Integrated Platform for Computer Assisted Rehabilitation for Romanian Aphasia Impaired Patients

Dorin Carstoiu, Alexandra Cernian, Adriana Olteanu

University Politehnica of Bucharest, 313 Splaiul Independentei, sector 6, Bucharest, Romania

Abstract

This paper presents an interdisciplinary approach for creating an innovative computer-based platform for the rehabilitation of aphasia patients, dedicated to the Romanian language and culture. Aphasia is a neurological disorder of speech, with moderate to severe dysfunction of the mechanisms involved in language expression and understanding, affecting a large population of patients. With a wide area of symptoms, it leads to an important decrease in the patients’ quality of life and social functioning. Due to the high costs, long-term duration and lack of accessibility of the classical methods of recovery, our goal is to develop a more user-friendly, multimedia, software-based solution to aid in the rehabilitation of aphasia-related symptoms. Integrating a computerized system as a treatment option for aphasia provides several advantages and benefits, from medical, technical and social perspectives.

Keywords: aphasia; computer assisted rehabilitation; neurological disorders; Romanian language and culture

1. Introduction

Aphasia is a neurological disorder of speech, with moderate to severe dysfunction of the mechanisms involved in language expression and understanding, affecting a large population of patients. With a wide area of symptoms, it leads to an important decrease in the patients’ quality of life and social functioning.

* Corresponding author.
E-mail address: dorin.carstoiu@aii.pub.ro
At present, there are numerous experimental studies demonstrating the successful computer-aided treatment of aphasia speech deficiencies. The current technological advance allows the implementation of computerized treatment strategies, while having a most accurate patient-oriented approach, by focusing on his personal characteristics and needs [1].

Although currently there are dedicated computer applications for aphasia rehabilitation, there is no such specialized software for the Romanian language. Due to the high costs, long-term duration and lack of accessibility of the classical methods of recovery, our goal is to develop a more user-friendly, multimedia, software-based solution to aid in the rehabilitation of aphasia-related symptoms. Computer-assisted aphasia treatment requires the implementation of user-friendly, dynamic and flexible software applications for individualizing treatment. It is also important to take in consideration that this is the first attempt to create such a platform based on the linguistic and cultural specificities of the Romanian language.

The paper is structured as follows: Section 2 discusses the current context for computer assisted treatment in neurological affections, focusing on aphasia symptoms, classification and therapy options; Section 3 presents the architectural design and functionalities of the AFARom integrated system, a Web platform dedicated to assist aphasia rehabilitation for Romanian linguistic and cultural specificities; Section 4 draws the conclusions of this paper and discusses future developments.

2. Computer assisted treatment in neurological diseases

In the medical field, the computer has proven to be an indispensable tool for disease monitoring, diagnosing diseases based on intelligent algorithms, but also for the treatment of certain diseases. An area of medicine in which the computer has had a major impact is neurology, where it has been used successfully in the treatment of speech disability therapy following injury or innate. Efficacy of computer-assisted medicine in this area has increased significantly with increasing processing capacity and image and sound rendering capabilities of modern computers.

In 2004, Falconer stated the response of neurological patients to computer-aided therapy is positive [1]. He explained that patients are able to work independently for the first time since their accident and tend to respond more quickly to a specific type of treatment, because the computer is less critical then a therapist when the patients’ performance is unsatisfactory, suggesting that the impersonal treatment may have greater benefits. When used properly, these tools can increase the performance in rehabilitation therapy of cognitive and speech impaired patients and provide the following benefits:

- Minimize the cost of treatment
- Record and generate statistics for further analysis
- Provide impaired people ways to interact with people around them
- Reduce the need for surveillance, since patients can practice in the comfort of their own homes
- Enhance rehabilitation therapy

Thus, computerized treatment can be a powerful tool that provides physicians the possibility to easily personalize treatment for patients, but also a way for patients to work independently in their own home, in order to improve skills lost due to suffered trauma.

2.1. Aphasia symptoms and classification

According to specialized literature, there is a distinction between speech and language [2]. Obstacles of articulation and pronunciation of words are defined as elocution disorders, while difficulties in forming sentences and understanding the meaning of a sentence is altered language. Aphasia usually results from lesions to the language related areas of the brain, such as Broca’s area, Wernike’s area, and the neural connections between them. These areas are usually located in the left cerebral hemisphere, and in most people, this is where the ability to produce and comprehend language is to be found. Patients with aphasia
have difficulty using language to express their thoughts [3]. The disease affects the language in different ways, both characterized by deficiencies in verbal flow - the ability to speak and difficulty in understanding concepts expressed by others.

