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Digital tool as speech and language therapy for patients with post-stroke aphasia

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Abstract

Introduction: New technologies could play a role in post-stroke aphasia (PSA). Our aims were to develop a digital tool; to evaluate its acceptance and usability by patients and caregivers; and to demonstrate its effectiveness in improving language skills in patients with PSA, applying it from the acute phase.

Methods: The study consisted of two phases: development of a digital tool; and an interventional before-and-after study. During the first week of admission, the digital tool, VerbalizAPP®, was installed for use with the help of family/caregivers. PSA was evaluated by a summarised version of the Boston Diagnostic Aphasia Examination (sBDAE) with 0–64 points. After 3 months of using VerbalizAPP®, the sBDAE and scales to assess user satisfaction were applied.

Results: Forty patients (29 men, mean age 68.3 years) were included. Aphasia description: Broca's 12 (15.0%), Wernicke's 13 (32.5%), mixed/global 15 (37.5%) cases. Patients began using VerbalizAPP® 4.8 days (range 2–7) after stroke onset. A significant improvement in sBDAE scores was found after 3 months of VerbalizAPP® use: 35.1 (SD 17.6) versus 51.1 (SD 14.4) points; $p < .001$. Academic level was the only baseline parameter related to outcomes. Comfort of use scored 8.8, and complexity 2.2 points. Expectations were exceeded in 61.1%, and impression of improvement in 83.3% of cases. No adverse effects were reported, and all participants would recommend VerbalizAPP® to other patients.

Conclusions: Our results show the effectiveness of VerbalizAPP® for the treatment of PSA. However, larger prospective validation studies should be conducted to recommend its widespread use.

Keywords

Stroke, digital health, eHealth, neurology, apps, post-stroke aphasia

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Introduction

Cerebrovascular disease is the primary cause of disability worldwide.[1,2] When this produces an alteration in any language modality, it is called post-stroke aphasia (PSA), whose frequency ranges between 15% and 42% of stroke survivors.[3] PSA is associated with greater long-term disability and higher mortality and is considered the most important predictor of social reintegration.[4] Moreover, aphasia is a

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condition that has one of the largest negative impacts on a person's health-related quality of life,[5] with a high risk of depression and a lower likelihood of returning to work.[6]

Recovery-related processes after a stroke are time-dependent and primarily rely on the neuroplasticity that is activated early after stroke onset. Neuroplasticity refers to the brain's ability to undergo changes at various levels – synaptic, cellular, and macrostructural – that promote brain repair.[7] Rehabilitation approaches for aphasia focus on enhancing neuroplasticity to facilitate the relearning of language components and processes. It is well established that the greatest motor recovery typically occurs in the first few months following a stroke. However, most studies concerning language treatment strategies have been implemented later on, when patients are often in the sequelar phase, and the brain's repair mechanisms are less efficient. The importance of assessing communication difficulties – both in speech articulation (dysarthria) and language – within the first days after the onset of stroke symptoms has been emphasised. Early assessment is crucial to initiate and plan appropriate recovery strategies.[8]

Aphasia treatment consists of rehabilitation, mainly through speech and language therapy (SLT) techniques, as current international guidelines recommend.[9] The aim is to improve the patient's ability to communicate by regaining their language skills or by learning other forms of communication, such as through gestures or with the support of images. According to a Cochrane meta-analysis including at least 20 distinct therapies, SLT improves PSA. However, there is no evidence for the superiority of one particular method over another.[10]

Drawings and other images can improve communication skills in people with aphasia.[11] However, use of pictograms or children's drawings for patients with stroke might make it difficult for them to recognise the objects or their semantic meaning, which might lead to the rejection of this material due to it seeming inappropriate for the patient's age.[12] Recently, new technological tools have been incorporated into the rehabilitation of patients with PSA, mainly developed for the treatment of language disorders in children or for patients with degenerative disorders.[13] They have various shortcomings, such as being rudimentary, not intuitive, or difficult to understand. Moreover, some of them have limited application due to poor patient acceptance and a lack of supporting evidence from clinical trials.[14]

