوي قبل العلاج وبعده باستخدام تقييمات موحدة. أظهرت النتائج تحسنًا ملحوظًا في القدرات اللغوية، وخاصة في التعبير اللفظي والفهم، في المجموعة التي عولجت بـ IRMF مقارنةً بمجموعة الضبط. تدعم هذه النتائج إمكانات IRMF كأداة فعالة في إعادة تحفيز اللغوية العصبية عند الحبسة، وتفتح آفاقًا جديدة للعلاج اللغوي العصبي.

كلمات مفتاحية: الحبسة، التصوير بالرنين المغناطيسي الوظيفي (IRMF)، علم اللغة العصبي.

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1. Introduction

Aphasia is a neurological disorder that affects the ability to produce or understand language as a result of damage to specific areas of the brain, often leaving profound implications for the patient's social and functional interactions. Despite numerous conventional therapeutic approaches, recovery of language functions remains partial and slow, especially in chronic cases.

In this context, functional magnetic resonance imaging (fMRI) has become a precise tool used to understand neural activity associated with language, by monitoring blood flow in brain regions during language tasks. However, the role of this technology is not limited to diagnosis; it has also begun to be used to design treatment plans that stimulate remaining neurolinguistic abilities.

However, the question remains:

To what extent can fMRI contribute to stimulating the reorganization of language activity within the brain in aphasia patients?

Can it be considered an effective means of neurolinguistic rehabilitation, or is it simply an assessment tool?

And what are the limitations of this technology in terms of its ability to intervene in the neural structure of language?.

The use of functional magnetic resonance imaging (fMRI) to track and analyze the activity of language areas in the brain of aphasia patients contributes to improving the language rehabilitation process by stimulating the remaining neural networks and directing therapeutic intervention more effectively.

- 1- Understanding the role of fMRI in identifying language areas affected by aphasia.
 - 2- Measuring the effectiveness of treatment based on functional imaging data.
 - 3- Comparing rehabilitation outcomes with and without fMRI.
 - 4- Analyzing the philosophical potential of linking language to neural activity.
- Methodology

A quasi-experimental study was proposed, including two groups of patients: one group receiving conventional treatment, and the other using fMRI-based treatment. Standardized language assessment tools were used, and performance was measured before and after treatment using statistical analyses such as the T-Test.

2. The Concept of Aphasia:

A- Linguistically: Aphasia is defined from the verb "habsa," meaning to imprison. "Habsi"

means imprisoned, without freedom.

B- Technically: Aphasia is the partial or complete loss of language and the ability to express linguistic production. This is due to a defect in the left hemisphere, known as the language area. (Pialoux P, 1975, p. 227)

II- 2- Aphasia and its Definitions:

Aphasia is the complete or partial loss of linguistic ability, in terms of understanding and expression, or the blockage of speech. The defect occurs in the outer part of the third frontal gyrus (F3) of the brain, which is close to the speech motor centers. The defect is located in the nervous system, i.e., the language area, resulting in a disturbance in speech comprehension, reading, and writing.

According to Trousseau, aphasia is a disorder of linguistic symbolization that affects encoding (i.e., expression and decoding (comprehension), as well as written and coded language, and is due to a vascular, traumatic, or tumorous brain injury).

A La Jouanine defines aphasia as a disorder in the psychomotor mechanisms involved in the perception and transmission of language, located in a specific region of the dominant cerebral hemisphere.

Pialoux defines it as a disorder in choosing the appropriate order of letters or in the use of words, and he focused on the linguistic aspect of the disorder, believing that the problem suffered by the afflicted person is their inability to choose the appropriate order of letters.

