



Developing a Computer System Prototype to Support Aphasia Rehabilitation

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ABSTRACT

The purpose of this study is to describe the construction process and the evidence of content validity of SCARA, a prototype of a technological system to support language and communication rehabilitation in people with aphasia, providing a tool that serves both patients and health professionals who accompany the respective recovery process. The process followed four stages: internal phase of the program's organization, with research in the literature and analysis of the materials available in the Portuguese market; construction of the SCARA prototype; evaluation by experts; and data analysis. A Content Validity Index was calculated to determine the level of agreement between the experts. The level of agreement between experts showed the validity of SCARA. SCARA has shown to help the work of the speech-language pathologist and persons with aphasia, contributing to a higher therapeutic quality, enhancing linguistic recovery, and compensating for the impossibility of direct support more frequently and/or prolonged intervention.

CCS CONCEPTS

• Applied computing; • Life and medical sciences; • Health informatics;

KEYWORDS

Aphasia, Rehabilitation, Computer application

ACM Reference Format:

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1 INTRODUCTION

Stroke is one of the most severe health problems today, with high incidence, and is considered the most common cause of Portuguese and European mortality and morbidity [1]. The survival rate is growing [2], with a consequent increase in temporary or permanent sequelae, with an impact on the quality of life of the stroke survivor.

Aphasia is an acquired communication disorder caused by brain damage and associated difficulties in understanding, producing, and using oral or written language [3]. It is also known as a symbolic communication disorder, with the relatively intact maintenance of cognition [4]. The impact of aphasia and its implications at the personal, family, and socioeconomic levels underlie the importance of rehabilitation [5, 6] since it aims to reduce the effects of aphasia and restore linguistic functions.

Good practices in the care continuum in aphasia mainly recommend intervention in speech therapy, aiming to improve functional communication, reading, writing, and expressive language, with an indication for direct and intensive intervention [6]. The main objective of aphasia recovery is to allow the person with aphasia (PWA) to manage and overcome their disability and become as autonomous as possible [7]. Thus, rehabilitation can be understood as improving deficits and language functioning or as a process of learning and adapting to difficulties and living successfully, regardless of the presence of aphasia [8]. It is possible due to neuronal plasticity or neuroplasticity, which allows neurons from other areas of the brain not affected to assume certain functions performed by neurons in the injured area [7].

Randomized and meta-analysis studies [6, 9, 10] concluded that the therapeutic intervention of language after a stroke is adequate, even in the chronic phase, if it is administered with sufficient intensity (≥ 10 hours per week). It demonstrates that the intensive therapeutic intervention can be considered an intervention based on evidence and is more effective in the absence of intervention or low-frequency intervention (< 5 h per week). This highlights the importance of intensive and prolonged recovery from aphasia over time. However, in Portugal, the number of human and technical resources, namely speech therapists, in the rehabilitation units is deficient [11, 12].

The recovery from aphasia is highly variable and occurs individually [12]. It must be programmed according to the PWA, their abilities, and their limitations, and the SLP must graduate the difficulty, measure progress and adjust the therapeutic plan whenever

Table 1: Nomenclature

Acronym	Description
AAC	Alternative and augmentative communication
PWA	Person with aphasia
SCARA	Computer System to Support Aphasia Rehabilitation (acronym portuguese to ‘ <i>Sistema Computacional de Apoio à Reabilitação da Afasia</i> ’)
SLP	Speech-language pathologist

necessary [7]. SLP that treats aphasia must follow some basic principles, such as assessing language, being versatile, having common sense, and being a good listener.

Alternative and augmentative communication (AAC) systems that use assistive technologies, information systems, and technologies maximize the functionality and effectiveness of the communication of people with aphasia [14]. These data are favorable to the acceptance/ feasibility of using information technologies as tools for intervention in rehabilitating people with aphasia. The SLP is based mainly on a low technology system (paper and pencil) in therapy. However, with technological advancement, digital products have started to appear that have proven to be solutions of great therapeutic applicability [11].

The data presented supports that technological systems could be a practical solution to leverage existing resources, as they allow an extension of the moments of therapeutic intervention, enabling an increase in the intensity and frequency of therapeutic intervention.