From our point of view, a simple and intuitive digital tool, adapted to people who have just had a stroke, would improve communication during hospitalisation and subsequent recovery. Given that the app is comfortable and easy to use, with an understandable iconography, it could achieve greater patient motivation to communicate, promoting the patient's interaction with relatives throughout the recovery process. This new tool would comply with the conclusions of previous meta-analyses that propose an early intervention to maximise language recovery,[15] associated with frequent, functionally tailored, receptive-expressive SLT, with prescribed home practice.[16] The demonstration of its usefulness in clinical practice would also allow more widespread accessibility to PSA treatment, increasing equity, improving functional recovery, and achieving greater social reintegration. Our aims were to design and develop a digital tool for improving functional communication for patients with PSA; to evaluate its acceptance and usability by patients and caregivers; and to demonstrate its effectiveness in improving communication and language skills for patients with PSA, applying it from the acute phase.

Methods

Phase 1: Development of a digital tool for PSA

The need for a new tool was assessed through a survey aimed at stroke survivors with aphasia, the distribution of which was assisted by patient associations. A multidisciplinary team led by neurologists and made up of rehabilitation doctors and speech therapists developed VerbalizAPP® as a digital tool to support PSA treatment. It consists of digitising selected material or resources commonly used in the speech therapy room, mostly in paper format, but using real images to ensure patients' semantic understanding. Earlier prototypes were tested by patients who had the opportunity to make suggestions to improve the app. Their feedback was considered in the development of the current version, which includes exercises and other resources to work on aspects of the various language domains. This tool has basic communication options, vocabulary categories, and exercises that combine images, audio, and texts with various levels of complexity according to the patient's PSA severity. It has been registered in SafeCreative (ID 2301243252217; 23 January 2024).

Phase 2: Interventional before–after study

Design. We conducted a prospective, observational study from February 2022 to July 2023 including patients with acute stroke who met the following inclusion criteria:

1. Impairment in language comprehension and/or emission secondary to stroke (ischaemic or haemorrhagic) regardless of stroke aetiology and severity.
2. Personal availability of a tablet with Android software version 7.0 or higher.
3. Enough family support for the implementation/supervision of the programme, with basic knowledge (user level) about using a computer.
4. Availability of at least 30 min daily to follow the programme.
5. Signature of informed consent by the legal representative/caregiver. Due to the patients' aphasia, their

ability to comprehend the content of the informed consent form may be in doubt. For this reason, the ethics committee approved the signature of the informed consent by the patient's guardian or relative.

Exclusion criteria:

1. Blindness/visual impairment limiting the use of a tablet.
2. Life expectancy less than 6 months.
3. Poor pre-stroke functional status (modified Rankin Scale score higher than three points).
4. Pre-stroke moderate or severe cognitive impairment.
5. Low level of consciousness.
6. Treatment with psychotropic drugs that could significantly interfere with their recovery and evaluation (e.g. neuroleptics, benzodiazepines).

Variables. The following parameters were recorded in a specific database: demographic characteristics (age, sex); marital status (single, married/has partner, widowed); living circumstances (lives alone, lives with partner, lives with son/daughter); has descendants (son/daughter, grandson/granddaughter); retired or not; educational level (less than 7 years, less than 12 years, or more than 12 years); speaks a second language; has a smartphone; and stroke subtype (ischaemic or haemorrhagic). A classical model (Broca's, Wernicke's, or global/mixed), and a functional model (fluent or non-fluent) were applied to characterise the aphasia subtype.

A summarised version of the Boston Diagnostic Aphasia Examination[17] (sBDAE) was developed to evaluate the PSA severity. Applying the BDAE takes approximately 2 h; thus, this summarised version was designed to be used during the acute phase, during which prolonged tests are not recommended. This scale was recommended by our work group to be applied in no longer than 20 min to avoid fatigue or language blocks in patients during the acute phase of stroke. With a range of 0 to 64 points, the sBDAE is made up of various language domains as follows: Listening comprehension (18 points): word comprehension (12), simple and complex commands (4), and complex ideational material (2); Oral expression (26 points): description of a sheet (2), automated sequences (2), repetition (5), and naming (17); Reading (10 points): relate image to word (2), word reading (4), sentence reading (2), and reading comprehension (2); Writing (10 points): writing the name (1), dictation (6), and spontaneous writing (3). Severity was defined by the points attained on the sBDAE: low $\geq$45; moderate 23–44; and severe $\leq$22 points.