Paul Brouca defined it as the partial or total loss of language and speech ability, while retaining the ability to write. (Pialoux P, 1975, p. 227)

Rondal defines it as a language disorder that appears as a result of a brain injury to the central nervous system in individuals who have previously acquired a linguistic background. Aphasia is a disease or trauma that affects the brain, suddenly leaving the affected person unable to speak. Nasira Zellal defined it as: "Aphasia is a variety of neuropsychiatric disorders, characterized by a disruption in the sequence of time periods. The aphasia patient loses the ability to monitor different time periods, leading to a separation of verbal communication. A temporal disturbance is a problem in focusing on the three physiological time periods. (Zellal. N, 1986, P P 17-18)

1- Types of Aphasia:

As we mentioned, aphasia varies according to the site of the lesion. Therefore, we find several types that have been classified by many doctors, physiologists, and specialists based on difficult anatomical foundations. Among these types, we find:

1-1- Broca's Aphasia:

The credit for its discovery goes to the French surgeon Paul Broca, who believed that aphasia

is the total or partial loss of linguistic ability during the articulation of the phonological loop. Broca's aphasia is named after him. Head referred to it as verbal aphasia, Coldstein as motor aphasia, Cohen called it phonological investigation aphasia, MC BRIDE as expressive aphasia, and Luria as efferent motor aphasia. We find that those afflicted with this type of aphasia are characterized by several characteristics, in addition to the linguistic characteristics, as follows:

The oral aspect: Difficulty in Word recall, despite intact speech organs, is poor in expression and unable to verbally name words. In written form, the writing is disturbed, with a pervasive degree of oral language impairment.

(Trousseau, 1877, p. 669)

1-2- Wernicke's Aphasia:

This aphasia is a result of Carl Wernicke's aphasia. It refers to damage to the cells that help form the auditory image of words. It is characterized by incomprehension, a disturbance in word formation, and excessive, nonstop speaking.

1-3- Communicative Aphasia:

This type of aphasia is rare. Those afflicted with communicative aphasia have difficulty repeating spontaneous speech, which is nearly normal. Comprehension is also nearly normal. It is due to damage to the connective fibers between the auditory, sensory, and motor areas. Expressive aphasia also results in errors in writing, and speech is characterized by a lack of words.

1-4- Total Aphasia:

This aphasia is characterized by a problem with both quantitative and qualitative expression, whether verbal or written.

1-5- Amnesic Aphasia:

A person with this condition is unable to name objects and structures within their field of perception. It is characterized by a lack of vocabulary and impaired writing, while they have no difficulty translating texts or words. Language comprehension is impaired.

1-6- Mixed Aphasia:

This is an intermediate condition between Broca's aphasia and Frenki's aphasia, occurring more frequently on the left than on the right.

2 The Concept of functional magnetic resonance imaging (fMRI):

2-1 The concept of functional magnetic resonance imaging (fMRI):

It is a modern, extensive, and safe technology for measuring and mapping brain activity. It is used to understand how the brain works by examining the normal functioning of complex

cognitive neurons. It demonstrates the functional physiological changes of the brain's nervous system during neural function, such as language comprehension during conversation. Activities involving vision, hearing, touch, language, memory, the phonological loop, and so on exhibit different patterns of activity. The functional process directly reveals the neural flow during neural function. This is evident when the functional information flows through the phonological loop in a person with aphasia. (Allen M. J. 2004, p. 07)

2-2 Definition of functional magnetic resonance imaging (fMRI):

It is a more advanced and sophisticated modern technology than magnetic resonance imaging (MRI). IRMF uses magnetic fields to directly detect neural activity and is related to changes in functional neural activity, according to Brian Dong's definition: "fMRI is a standard radiological tool because it provides high-resolution images of neural activity in the phenotypic loop. IRMF fMRI measures brain activity by monitoring changes associated with blood flow. This technique relies on the fact that cerebral blood flow and neuronal activation are linked" (Borel A, 2001).

