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PictoConecta: Technological Support for Communication for Autistic People in daily enviroments

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PictoConecta: Technological Support for Communication for Autistic People in Daily Environments.

Abstract

PictoConecta is a mobile application designed to enhance communication for individuals with Autism Spectrum Disorder (ASD) who are nonverbal or face significant verbal communication challenges. It enables users to communicate through pictograms, translating text into pictograms and leveraging two integrated Artificial intelligence (AI) to support text redaction and improve contextual accuracy. The application also features an activity planner that uses AI for context development, improving the user's interaction with their environment.

A multidisciplinary approach was adopted to evaluate PictoConecta's effectiveness, combining elements of the UTAUT and PACMAD models. A sample of 10 participants with ASD, aged 10 to 25 years and classified under support Levels 2 and 3 with advanced knowledge of the PECS system, participated in the study. The application's usability was assessed through caregiver surveys focusing on interface clarity, ease of navigation, and task efficiency. Communication effectiveness was measured using the ABLLS-R questionnaire, which evaluated participants' ability to achieve communication goals and interact more effectively. This assessment included comparing the traditional use of physical pictograms to determine relative effectiveness.

Results demonstrate that the application significantly enhances task efficiency and communication outcomes, with 100% of participants achieving their communication goals and 80% noting increased task efficiency. The application's intuitive design also received a 90% positive rating for usability and interface clarity. Comparative analysis with traditional PECS books shows that PictoConecta provides a slight performance advantage, particularly for users requiring less support.

Keywords: Autism Communication, planning activities, Mobile Application, Pictograms, Technology Acceptance Model, Artificial Intelligence (AI)

Introduction

Autism Spectrum Disorder is a developmental disability characterized by deficits in social interaction or communication and the presence of restricted interests or repetitive behaviors [1]. According to the World Health Organization (WHO), it is estimated that approximately 1 in 160 children worldwide (0.625%) has the condition. Studies conducted in the United Kingdom indicate that around 1% of children and adolescents present the condition more frequently in boys than in girls. [2]. A survey conducted among parents across the United States found that 1 in 40 children (2.5%) has it, representing approximately 1.5 million children aged 3 to 17 [3].

Communication is essential to human interaction and is fundamental in developing relationships, expressing ideas, and transmitting information. However, communication is a complex process involving an environment where interlocutors exchange information, verbal and non-verbal language, public and private cues, environmental variables, and the medium that both interlocutors must interpret correctly to be effective [4]. The summary and connections of these concepts are graphed in Fig.1

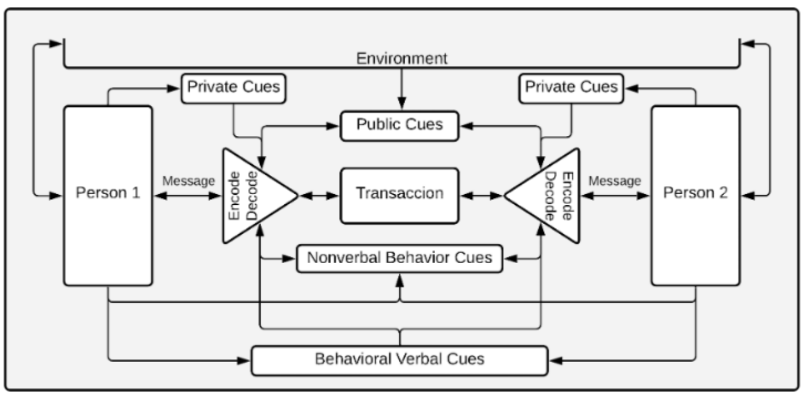

Fig. 1. Transactional Communication System Model [5].

People with Autism Spectrum Disorder (ASD) often face significant challenges with communication, both in understanding and expression. These difficulties can include interpreting verbal and nonverbal language and using language effectively to convey thoughts, needs, and emotions [5]. While verbal individuals with ASD may have learned to speak and communicate using conventional language, nonverbal individuals face additional barriers. These may include relying on echolalia, producing only vowel sounds, repeating phrases, or being limited to non-functional language [6].

One effective way to enhance communication for nonverbal individuals with ASD is through pictographic language. Pictograms—visual representations of words or concepts—enable nonverbal communication by facilitating the expression of needs, emotions, and ideas. For instance, the Picture Exchange Communication System (PECS) is a structured program comprising six phases, progressing from concrete to abstract concepts. This system promotes autonomy, enhances daily interactions, and is particularly beneficial for visual thinkers, significantly improving their quality of life [5].

However, despite the benefits of PECS, there are inherent limitations. One critical issue lies in the standard classification of words within the system, which may not align with the user's unique communication needs. This often requires users to search for pictograms word by word, a time-consuming and inefficient process. Advanced technologies offer promising solutions to address these challenges. Integrating intelligent search algorithms and natural language processing (NLP) techniques into mobile applications makes optimizing phrase construction in pictographic communication possible. Such innovations could allow users to locate relevant pictograms faster and more accurately, enabling smoother and more effective conversations [7].

PictoConecta is designed as a solution for individuals with ASD who are nonverbal or face severe challenges in verbal communication and use the PECS system. The app aims to streamline communication by suggesting complete phrases and summarizing text, eliminating the need for word-by-word translation from Spanish to pictograms. Instead, it focuses on presenting the key ideas of the communicative interaction, making communication more efficient and meaningful.

In this article, we address the issue of communication difficulties in individuals with ASD who are non-verbal or face severe challenges in verbal communication. Firstly, we present a review of the existing literature on communication in individuals with ASD, using PECS, other similar applications, and artificial intelligence in the issue. In the next section, we describe the methodological approach adopted to study the development of applications for people with disabilities and how we evaluated the app and communication. Then, the features of the software are presented. The results of this study are presented, and in the following section, we discuss their implications in the context of application development. Finally, we propose conclusions and possible future lines of research.