Due to the complexity of the disease, a complete taxonomy could not be defined. Experts in the aphasia field were not able to agree on a universal classification. However, there are four basic types on which most neurologists have reached a consensus [4][5]:

1. Anatomical Aphasia is the least severe form of aphasia, in which patients have difficulty communicating only with certain people in certain situations, while the rest of the conversation unfolds naturally and normally.

2. Expressive aphasia or Broca aphasia is characterized by incoherent speech, with disruptions and difficulties in both verbal and written language. The patients are not confronted with an inability to understand the language of others, but they express themselves with difficulty, often repeating the same idea several times.

3. Receptive aphasia, also called Wernicke's aphasia is a type of aphasia that affects both the understanding of language and the ability to speak coherently. Patients will have difficulties in understanding others, although they are able to read and hear. They can pronounce words fluently, but include meaningless phenomena and not know the meaning of words and the correlations between terms.

4. Global aphasia is the most severe form of aphasia, resulting from extensive trauma portions of the brain responsible for language, the patient will be unable to communicate and fully understand people around him.

2.2. Aphasia treatment options

The goal of aphasia rehabilitation is to improve the patients’ understanding and communication, as well as to ensure their social re-integration [6]. For instance, treating aphasia after a stroke is a very important aspect of the recovery process for a patient with impaired language [3]. The lack of medication or surgery to treat the disease leads to the need for treatment methods that rely on memory and vocabulary practice [6].

The neurologist will determine the recovery schema for aphasia patients based on clinical examinations. Once a diagnosis has been made, the adequate treatment must be tailored according to each individual’s needs. Usually, it is recommended that speech therapy starts within the first month after the accident which caused aphasia [7].

According to Jose Vega, for best results it is recommended to increase the intensity of the treatment over time. Moreover, the effectiveness of treatment will greatly improve if the patient is subjected to several different stimuli, such as pictures, sounds, drawings, etc.. Another aspect to be taken into consideration to improve the healing process is to increase the degree of difficulty of the language exercises [3].

According to [8], there are three approaches to aphasia rehabilitation therapy:

• Disease-oriented therapy focuses on the functions of the body. It is based on linguistic treatment, aimed at restoring language processing [6]. In this type of treatment using exercises that focus on semantics, phonology and syntax.

• Functional therapy focuses on the second area defined by the ICF, namely activities. This type of treatment focuses on ways to obtain "an optimal level of communication" [6], by teaching the patient to use their residual language abilities as effectively as possible, attempting to use gestures or communication alternatives to substitute for linguistic communication.

• Participation oriented treatment aims at the direct social participation. The approach focuses on "living with the consequences of aphasia" [6]. The therapist will focus on integrating the patient in society, communication with family and friends, return to work. Family and friends are directly involved in this area of treatment.
The latest trend in aphasia treatment, as well as the goal of the application presented in this paper, involves the use of new generation computer technology. According to several studies, there is evidence of positive effects computer-assisted therapy has for people with aphasia [9], [10], [11].

Van de Sandt-Koenderman [12] developed and evaluated a portable communication platform (PCAD) for aphasics to support communication in everyday life. The study showed that a select group of patients with chronic aphasia is able to acquire the necessary skills to operate the PCAD. The software ran from a portable device, and consisted of an empty vocabulary that can be filled with items that are personally relevant for each individual. The therapist and client chose relevant vocabulary using pictures, drawings, photos and text. This vocabulary can be used to create messages that are displayed by the device, with or without speech output.

Van de Sandt-Koenderman [13] undertook in 2007 an interesting study investigating the efficacy of the TouchSpeak system. The training focused on using the vocabulary of the device in specific day-to-day situations and included role-play sessions and time to practice at home. Following training, around half of the participants could navigate the complete set of 176 buttons on the device. The patients’ communication abilities were significantly improved after this training.

Joshua Hailpern (2011) [14] introduces a novel system and model, called Aphasia Characteristics Emulation Software (ACES), which enables users to experience the speech-distorting effects of aphasia. The ACES system was designed to distort a user’s Instant Messages (IMs) from the original message to one that appears like a message spoken by an individual with aphasia. Results from an evaluation of 64 participants indicate that ACES provides a rich experience that strongly increases understanding and empathy among aphasia patients.