When a brain region is in use, blood flow to that region also increases. The primary form of fMRI uses blood oxygenation-level-dependent (BOLD) fMRI. Discovered by Seiji Ogawa in 1990, it is a specialized type of body and brain scan. It is used to map neural activity in the human brain or spinal cord by imaging changes in blood flow (circulatory response) associated with brain cells' use of energy. (Same reference next, same page)

2-3 The first to discover magnetic resonance imaging was the Japanese Seiji Ogawa in 1990, when he discovered the blood oxygen-dependent contrast (BOLD), which is the MRI contrast of hemoglobin lacking oxygen. In 1990, in a seminal study based on the previous work of Tolleurn and others, Seiji Ogawa and his colleagues examined in a magnetic field equal to (0.7 N) in magnetic resonance imaging to manipulate the oxygen level. They changed the percentage of oxygen depleted, and with the decrease in this percentage, a map of blood flow in the brain was seen in the MRI. They verified this by placing test tubes with (oxygenated blood) and (deoxygenated blood), creating separate images. They also showed that the slope echo images, which depend on a form of magnetization loss called (OLT2) decay, produced the best images to show that these changes in the blood were related to the functional activity of the brain. They changed the proportions of air we breathe, and monitored brain activity with an electroencephalogram. Ogawa concluded that the magnetic properties of blood vary depending on the percentage of oxygen in it. He concluded that blood oxygen can be used to measure brain activity by exploiting the amount of oxygen in the blood when cells are engaged in a specific activity compared to other cells. He also concluded that cognitive brain functions, such as language, depend primarily on oxygen levels during activity and inactivity. (Borel A, 2001, p. 04)

Blood Oxygenation Level Dependent Bold

This is a specialized type of body and brain scan that maps neural activity in the brain or spinal cord of humans by imaging changes in blood flow (the response of blood movement associated with the use of energy cells). In 2003, the Harvard Medical School's Physiology of Medicine, led by Bellevue and colleagues, made the first attempt to monitor physiological brain activity in a specific area using functional magnetic resonance imaging (fMRI), using a contrast agent called magenatsite, a magnetic substance that remains in the bloodstream after intravenous injection. This method is not common in human fMRI because the contrast agent injection is uncomfortable and because the agent only remains in the blood for a short time.

3. The concept of Neurolinguistics:

Neurolinguistics is the study of neural mechanisms in the human brain that control the comprehension, production, and acquisition of language. As an interdisciplinary field, neurolinguistics draws methods and theories from fields such as neuroscience, linguistics, cognitive science, communication disorders and neuropsychology. Researchers are drawn to the field from a variety of backgrounds, bringing along a variety of experimental techniques as well as widely varying theoretical perspectives. Much work in neurolinguistics is informed by models in psycholinguistics and theoretical linguistics, and is focused on investigating how the brain can implement the processes that theoretical and psycholinguistics propose are necessary in producing and comprehending language. Neurolinguists study the physiological mechanisms by which the brain processes information related to language, and evaluate linguistic and psycholinguistic theories, using aphasiology, brain imaging, electrophysiology, and computer modeling.

3.1 The Relationship of Neurolinguistics to Functional Magnetic Resonance Imaging (fMRI) :

Neurolinguistics is a scientific field that seeks to understand how language is processed within the brain. It relies primarily on neuroimaging tools and techniques, most notably functional magnetic resonance imaging (fMRI), which has revolutionized the study of the functional structure of the brain.

fMRI allows for real-time imaging of brain neural activity by measuring the flow of oxygenated blood to areas active during language tasks such as reading, listening, or speaking. This aligns perfectly with the goals of neurolinguistics, which aims to identify brain regions responsible for various aspects of language, such as grammatical, semantic, or phonological processing.

Thanks to this technique, the existence of specialized brain regions has been confirmed, such as:

Broca's area (in the left frontal lobe): responsible for language production.

Wernicke's area (in the left temporal lobe): responsible for language comprehension.

fMRI has also contributed to:

Precise mapping of linguistic neural networks.

Diagnosing types of aphasia and pinpointing the exact location of the lesion.

Directing language rehabilitation programs based on actual neural activity.

Thus, the relationship between neurolinguistics and fMRI is complementary and applied, with the technology providing a precise tool for analysis, while neurolinguistics provides the theoretical framework for understanding the clinical and linguistic implications of this analysis.