In the current Portuguese market, few tools based on web technology support the SLP’s work in treating PWA [11, 14], like Lingraphica, Proloquo2Go, TactusTherapy and Tapgram. The existing platforms show some negative aspects, such as the lack of information in the open area, which makes divulging difficult. Moreover, the absence of terms of use, indications regarding the general regulation on data protection, and the request for consent regarding the use of cookies make this understanding even worse. In the existing solutions, the platform interfaces’ visual aspect may compromise their viewing, as they do not use solid or soft background colours, contrary to what is advocated in Web Design. This aspect assumes particular importance as it may make it difficult to view, depending on the type and characteristics of the users’ monitor [16]. In their exercise area, there is a contrast between the intense background colour and the light colour of the exercise cards, which can impair PWA’s understanding and execution. Because there is a high degree of interdependence between language and other cognitive domains, such as attention and perception [17], PWA usually has associated sensory impairment [18]. Thus, the visual and information characteristics transmitted are fundamental because they can interfere with the visual-spatial capacity of PWA. Also, these tools have been developed for personal use, not allowing to follow the evolution process, nor do they allow sharing information with the therapists or medical doctors involved with the patient.

2 METHODOLOGY

Within the project’s scope was the development of the SCARA prototype, a computer system to assist and enhance therapeutic

intervention in people with aphasia. This solution is entirely supported by web technologies, creating more accessible communication between the PWA and the SLP.

The basis of the methodological approach of the investigation is the development of a project, which aims at the idealization and creation of a technological platform that supports the recovery of language and communication carried out by the SLP/ rehabilitation team, and that fills in the gaps found in the other existing tools.

2.1 Procedures and instruments

The process of creating the SCARA took place in four stages (see Fig 1)

2.2 Evaluation and Data Analysis

After the design of the prototype of the SCARA platform, we will perform an evaluation based on interviews with experts previously exposed to the SCARA tool and after some time using it.

The evaluation protocol is composed of 10 questions, which aim to understand the system’s functionality, whether the objectives of this research were achieved, and to answer the research guiding question. The questions are listed in the following table, together with the objectives of each one.

A Content Validity Index (CVI) was calculated to determine the level of agreement between experts and verify the validity of SCARA in general [19]. CVI allows measuring the percentage of experts who agree to a specific item when Likert scales are involved. The index is calculated by adding the items rated 3 or 4 by the experts. The sum is divided by the total number of responses in the item’s evaluation using the following formula.

$$CVI = \frac{\text{Number of answers with '3' or '4'}}{\text{Total number of answers}}$$

3 PROTOTYPE DESIGN

After defining all the methodological aspects, the requirements for the prototype development have been collected and organized. We conducted interviews with several SLP to collect those requirements, precisely the non-technical requirements. The collected requirements are presented in table 3.

3.1 Stage 1: Program organization

SCARA is a web platform with features designed for a specific population, usually with some associated degree of sensory impairment and in the cognitive domains of attention and perception.