Intervention. Patients were selected during the acute phase because, to our knowledge, there are currently no tools that have proven effective at this stage. We aimed to take advantage of this critical period of heightened brain plasticity to achieve better functional outcomes. During the first week of admission, the patient's relatives were invited to bring in a tablet on which VerbalizAPP® was installed and personalised according to the patient's aphasia severity. Basic instructions about usability were provided, emphasising where to find further general and specific explanations to improve the user experience. A minimum usage time of 30 min each day was recommended.

Patients and their relatives/caregivers were given basic recommendations to work together to improve their communication. They could increase or adapt the difficulty of the exercises based on the patient's performance. The main screen of the VerbalizAPP® and a vocabulary category are displayed in Figure 1.

The patients followed the conventional rehabilitation treatment on an outpatient basis, going to the speech therapy rooms where they also used VerbalizAPP® as part of their treatment under the supervision of the speech therapist.

Outcomes. After 3 months of using VerbalizAPP®, the language evaluation was repeated with the same sBDAE. A good outcome was defined as an improvement of at least 20 points, or complete recovery achieving 64 points on the sBDAE. In addition, we evaluated the usability and feasibility of VerbalizAPP® by means of validated survey tools. First, patients and their relatives/caregivers were asked to rate the app's comfort and complexity, employing a Net Promoter Score (scale from 0 to 10). Second, a Likert scale was applied to ask about expectations (much less than expected, less than expected, as expected, more than expected, much more than expected) and impression of improvement in the patient's aphasia (not at all, a little, quite a bit, a lot). Lastly, they were asked to describe any adverse effects and whether they would recommend it to other patients.

Statistical analysis. Data are shown as absolute and relative frequencies for categorical variables or mean and standard deviation (SD) for numeric variables. Data were first compared using a chi-squared test, Student's t test, or the McNemar test, as appropriate. To improve the adjustment of baseline differences between groups, a Bonferroni correction adjusted α of 0.00625 was used to compensate the probability of observing a rare event increase, testing multiple hypotheses. All analyses were conducted with IBM SPSS Statistics Version 28.0.1.0 (Chicago, IL, USA). This study was approved by the local Clinical Research Ethics Committee and all participants (or their family members, if appropriate) signed the study's informed consent.