3.2 The Applied Aspect:

As a prelude to any fieldwork, we need to familiarize ourselves with the steps of field research. We have divided the fieldwork into three chapters, each representing the following field procedures:

- **The Exploratory Study:**

This is one of the most important steps from which every researcher begins. It is an exploratory field study that provides the researcher with specific information about the field, the experimental sample, and the effectiveness of the research procedures, in terms of the tools the researcher uses to measure the study variables.

- **Research Methodology:**

Our research methodology is based on the quasi-experimental approach, which is a study in which the researcher begins by observing the dependent variable without controlling or adjusting the independent variable, as this has already occurred. Therefore, after studying the changes occurring in the dependent variable, the researcher returns to studying the independent variable.

- **Research Tools:**
- **The first research tool:** For this study, we used the IRMF test to assess the activity of neurolinguistic stimulation in people with aphasia and to determine the phonological function of those with aphasia. We did this by using it in the Kabyle dialect, which includes six items: Item 1: Directed Dialogue, Item 2: Automatic Chain, Item 3: Word Repetition, Item 4: Naming Pictures, Item 5: Identifying Pictures, and Item 6: Oral Movements.
- **The second research tool** is a phonemic-phonological protocol in the Kabyle dialect. This phonemic-phonological therapeutic protocol aims to develop neurolinguistic stimulation activities and to understand the phonological function of the phonological functional image in aphasia patients. This is done based on the Kabyle dialect and includes seven exercises, each with its own specific purpose. This is to correct the aphasia patient's pronunciation and eliminate symptoms such as mutism, word deficiency, paraphasia, deletion, and substitution. The sample is an exploratory study:

This study consists of investigating the test that was applied, which is a test to evaluate the activity of the physiological functional image of the phonological loop in the Kabyle dialect in aphasia patients in (30) cases. We then randomly selected (06) cases with aphasia from the Chahid Mahmoudi Brothers Hospital and the NEDIR MOHAMED C.H.U University Hospital in Tizi Ouzou. Ben Aknoun Hospital and Mustafa Pacha Hospital in Algeria, as well as my private clinic located in Tizi Ouzou, Lijouni neighborhood. This sample represents the study population (the standardization sample), to which the assessment test of the

physiological activity of the phonological loop was applied in the pretest. Every four years, we repeated the same test for the same sample in the posttest. During this period, we implemented the phonemic-phonological therapeutic protocol in the Kabyle dialect to develop the activity of the physiological functional image of the phonological loop and to determine the effectiveness of the phonemic-phonological therapeutic protocol. We utilized the modern IRMF (functional magnetic resonance imaging) technology, which confirms and clarifies the effectiveness of the phonemic-phonological therapeutic protocol in the Kabyle dialect for aphasia patients and provides accurate results.

The exploratory study had several objectives:

- To familiarize ourselves with the field and engage directly with aphasia patients.
- Creating a space and opportunities to explore the relationship between theory and practice by implementing therapeutic programs and orthophonic protocols.
- The importance of the mother tongue, Kabyle, in the use of the therapeutic protocol in the practical field.
- The importance of using modern technological techniques, such as IRMF, in the orthophonic field.

C- Defining the research sample: Standardization sample:

The examination included a standardization group consisting of 6 cases of aphasia, characterized by being adults.

- Adult patients.
- Gender - 3 males.
- 3 females.
- Language used: Kabyle.
- Duration of care: Protocol implementation for 7 years.