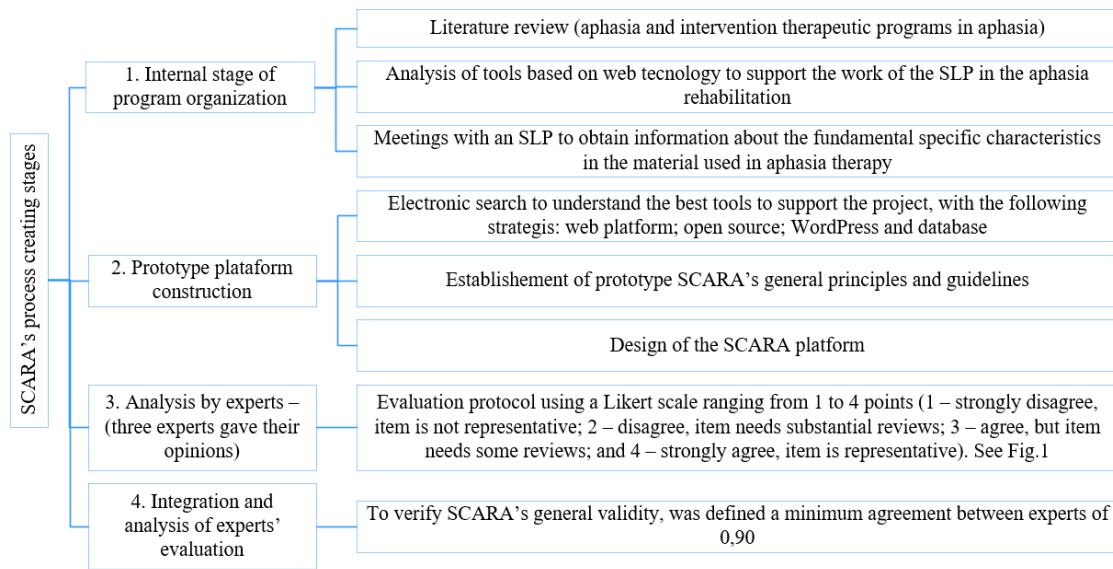


Figure 1: SCARA's process creating stages

Table 2: Evaluation protocol used in experts' analytical process and corresponding objectives

#	Questions	Objectives
1	Is SCARA suitable for people with aphasia?	The usefulness of the tool
2	Is navigation clear and intuitive?	Quick and convenient tool repository
3	Are the platform interfaces suitable for people with aphasia?	The usefulness of the tool
4	Are the functionalities to be made available in the SCARA-public area relevant?	The communication path between the SLP and the PWA facilitating interaction, regardless of physical distance
5	Are the functionalities to be made available in the SCARA-private area relevant?	The communication path between the SLP and the PWA facilitating interaction, regardless of physical distance
6	Do you consider the possible interaction between the three types of users for the therapeutic process helpful?	Provides data about the evolution of the PWA
7	Do the exercises available on the platform have aesthetic characteristics (such as clarity of instructions, type and layout of the images) that allow them to be used to recover from aphasia?	Quick and convenient tool repository
8	Can the use of SCARA contribute to a greater motivation of users to perform exercises at home?	Facilitates and motivates PWA in carrying out the exercises proposed by the SLP
9	Will the use of the tool in therapeutic intervention be beneficial for the recovery from aphasia?	As a facilitating communication route in the therapeutic intervention of aphasia and thus improve the quality of the therapeutic intervention in PsCA
10	Would you like to use this platform in aphasia therapy?	As a facilitating communication route in the therapeutic intervention of aphasia and thus improve the quality of the therapeutic intervention in PsCA

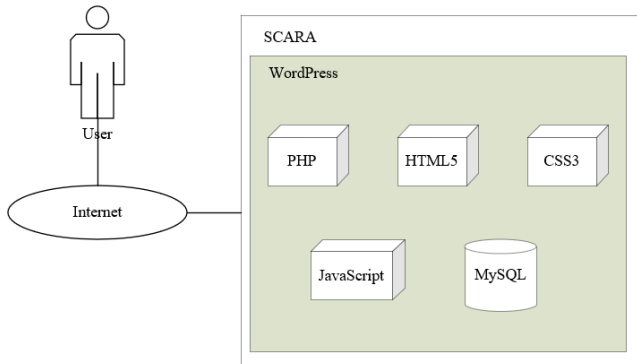
The SCARA logo (Fig 2) is based on the schematic representation of the left cerebral hemisphere (dominant for language), the cerebellum, and the brainstem, so it is composed of distinct colours, which represent the four primary lobes of the left cerebral hemisphere, the cerebellum, and the brain stem.

The user interface was thought of: in the physical dimension (the elements that the user can manipulate); in the perceptual dimension

(the elements that the user can perceive); and in the conceptual dimension (processes of interpretation and reasoning of the user triggered by their interaction with the system, based on its physical and cognitive characteristics, its objectives and its work environment). Thus, we opted for interfaces with visual and sound elements, with data input via keyboard, mouse, and voice. To design SCARA

Table 3: Prototype requirements

Type	Requirement
Technical	Open-source technologies Database Web-based platform for accelerating the development process
Non-Technical	Ease of learning Ease of use The efficiency of use and productivity Allow user satisfaction Flexibility Utility Safety in use


Figure 2: SCARA logo

Figure 3: Technology adopted in the SCARA project

in order to adequately support users in their tasks and in the environment in which it will be used, several interviews with an SLP were carried out to identify the needs of users, care to be taken at the interface, and in the specificity of the population to which the platform is intended. Therefore, they were defined as priority factors to the system in the concept of usability [20]: ease of learning; ease of use; efficiency of use and productivity; user satisfaction; flexibility; utility; and safety in use.