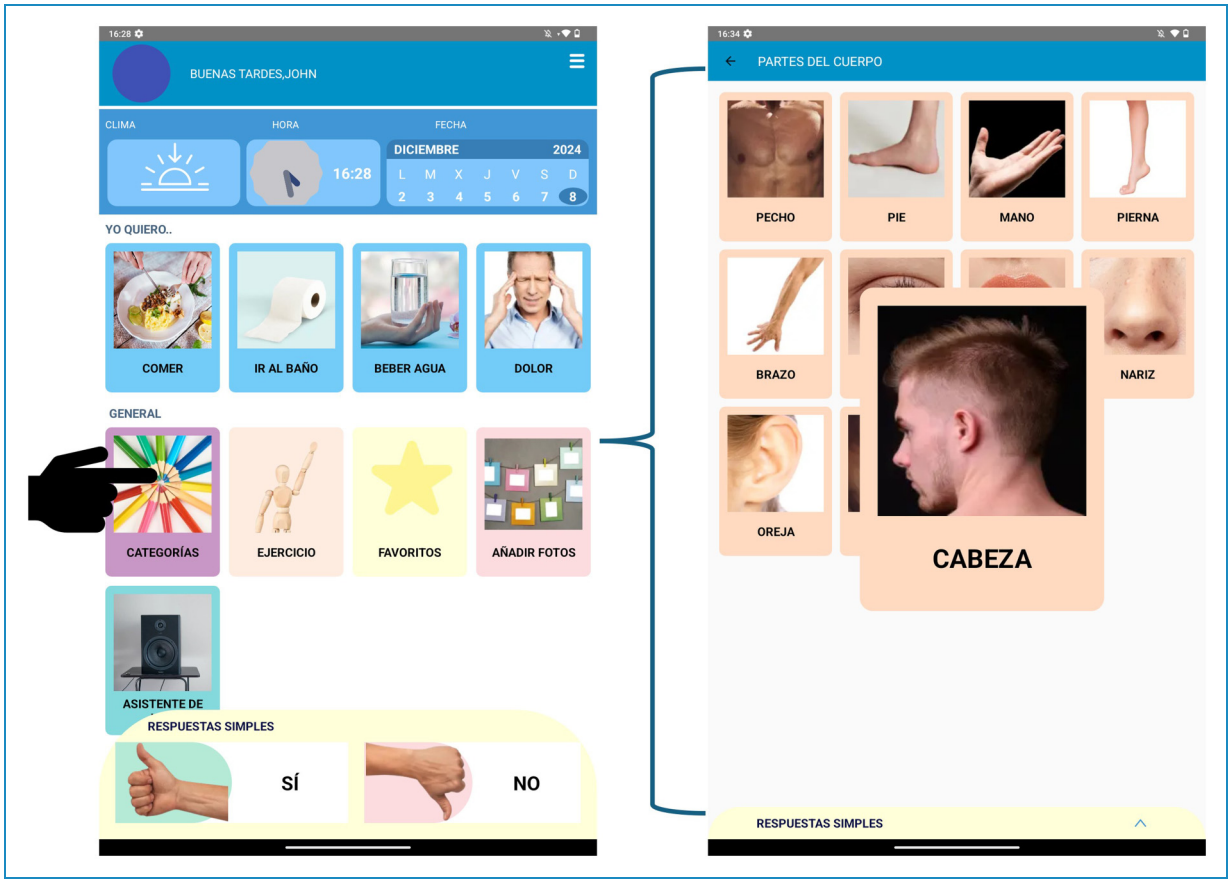

Figure 1. The main screen of VerbalizAPP® is shown on the left side. The hand (in black) represents the click on the 'Categories' vocabulary, which displays more options. On the right you can see the content of the 'Body Parts' category and how the selected image is enlarged while the audio that defines it is played.

Results

Sample characteristics

Forty patients (29 men, 72.5%) were included in the study. Their mean age was 68.3 years (SD 13.3, range 40–90), and all were white. Regarding baseline characteristics, 29 (72.5%) patients were married, 28 (70.0%) lived with their partner, 35 (87.5%) had children, and 28 (70.0%) were retired. Twenty-four (60%) patients had less than 12 years of education, and six (15%) spoke a second language. Considering contact with digital devices, 36 (90%) used a smartphone daily. The baseline characteristics and their distribution are summarised in Table 1.

The predominance of the involvement of the various language domains was considered as an approximation of the Boston classification of aphasias, which was described as Broca's in 12 (30.0%), Wernicke's in 13 (32.5%), and Global/mixed in 15 (37.5%) cases. Similarly, 12 (30.0%) patients were classified as having fluent aphasia, and in terms of severity, 10 (25.0%) were mild, 17 (42.5%) moderate, and 13 (32.5%) severe. On average, patients started using VerbalizAPP® 4.8 days (range 2–7) after stroke onset.

Outcomes

Thirty-six (90%) patients completed follow-up. A total of four patients could not attend the 3-month visit: a 79-year-old woman who died 10 days after discharge due to intestinal obstruction; an 84-year-old woman who refused to attend follow-up; a 90-year-old woman who was diagnosed with an ovarian neoplasia and was institutionalised (her family reported that her language had improved a lot but they did not consider it appropriate to bring her to hospital); and a 79-year-old woman who was institutionalised and we could not locate her relatives.

A significant improvement in the mean sBDAE scores was found after 3 months of VerbalizAPP® use: 51.1 (SD 14.4) versus 35.1 (SD 17.6) points; $p < .001$ (Figure 2). Good outcomes with an improvement of at least 20 points on the sBDAE or complete recovery were found in 17 (44.4%) patients. The improvement in the sBDAE score was not related to age or sex. Figure 3 shows the improvement in the sBDAE distributed by age as a reflection of the heterogeneity of each patient's response regardless of age. Speaking a second language was also not associated with a differential response to the app. A trend towards a higher proportion of

Table 1. Demographic and clinical data of the case group.