Table 1: Guided Dialogue

Measurement	Mean Score	Standard Deviation	Degrees of Freedom	t- Calculated	t- Critical	Significance Level
Pre-test	23.63	13.02	38	10.83	2.43	0.01
Post-test	35.00	7.88	—	—	—	—

Table 2: Automatic Sequence Item

Measurement	Mean Score	Standard Deviation	Degrees of Freedom	t- Calculated	t- Critical	Significance Level
Pre-test	5.31	2.78	38	6.44	2.43	0.01
Post-test	—	1.33	—	—	—	—

Table 3: Word Repetition Item

Measurement	Mean Score	Standard Deviation	Degrees of Freedom	t-Calculated	t-Critical	Significance Level
Pre-test	38.21	6.28	38	14.48	2.43	0.01
Post-test	65.36	6.46	—	—	—	—

Table 4: Picture Naming Item

Measurement	Mean Score	Standard Deviation	Degrees of Freedom	t-Calculated	t-Critical	Significance Level
Pre-test	5.31	2.78	38	6.44	2.43	0.01
Post-test	—	1.33	—	—	—	—

Table 5: Picture Identification Item

Measurement	Mean Score	Standard Deviation	Degrees of Freedom	t-Calculated	t-Critical	Significance Level
Pre-test	43.81	36.81	38	18.02	2.43	0.01
Post-test	75.68	23.67	—	—	—	—

1. Discussion and Interpretation of Study Results:

The statistical processing of the results obtained for the linguistic assessment test for aphasia patients in our study demonstrated an application to the same sample of patients with aphasia who spoke Kabyle, which included the following:

1. Interpretation and Discussion of the Results of the First Hypothesis for the First Item: Directed Dialogue Speaking Kabyle.

In light of the study hypotheses and through the statistical methods adopted to verify these hypotheses, and after reviewing the results of the study, we discuss and interpret them from the theoretical side and previous studies. Some studies have shown the importance of therapeutic programs for developing oral expression in a person with aphasia, as well as speech production. We have found statistically significant differences at the level of the item of dialogue directed at oral expression in the Kabyle language after applying the educational program for the post-measurement, meaning that the person with aphasia finds difficulty in oral expression, l'expression orale, and this is what studies on aphasia have proven. We have also found that the phonetic training program in the item of dialogue directed at oral expression in the Kabyle dialect has had a positive impact on the person with aphasia who speaks the Kabyle dialect. According to the study conducted by the researcher "Charles Foix"

(1977), he developed a therapeutic program to correct expression in a person with Broca's aphasia. The method of re-educating speech disorders and speech production is through the use of directed dialogue, grammar, and the concept of the word through signifier and signified. The goal is to eliminate speech production difficulties.

What is noticeable from the results of those with Broca's aphasia in the directed dialogue section is that:

- All those with aphasia in the Kabyle dialect took a long time to recall phonemes, especially words and nouns.
- They were unable to identify nouns, verbs, and sentence order.
- They were unable to produce phonemes pronunciation.

2- Interpretation and discussion of the results of the first hypothesis for the second section: automatic series for calculating numbers, days of the week, and months.

The calculated (t) through this item shows us that there are statistically significant differences in the tabulated value. This is evident in the presence of differences between the pre-test and the t-test, which are greater than the post-test value in the second item of the series for calculating numbers, days of the week, and months for a person with aphasia who suffers from difficulty in the process of calculating automatically. He may not be able to calculate on his own, even after repeating and recalculating with him. Therefore, we find that the effectiveness of the phonemic-phonological therapeutic protocol has a great impact on the person with aphasia, through the results of the post-test, using this is what appears in the study of "Albert Helen Spark", using a therapeutic protocol for re-education, using the automatic series, which consists of giving the person with a command to recalculate the days of the week and months. The goal of this study is to rearrange the automatic series and retrieve it for the person with Broca's aphasia. Through pronunciation.

-3 Interpret and discuss the results of the third partial hypothesis for the third item: Repronunciation of words spoken in the Kabyle dialect.