The platform base was selected based on technological solutions that followed the criteria: being open-source, having a database, and serving as an information platform.

The technological options are represented in Fig. 3. The MySQL open-source database was selected. This database has proved to be quite powerful, having a vast community contributing to its development and being the number one database on the web [21]. To serve as the basis for the project, the WordPress platform was selected, as it has a strong presence on the web, supporting a large

percentage of internet sites [22]. It is the basis for installing applications that support issues such as GDPR management, cookie consent, interactive games, user management, and display themes. Version 5.4 of the WordPress platform was chosen.

3.2 Stage 2: Prototype platform construction

Structurally SCARA consists of two areas, one public and one private (SCARA-public area and SCARA-private area), as seen in Fig. 4

The SCARA-public area intends to respond to users in general, focusing on informative aspects regarding the problem of aphasia and its recovery, containing clarifications that are mainly aimed at patients, family members, and caregivers.

SCARA-private area is a platform area with access restricted only to users with valid credentials. This area is divided into three zones according to the type of user, SLP, PWA, or physician. The PWA zone for access to users is accredited by the SLP, the Physician zone for the doctor responsible for accessing the rehabilitation process, and the SLP zone for restricted access to the SLP.

SCARA users, after gaining validated access into the SCARA-private area, can assume one of three roles, as shown in Fig. 5. For the system to initiate a recovery process, it is necessary to check a minimum of papers from an SLP and a PWA. The connections between the other roles of Physician-SLP and Physician-PWA are optional, as it is possible to perform the recovery process independently of creating these roles and consequent relationships on the platform.

For the system interface, a visual aspect with light colours and a clear aspect was chosen to facilitate its use by PWA. The SCARA's visual aspect is similar across the platform, with only minor occasional changes.

The SCARA-private area followed the guidelines of the interface of the SCARA-public area. However, the space of the navigation sidebar was removed to extend the length of the contents area.

This change made it possible to increase the available field for the functional work area. It allowed to present exercises with videos or larger images and thus facilitate the user's visualization and interaction. On the other hand, as the platform is intended to be responsive, this change facilitates the use and performing of exercises even on equipment with smaller screens.