Sample characteristics	Cases ($n = 40$)
Age, mean (SD)	68.3 (13.3)
Male sex, *n* (%)	29 (72.5)
Marital status	
Single, *n* (%)	5 (12.5)
Married/has partner, *n* (%)	29 (72.5)
Widowed, *n* (%)	6 (15.0)
Living circumstances	
Lives alone, *n* (%)	7 (17.5)
Lives with partner, *n* (%)	28 (70.0)
Lives with son/daughter, *n* (%)	5 (12.5)
Has descendants	
Son/daughter, *n* (%)	35 (87.5)
Grandson/granddaughter, *n* (%)	23 (57.5)
Retired, *n* (%)	28 (70.0)
Educational level	
Less than 7 years, *n* (%)	9 (22.5)
Less than 12 years, *n* (%)	24 (60.0)
Second language, *n* (%)	6 (15.0)
Smartphone, *n* (%)	36 (90.0)
Ischaemic stroke, *n* (%)	33 (82.5)
Aphasia subtype	
Classical model	
○ Broca's	12 (15.0)
○ Wernicke's	13 (32.5)
○ Global/mixed	15 (37.5)
Functional model	
○ Fluent	12 (30)
○ Non-fluent	28 (70)
Severity	
○ Low, *n* (%)	10 (25.0)
○ Moderate, *n* (%)	17 (42.5)
○ Severe, *n* (%)	13 (32.5)
Basal summarised Boston test score, *m* (SD)	35.1 (17.6)

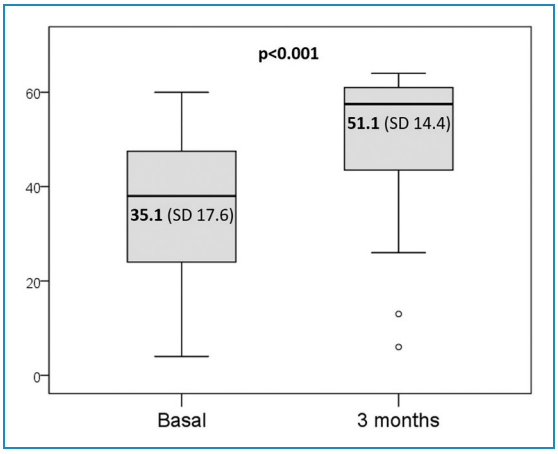

Figure 2. Box-plot of mean punctuation in summarised Boston aphasia examination showing the improvement after using VerbalizAPP® for 3 months.

good outcomes was observed for patients with ischaemic stroke than those who had had a haemorrhagic stroke (51.7% vs 14.3%; $p = .084$); however, few cases were included in the latter group. Baseline characteristics that were related to the most significant improvements with the use of VerbalizAPP® were having grandchildren (68.8% vs 25.0%; $p = .009$), living with a partner (55.5% vs 11.1%; $p = .023$), and academic level with tertiary/university studies (68.8% vs 18.8%; $p = .004$), with no significant effect of the aphasia's subtype or severity. Considering Bonferroni correction, the academic level was the only baseline parameter related to outcomes when using VerbalizAPP®.

User satisfaction

The results of the user satisfaction survey 3 months after installing VerbalizAPP® were as follows: Comfort of use obtained an average of 8.8 (SD 1.2) points, whereas

complexity was valued with 2.2 (SD 2.0) points. Expectations were exceeded in 61.1% of the cases, distributed as follows: less than expected 2 (5.6%), as expected 12 (33.3%), more than expected 16 (44.4%), and much more than expected 6 (16.7%). The impression of improvement was positive in 83.3% of users, who rated it as follows: 6 (16.7%) a little, 21 (58.3%) quite a bit, and 9 (25.0%) a lot (Figure 4). No adverse effects were reported, and all of those surveyed would recommend it to other patients.

Discussion

To our knowledge, this is the first study to show the feasibility and usefulness of a digital tool specially designed for patients with PSA in which they have participated in the development and validation of the various prototypes.