The calculated value is greater than (t) in this item, indicating the presence of statistically significant differences in the tabulated value. We see that the person with aphasia suffers from a deficit at the level of production (t) the phonetic value of words and the recall of phonetic units and phonemes to form a word in the phonetic production of letters, the letter at the beginning of the word, the letter in the middle of the word, and the letter at the end of the word, in the Kabyle dialect, such that this third item contains (22) words spoken in the Kabyle dialect, and these words are the same in all regions and villages of Kabylia in Tizi Ouzou. This showed the effectiveness of the training program for phonetic production for the person with Broca's aphasia, especially the words in this item. This appears during the results of the post-test applied to the same sample. This is what studies on aphasia have shown regarding the phonetic production of words, phonetic units, and phonemes. According to the study

(André Roch lecours) on how to manage re-education by setting a program Therapeutic training for a person with aphasia involves attempting to create a normal linguistic situation, even though linguistic communication is difficult due to aphasia. Therefore, when selecting exercises for the therapeutic program, the researcher must select linguistic tools based on linguistic, phonological, and grammatical information about the phonetic units to achieve appropriate linguistic behavior. For example, he resorts to helping the examinee pronounce the first letter of the appropriate word, as well as the second and third letters, in order to form the correct pronunciation of the word. As we find in the study conducted by Michele Bergeron, the researcher finds that the language of a person with Broca's aphasia is characterized by changes affecting the word, such that phonemes are distorted, their sequence is disturbed, and their pronunciation is difficult. This means that there is a phoneme dissociation. Therefore, he must develop a therapeutic training program to correct the phonetic production of phonemes and arrange the word sequence. This is done by using a word re-articulation exercise, using the phonetic production of the first, middle, and final letters of the word in sequence. Thus, the phonetic production of the word is corrected.

-4. Interpretation and discussion of the results of the fourth hypothesis for the fourth item: Naming pictures in the Amazigh language spoken in the Kabyle dialect. The results revealed through the table the presence of statistically significant differences through the results of the (t) test between the averages of the test to assess the linguistic abilities of a person with aphasia who speaks the Kabyle dialect in the fourth item, naming pictures by pronouncing them in the Kabyle dialect after applying the therapeutic phonological training program in the pre- and post-measurements in favor of the post-measurement for the sample with Broca's aphasia, as the calculated (t) value was greater than its counterpart (t) tabulated, and these differences indicated the effectiveness of the therapeutic program, as item 4 for naming pictures contains (30) that were divided into pictures indicating actions, pictures indicating things, as this item measures the ability of the person with aphasia.

After presenting and analyzing the results obtained through our current study, our research deals with a research group consisting of (20) cases with aphasia aged 20 years and above, using the test to evaluate the functional physiological image of the phonological loop, which includes 6 items, respectively: Item 1: Directed dialogue, Item 2: Automatic series, Item 3: Repetition of phonological sounds and repetition of words in the Kabyle dialect, Item 4: Naming the picture in the Kabyle dialect, Item 5: Identifying the picture, Item 6: Orofacial movements. This current study also aimed to investigate the effectiveness of the phonemic-phonological therapeutic protocol using the Kabyle dialect to correct and develop the functional physiological image of the phonological loop in aphasia patients. To achieve this goal, we relied on the IRMF technology, functional magnetic resonance imaging, in order to verify the effectiveness of the therapeutic protocol through the results obtained, and also to achieve the goal of the study. The experimental approach was adopted, with the sample size

reaching (06) aphasia cases, and this protocol includes 7 exercises, each with its own specific morphological and syntactic objective.

To develop and enhance the functional physiological picture of the phonological loop, the data was processed using the statistical program (EXCEL) using statistical tests, the t-test, arithmetic means, and standard deviations.

Through the psychometric study, which consisted of adjusting the test items to measure linguistic abilities and oral comprehension, we addressed this objective by presenting the test items to a group of professors specializing in orthophony and methodology, as well as linguistics specialists and Amazigh language teachers. Their suggestions were taken into consideration, and the test content was modified and its items were arranged according to their importance and difficulty. We then calculated the experimental validity coefficient. On the other hand, we verified the reliability of the test by calculating the Cronbach coefficient of internal consistency, which is equal to the value of each test and a directed value for each item, which indicates the reliability of the test. As confirmed by the results obtained through calculating the correlation coefficients of the items by application and reapplication of the test on the research group, they are all statistically significant at the significance level of 0.01. Accordingly, the test of linguistic abilities and oral comprehension was applied, and the phonemic-phonological therapeutic protocol in the Kabyle dialect is effective and stable. It was applied to the study group to confirm the validity of the hypotheses. The results were produced after statistical processing using the (t) test, and we concluded that there are differences between the pre-measurement and post-measurement in the results obtained from the IRMF technique of functional magnetic resonance imaging in the results of each item, which shows that both the phonemic-phonological therapeutic protocol have an effective and positive impact in developing the functional physiological image of the phonological loop in aphasia patients speaking the Kabyle dialect.