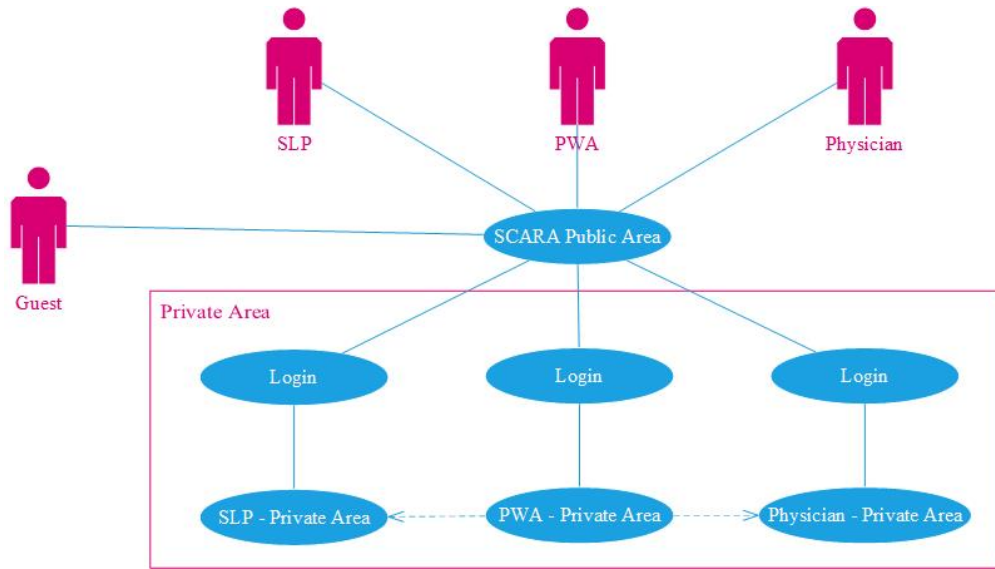


Figure 4: SCARA-public area interface

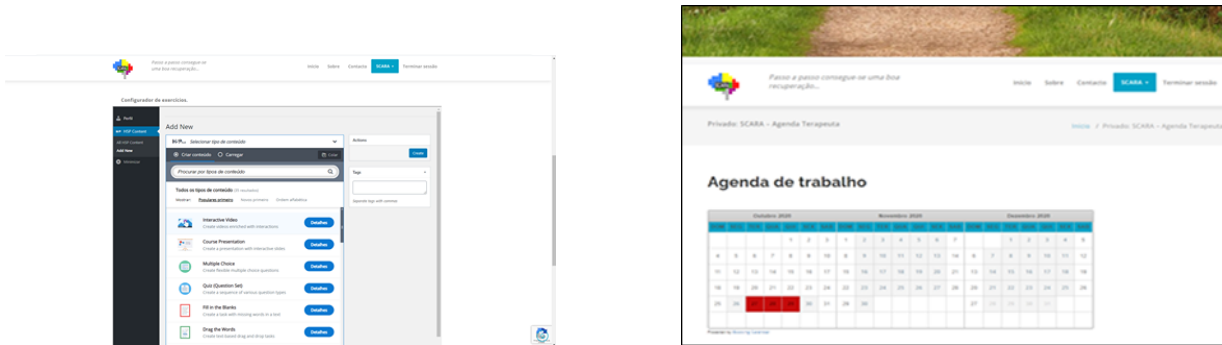


Figure 5: SCARA-SLP User area examples: (a) exercise configurator option; (b) schedule the activities to be performed by the PWA user.

The content area was left with a white background colour to give more contrast and facilitate the exercise execution.

Structurally, each area of the SCARA-private area is composed of:

- **SLP User:** This zone is restricted to the SLP. This user will be able to send messages to other users; create exercises/activities in the exercise configurator option (see fig. 5a); schedule the activities carried out by the user (see fig 5b); consult the results of the exercises carried out by the user PWA;
- **PWA User:** This zone is accessible to the PWA accredited by the SLP. This user will be able to send messages to other users, access the schedule made by the SLP, access the exercises prescribed by the SLP (fig 6a), and access the results (fig 6b);
- **Physician User:** This area is accessible to the physician. This user will have access to informational data about the rehabilitation process provided by the SLP and will be able to send messages to the other two users.

4 EVALUATION AND RESULTS

As planned and presented in the methodology, after building the prototype, we started an evaluation process, using a group of experts and the questions previously defined to analyze SCARA responsiveness to the initial purpose. Thus, the SCARA prototype was assessed by a panel of experts composed of three specialists in aphasia rehabilitation. In this sense, the collaboration of three SLPs was requested as experts. Each of those experts had more than ten years of working with people with aphasia. The rigour of their professional and academic background was considered in the selection of the group of evaluators. Table 4 shows the time experience and level of education of each expert. The experts had access to the platform's prototype to explore and test it. Subsequently, they were asked to complete an assessment protocol (Table 5) with a Likert-type scale (score from 1 to 4) to assess the SCARA.

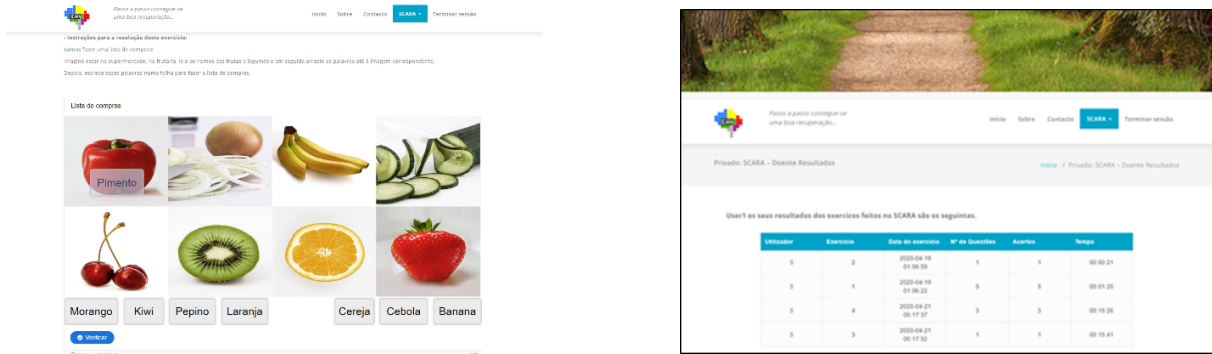


Figure 6: SCARA’s interface examples of PWA User: (a) exercises prescribed by the SLP; (b) results obtained in the exercises performed.