3. Intelligent platform for neurological patients with speech and language disorders

Although there are several computerized systems designed to assist aphasia treatment, they are only adapted to a few languages (English, Spanish, Italian). Thus, it is difficult to adjust them for being used worldwide, since each language has its own specificities. The aim of the project presented hereby is the design and implementation of a computerized system for aphasia rehabilitation, integrating the Romanian cultural and specific linguistic aspects. This involves a multidisciplinary approach, bringing together specialists from two important domains: medical and information technologies.

The main objectives of this project can be synthesized in two main areas:

1. Technological and medical progress in aphasia rehabilitation
   This involves the contribution to the current state of the art in neurological science, by developing an integrated, intelligent and cost-effective platform for rehabilitation patients with aphasia and demonstrating the efficiency of this system as scientific support in current medical practice.

2. Improving the quality of life
   This involves increasing the quality life indicators for aphasia patients, enhancing their social and economic integration and communication abilities.

   At the moment, there is no such product on the medical market in Romania. Given the fact that similar products have shown good results for other languages, there is no doubt that such a system could bring enormous benefits to the Romanian medical advances in treating patients with aphasia disorder.
3.1 The system architecture and functional capabilities

The application was developed on web-based architecture and it acts like a Web portal interconnecting two main actors: the patient and the medical therapist. As a future development, we plan to extend the system with a mobile platform for smart phones and tablets. The main components of the system are the following:

1. Patient and doctor modules. Each module provides specific functionalities for enhancing computer assisted aphasia treatment. Each module is provided with specific user interface. The main criterion here was to provide a user-friendly and intuitive interface, in order to enhance a pleasant experience for both patient and doctor.
2. Storage database. The main repository consists of a relational database used for storing all information related to patients and their customized therapy and personal history.
3. Expert system module. This component provides decision support for the medical therapist in evaluating and prescribing the therapy schema for each individual patient.
4. Web portal. This component synchronises and correlates the patient and doctor data, in order to provide an integrated and flexible platform.

Figure 1 depicts the architecture of the AFARom integrated system for aphasia rehabilitation.

![AFARom integrated system architecture](image)

The proposed architecture for the AFARom integrated system is the first multidisciplinary approach in Romania to attempt to bridge the gap between aphasia research and the rehabilitation of patients with this disorder. This artificial intelligence based approach will provide new sets of rules and criteria for categorizing patients with aphasia disorder in Romania, together with establishing therapy schemes adapted to each category. The expert system plays an important decision support role in the above architecture, assisting the neurologist or specialized medical therapist in defining and validating individualized therapy schemas.

One of the current drawbacks in treating aphasia is a certain lack of flexibility. The therapist cannot effectively monitor the patient’s evolution over time, since he does not always have control over the practice of the patient. For example, if the patient exercises at home, the therapist will not be able to evaluate the patient’s performance, without an integrated platform to store the results. This is one the main shortcomings AFARom aims to overcome.
The proposed solution aims to assist the doctor in creating customized treatment for each patient. The first step is to determine the type and degree of aphasia the patient is suffering from. The patient will undergo a series of clinical examinations. In parallel, the clinician will use a set of predefined tests included in AFARom. These preliminary tests assist the therapist in the process of diagnosing the patient and establishing his future therapy schema. The clinical evaluations and the AFARom diagnosing tests are complementary. The second step is for the therapist to develop the therapy plan for the patient and continue to monitor the patient’s evolution with the AFARom integrated system.

One of the main goals in developing this platform will be to provide a high degree of treatment customization. The application will be able to manage a large number of patients, monitoring their evolution and allowing the clinician to adapt their therapy at any given moment. The application provides a predefined set of treatment modules, established by experimented medical staff and based on scientific methods. Each module will be divided into different levels of difficulty. For each of these modules, a large number of exercises will be provided, designed for the Romanian language and aimed at improving the patients’ speech and language rehabilitation: image and sound recognition, image association, image and sound similarities, word recognition, word association, verb and actions recognition, semantic classification of words, identification of objects, transcription of letters and words, solving arithmetic operations, typing words, color identification. For each treatment module, the clinician can add new exercises. Moreover, the clinician is also able to define new treatment modules.

When establishing the treatment scheme for a specific patient, the therapists can combine exercises from different modules and difficulty degree, according to each patient’s specific needs. The scores obtained by the patient during his treatment and his overall progress are monitored and stored in the database of the application. Thus, at any time, the therapist can view the results of the conducted therapy and check on the progress and improvements made by the patient. Based on these previous results, it will be easier to decide upon the continuation of the treatment.