→ 4. Conclusion:

Through our current cognitive study, which aims to identify the effectiveness of the phonemic-phonological therapeutic protocol, which contributes to developing the functional-physiological picture of the phonological loop in Kabyle-speaking aphasia patients, we have identified the importance of using technological techniques in the field of orthophony, such as functional magnetic resonance imaging (fMRI), particularly in therapeutic programs, as it helps determine the neural activity of the phonological loop and accurately and directly demonstrates how the process of neurolinguistic stimulation and phonological storage, known as the phonological loop, occurs in aphasia patients. This is due to the development of the results of treating all types of aphasia, and the importance of the cognitive theory for treating

aphasia is evident, which includes linguistic, morphological, syntactic, syntactic, and phonological concepts, through which phonemes and sound units are formed. The first thing that an individual acquires and learns in the developmental stage is the language that the individual relies on, which is the basic foundation, and that the original mother tongue, such as the Amazigh language, has great importance in its use in therapeutic programs. This is what previous studies have demonstrated regarding the importance of modern technological techniques in therapeutic programs. A person with aphasia who speaks the Kabyle dialect suffers from difficulties in the functional physiological picture of the phonological loop during the process of phonological storage and retrieval during neural activity in the language center of the brain. This results in a complete or partial loss of language. Therefore, we relied on the technological technique of functional magnetic resonance imaging (fMRI), which directly demonstrates language function. We also used the assessment test for the physiological functional picture of the phonological loop, thanks to which we were able to assess the patient's aphasia symptoms. We then implemented the therapeutic program, which consists of the phonemic-phonological therapeutic protocol in the Kabyle dialect as a training program. This addresses two aspects through a practical study. We examined the theoretical and practical aspects. This allows us to verify our research hypothesis: the effectiveness of the phonemic-phonological therapeutic protocol in the Kabyle dialect is effective and has a positive impact on aphasia patients. This is achieved by using IRMF technology. IRMF is a modern technological technique that is effective in developing the physiological functional image of the phonological loop in aphasia patients and accurately demonstrates how to develop and evolve the phonological functional activity of the language. The theoretical aspect is divided into separate chapters. The practical aspect, to answer the research questions and verify the hypotheses, is divided into three procedural chapters. The first procedural chapter includes the exploratory study, the research methodology, spatial and temporal boundaries, the research sample, and research tools, including defining the research location, which included (20) cases of aphasia. The chapter also explores the statistical methods and scales used to answer the study questions, as well as the pre- and post-test measurements, using a physiological functional assessment test of the phonological loop. The second procedural chapter is devoted to presenting and analyzing the results, verifying the hypotheses through a psychometric study, embodying the validity and reliability of the test. We then applied it to the study group in the pre- and post-tests. During the specified period, we implemented the treatment protocol, after which the results were analyzed. The third procedural chapter examines the statistical processing of the results using an individual t-test, followed by an analysis and discussion of the results. In conclusion, our study demonstrated the effectiveness of a phonemic-phonological therapeutic protocol in the Kabyle dialect for Habsi patients who suffer from difficulties at the phonological loop level. Through the application of the protocol, it was shown to be effective in developing the functional-physiological picture of the phonological loop. It also validated the hypothesis regarding the

importance of using functional magnetic resonance imaging (fMRI) technology in the field of orthophony, particularly in the therapeutic program. Thus, it was demonstrated that the main and partial hypotheses of our study were achieved.

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