Table 4: Level of education and time (years) experience (t) of the experts

Expert	Education Level	Years of experience in aphasiology (t)
Expert 1	Expert in therapy and rehabilitation	17
Expert 2	PhD in Health sciences and technologies	30
Expert 3	PhD in Neurosciences	31

Table 5: Results of SCARA evaluation by experts

Evaluation criteria	J1	J2	J3	CVI
1 Is SCARA suitable for people with aphasia?	4	3	4	1
2 Is navigation clear and intuitive?	4	4	3	1
3 Are the platform interfaces suitable for people with aphasia?	3	3	4	1
4 Are the functionalities to be made available in the SCARA-public area relevant?	4	4	4	1
5 Are the functionalities to be made available in SCARA-private area relevant?	4	4	4	1
6 Do you consider the possibility of interaction between the three types of users for the therapeutic process useful?	4	4	2	0,667
7 Do the exercises available on the platform have esthetic characteristics (such as clarity of instructions, type and layout of the images) that allow them to be used to recover from aphasia?	3	3	4	1
8 Can the use of SCARA contribute to greater user's motivation, to perform exercises at home?	4	4	4	1
9 Will the use of this tool, in therapeutic intervention, be beneficial for the recovery from aphasia?	4	4	4	1
10 Would you like to use this platform in aphasia therapy?	4	4	4	1

To determine the level of agreement between experts and verify the validity of SCARA in general, we used CVI, as described in chapter 2.

The overall evaluation of the SCARA prototype showed a level of agreement (CVI) of 0,96. That suggests that, from the experts' perspective, this platform serves what it intends. Every judge agrees with almost all of the items assessed. Only one judge disagrees that the possibility of interaction between the three types of users can be helpful for the therapeutic process (question 6). And all experts strongly agree that the functionalities to be made available in SCARA are relevant (questions 4 and 5), as well as the use of SCARA contributes to a greater motivation of users to perform exercises at home (question 8), and that the use of this tool, in therapeutic intervention, being beneficial for the recovery from aphasia (question 9). They also agreed strongly to use this platform in future aphasia therapy (question 10).

With these results, the validity of SCARA was demonstrated. This project aimed to design the prototype of the SCARA platform. Analyzing the results obtained, it is observed that this future technological tool's prototype was able to meet a fundamental requirement of therapeutic intervention: providing a communication way between the SLP and the PWA in real-time regardless of the physical distance.

SLP constantly needs to select and adapt therapeutic exercises according to the therapeutic objectives and the difficulty level achievable by each PWA. It was also shown to be important that SCARA provided the SLP with the possibility of using a repository of tools for quick and practical access and enabling the SLP itself to create its exercises. It is also essential that SCARA enables the SLP to systematically supervise and evaluate the level of evolution/ difficulty presented by the user.

The fundamental requirements of this project were that this future tool would be able to help the work of the SLP and the PWA, contributing to a higher therapeutic quality, enhancing linguistic recovery, and compensating for the impossibility of direct support in more frequent and/or prolonged interventions. Another principle of this project was that SCARA would prove to be a captivating and facilitating tool for the PWA to carry out the exercises proposed by the SLP.

Thus, by analyzing the results, it is possible to infer that this project reached the objectives it set out to achieve.

5 CONCLUSION

SCARA is a platform that allows the extension of the work of the SLP in rehabilitating aphasia. This study presents the results obtained in constructing SCARA's prototype and validating this

tool from experts' analysis. The results obtained were favourable to SCARA's content validity. These satisfactory results are essential for constructing an instrument that is useful, efficient, and suitable for the therapeutic context, which will fill the lack of existing supplies in the Portuguese market and offer a more captivating, clear, and easy-to-use solution concerning existing solutions for PWA.

Although the present study has revealed interesting results, important limitations should be noted, such as the need to increase the validity of the results of this study by extending the evaluation of this platform to more SLP experts since the number of judges who participated in the validation process is quite small. Testing this prototype in a natural therapeutic intervention environment is also essential.

Future work with this prototype is essential to investigate the effectiveness of SCARA in a natural context with PWA. The consistent collection of evidence of the program's effectiveness is essential to guarantee not only its internal validity but also to identify its therapeutic applicability.

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