The application will also contain a statistics module, allowing therapists to have an overall image of the results produced by the treatments they have set up. Based on these figures, an ultimate outcome will be establishing some connections between certain aphasia symptoms and diagnosis, and successful therapy schemes. Thus, when a similar patient is identified, the expert system makes the connections with the history of similar cases and recommends the corresponding therapy schema and exercises, based on the successful stories stored in the AFARom database.

Figure 2 presents an overview of the main functionalities provided by the AFARom system for both the patient and the therapist.

![Fig. 2. AFARom system – main functionalities overview](image-url)
Thus, the AFARom system has two main actors: the patient and the therapist. Figure 3 represents the UML use case diagram, illustrating the functionalities the platform provides for both users and their interactions.

![AFARom UML use case diagram](image)

**Fig. 3. AFARom UML use case diagram**

### 3.2 Estimated benefits and outcomes

Integrating a computerized system as a treatment option for aphasia ensures barriers’ lifting, leads to the improvement of traditional therapy methods and provides several advantages and benefits, from medical, technical and social perspectives:

1. **Medical benefits**
   - *Increased intensity of therapy.* The intensity of the therapy is a key factor in the success of aphasia treatment. A minimum of 2-3 hours per day is required in order to obtain positive results. The main advantage of using computers is that the intensity of therapy can be significantly increased. These programs consist of a large variety of exercises and can be done at home, in addition to face-to-face treatment with a therapist.
   - *Customized practice.* Since aphasia presents differently among individuals, dedicated treatment schemes must be tailored according to each patient’s needs. Based on the progress of each patient, the therapist will be able to customize the computer program, in order to adapt to the evolution variability of each individual.
   - *Patients’ categorization.* Based on an in-depth analysis of the currently available criteria for classifying different types of aphasia patients, the medical team will define new sets of rules and criteria for categorizing the aphasia patients in Romania. The identified groups will also be integrated in the computerized system, the final aim being to establish specific and extendible treatment schemes for each category of patients.
• *Evolution tracking.* With the aid of a computerized system, the medical staff will be able to objectively keep track of the entire evolution of a patient. Based on the analysis of the score evolution of each patient, predictive reports can be generated and future therapy approaches can be easily established.

• *Reporting facilities.* The medical staff can benefit from a computerized system’s graphical reporting facilities. The entire evolution of a patient can be accessible at a glance, enhancing the clinicians to predict the outcome of the therapy and to individually tailor the treatment according to the patient’s needs.

2. **Technical benefits**

• *Scalability and configurability.* The project will produce a scalable and highly configurable platform. The users will be able to easily introduce and update data, as well as to generate reports and statistics regarding the patients’ information.

• *Modularity.* The solution will be modularized and structured on clearly defined layers. For instance, treatment options will be represented under distinct modules based on their purpose (visual, sounds etc.) and difficulty. When a clinician establishes a treatment scheme for a patient, he can combine in various manners the exercises defined under each module. Moreover, users can also define new modules, in an intuitive manner.

• *Open system architecture.* The computerized system for assisting clinicians in aphasia treatment falls under the open systems architecture paradigm.

• *Language specific.* The platform will be dedicated to the Romanian language, by taking into consideration all cultural and linguistic aspects.

• The medical and technical aspects are harmoniously combined to provide the users of the computerized system with a friendly and intuitive interface, making the platform easy and pleasant to use.

3. **Social benefits**

• *Friendly environment.* Patients may obtain better results when working at home, surrounded by their family and their friendly environment. This approach reduces the hospital-induced stress, making the patient feel more at ease. However, this does not eliminate or even reduce the importance of the clinicians, given the fact that the exercises undertaken by a patient at home are established and monitored by the therapist.

• *Increased health degree.* The increased intensity of the treatment provided by combining conventional therapy with a computer-based approach will lead to increased speed recovery for patients with aphasia. On the one hand - this aspect brings significant benefits from a medical point of view, on the other hand – the social aspects cannot be overlooked, since a faster recovery means a quicker re-integration in the social and professional activities.

4. **Conclusion**

Although the AFARom platform is in a prototype phase at present, we are confident that it will have a significant impact in the rehabilitation process for aphasia patients. As previous similar implementations demonstrate, integrating a computerized system as a treatment option for aphasia provides several advantages and benefits, from medical, technical and social perspectives. A bottleneck we have identified is the lack of a computer assisted aphasia rehabilitation system dedicated to the Romanian language and culture. And that was the inception point for developing the AFARom system. The next step is setting up an interdisciplinary team which integrates medical specialists, in order to develop adequate training modules and questions.
References