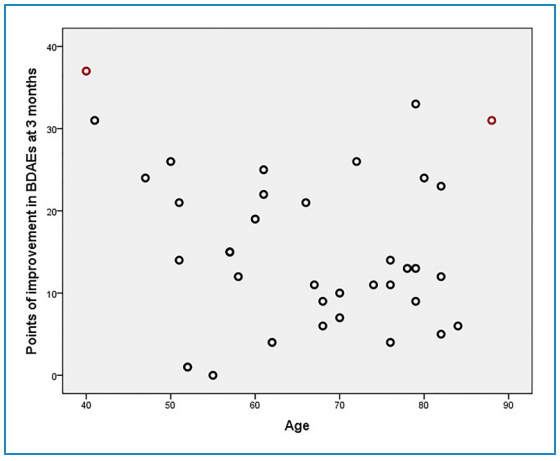

Figure 3. Scatter plot showing the increase in score on the summarised Boston diagnostic aphasia examination by age of each case after use of VerbalizAPP® for 3 months. The red circles highlight the extreme cases of a 40-year-old who improved 37 points and another 88-year-old who improved 31 points.

Despite multiple attempts to improve acquired aphasia, the fact that the patients' needs can change depending on the nature of their brain injury has typically been neglected; these needs should be considered in the development of any digital solution, following the principles of citizen science. Our study shows the feasibility of VerbalizAPP® use from the acute phase of stroke, as well as its effectiveness in the improvement of post-stroke at 3 months.

In recent years, there has been a change of paradigm in health care, accelerating plans to implement resources based on digital health. Thanks to technological advances and the fact that patients are increasingly familiar with employing digital solutions, progress is being made in incorporating new tools into aphasia treatment and rehabilitation. In a short time, countless digital solutions have emerged for aphasia treatment, although options targeting PSA are scarce. A recent study that analysed the applications available for patients with stroke showed that 35% were related to rehabilitation; however, few patients and health professionals participated in its development, while their collaboration is essential for generating high-quality tools.[18]

Our study is an example of citizen science because civil society has been involved in the development of our tool, through surveys on patient needs distributed through their associations. During its development, prototypes were designed and tested by patients who gave their suggestions as to how we could better modify the versions, until reaching the one used in our study. Another important aspect is the use of real images rather than the pictograms used by multiple digital applications, which has been listed as one of the most frequent causes of dropouts from treatment, in up to 25% of cases,[19] by patients who did not consider it adapted to their needs, both for their childlike appearance as well as difficulties in understanding their semantic meaning.

Although the incorporation of new technologies in the treatment of aphasia has experienced exponential growth

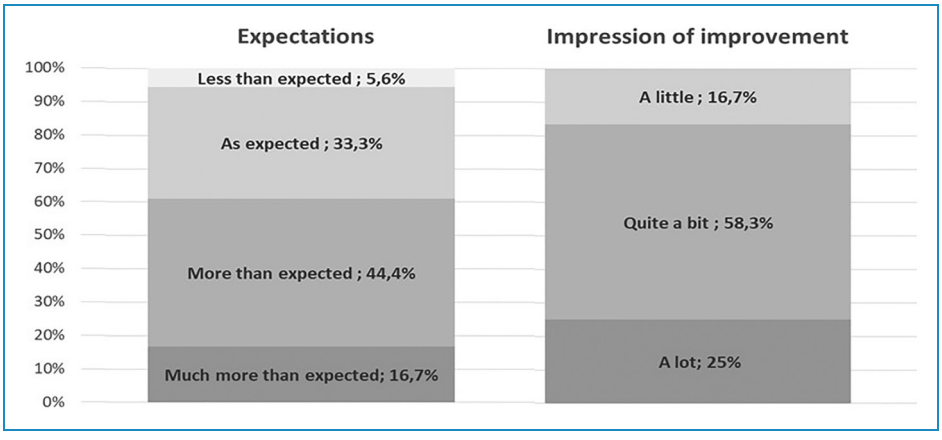

Figure 4. The columns represent user satisfaction: expectations were exceeded in 61.1%; impression of improvement was very positive in 83.3%.

in recent years, and software and applications for mobile devices have proliferated, validation studies are scarce. A review of the 70 applications available on the iOS and Android platforms that had focused on language rehabilitation showed a lack of scientific basis and few attractive elements, after evaluation of their quality by three certified speech therapists.[14] Furthermore, although telerehabilitation appears to be a cost-effective method compared with traditional therapy, even when applied to patients with severe aphasia, the current evidence is limited and individualised treatment is recommended to maximise its efficiency.[20,21]

During the acute phase of stroke, patients are often medically unstable and difficult to test. In up to 30% of cases, they do not have the physical or mental strength or ability to participate in time-consuming aphasia testing.[22] Two hours are required to apply the BDAE, the most widespread test for the global assessment of aphasia. For this reason, we developed a summarised version with the aim of spending no more than 20 min in a global assessment of the impact on the various components of the patient's language. As a limitation of the study, it must be recognised that this summarised version of the BDAE is not validated; however, it has many elements in common with the Quick Aphasia Battery (QAB), an open access, validated aphasia test that aims to provide a reliable and multidimensional assessment of language function in about a quarter of an hour.[23] The QAB has translations in at least 10 languages and has been validated in English and recently in Turkish.[24] Although it contains some childish images, and the assessment of written language is minimal, the Spanish version has several similarities with our sBDAE.

The various methods proposed for aphasia treatment have a wide range of characteristics, and their application must be adapted to the subtype of the patient's language impairment. Our patients improved their aphasia regardless of type or severity, highlighting the relevance of the results. Therefore, we consider it especially relevant that the proposed method was useful for cases with a predominance of impaired understanding, language expression, or both. Another aspect of interest is that there has been no evidence of an influence of age on the results, given that greater adaptation difficulties have been proposed for this type of method by patients considered non-digital natives.

Some of the characteristics that showed an association with the effectiveness of VerbalizAPP® were having grandchildren or living with a partner, which suggests that family support could be a determining factor in language recovery. This aspect has not been considered in previous studies but should be included in the overall assessment of each case and involve family members in the patient's social reintegration process. Regarding the educational level, it would be expected that patients with greater academic training would obtain better results; however, this is another understudied aspect. These data motivate a deeper reflection on the application of language therapies, opening new aspects to consider that would have prognostic value. Digital solutions are typically well accepted by users, who are open to any type of help. For this reason, several questions to better assess user impressions were included, the responses to which were very positive. User satisfaction is another important aspect to consider and should be incorporated in the evaluation of any innovative therapy.

Our study has several limitations. First, the development of VerbalizAPP® coincided with the COVID-19 pandemic, during which contact restrictions gave more importance to our product but prevented the creation of a control group as initially planned. As the study progressed, given the results shown by the patients and the impossibility of them attending the speech therapy rooms, the use of VerbalizAPP® was established and became part of our usual clinical practice. Once the pandemic was over, it was not considered appropriate to restrict access to the tool even if this meant a limitation of our study. However, this would leave our method at the same level as the rest of the speech therapies that have demonstrated effectiveness but which have no evidence of the superiority of a specific method.[10] Second, the lack of a control group does not allow us to compare user satisfaction ratings. Although these ratings are subjective, there is no other intervention with which we can compare these results. Third, the sample size was small, although it is within the typical range of the few studies reporting improvement in people with PSA in the acute phasse.[25–28] A multicentre study with a larger sample and expanded use of VerbalizAPP® to draw stronger conclusions would allow its application to be recommended in routine clinical practice. Fourth, we found no studies in the acute phase that use BDAE to assess evolution.

Conclusions

Our results highlight the effectiveness of using VerbalizAPP® for the treatment of PSA. Its digitisation of selected resources and exercises can be performed with the help of the caregiver and without the constant need for the presence of a health professional or speech therapist to supervise and guide the treatment. The experience acquired with the development and validation of this digital tool for the treatment of PSA has generated results we consider very positive in both efficacy and safety, achieving significant acceptance by patients and their families. These results have led to its incorporation into our usual clinical practice, thereby improving access to the treatment, reduce waiting lists, and increase equity, with the ultimate goal of achieving the social reintegration of patients with PSA. However, larger prospective validation studies should be conducted to recommend its widespread use.

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