State of art

The Picture Exchange Communication System (PECS) is an alternative communication method that uses images. This system is beneficial for people with ASD due to their concrete and structured thinking. Although PECS is not an official language and has been refined by its users over time, its implementation is crucial for non-verbal individuals with ASD, especially as they grow. Many of them remain nonverbal throughout their lives, and the ability to communicate is essential for their independence and quality of life [8].

Although there are various therapies to help people with ASD integrate into society, these can be hindered by communication difficulties. To overcome these challenges, therapists, the environment, and people with ASD resort to the use of pictographic language, as it better aligns with their concrete thinking style and facilitates effective communication [9].

One of the most enigmatic aspects of nonverbal conditions is why some people do not develop or use spoken language. While some individuals with ASD have childhood apraxia of speech, a neurological disorder that significantly impairs the use of spoken language, many nonverbal individuals with ASD do not have apraxia; they do not speak. Differences in brain function limit the use of spoken language. Still, there is no consensus on these differences or how they affect everyone precisely [10].

PECS is a language built word by word, and a pictogram represents each word. Each corresponding pictogram must be selected to form a sentence, repeating this process for each word. The complexity and duration of the process depend on the medium used for the language. For example, if printed pictograms are used, it is necessary to have all the pictograms corresponding to the words in the sentence and to search for them in a book, as shown in Figure 2. On the other hand, if a mobile application is used, a search function is employed to find each word and construct the sentence. This process can be repetitive and lengthy, and as communication becomes more functional, more pictograms will be required, increasing the time needed to construct each sentence.

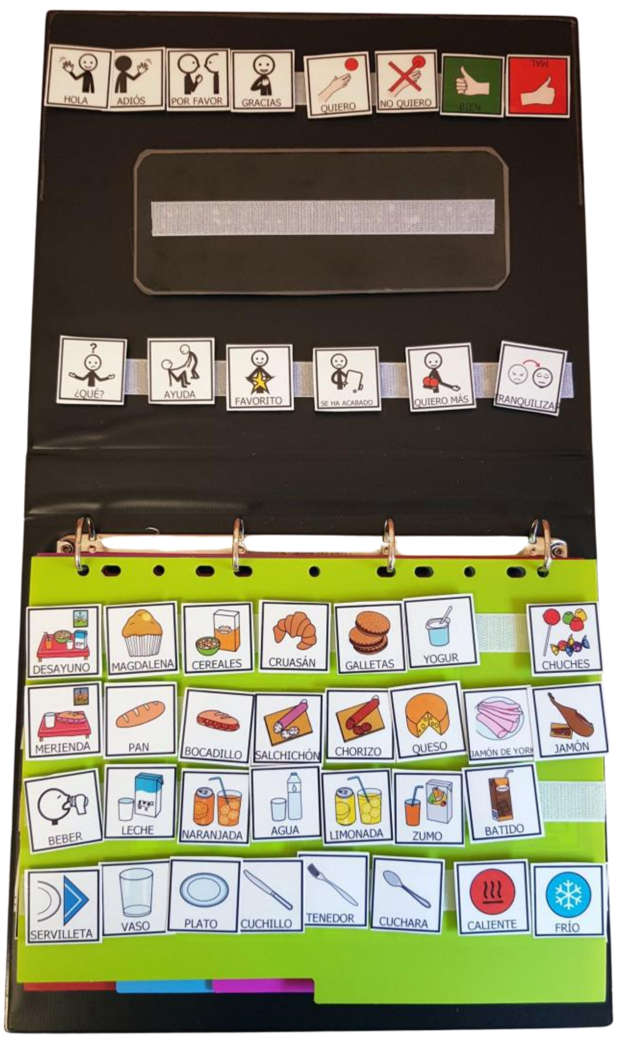

Fig. 2. PECS Communication Book. Source: arasaac.org

Various applications have been developed to facilitate the use of pictographic language. After using them, significant improvements in communication skills for individuals with autism spectrum disorder (ASD) were observed. Expression ability, language comprehension, and social interaction also increased. [10]. Augmentative and Alternative Communication (AAC) devices, such as physical or on-screen keyboards, assist in communicating with speaking individuals. However, the difference in input rates between AAC users and speakers creates a communication gap.

In recent years, the advancement of new technologies has experienced exponential growth, allowing the creation of solutions that improve the quality of life for people with communication difficulties (PCD). Natural Language Processing (NLP) is a branch of artificial intelligence that involves techniques for automatically analyzing and organizing text. NLP techniques, such as word prediction and language translation, are used in various applications like machine translation, speech recognition, and word prediction in assistive keyboard software [11]However, most systems are developed in English or other languages other than Spanish, creating a gap in communicative effectiveness by excluding the participants' contextual and cultural differences.

A possible application of NLP technology in AAC is the automatic reconfiguration of existing texts. Text simplification involves transforming complex documents into simpler sentence structures and vocabulary while preserving the original meaning. On the other hand, summarization aims to produce concise summaries of documents by extracting essential phrases. Although these approaches are not currently implemented in commercial AAC technologies, they have the potential to simplify reading materials and facilitate expressive communication for individuals with PCD. [11].

KWickChat is a multi-turn dialogue system explicitly designed for augmentative and alternative communication (AAC) users, leveraging advanced natural language processing (NLP) techniques. The application utilizes the Generative Pretrained Transformer 2 (GPT-2) model. [12], combined with keywords and contextual information to generate high-quality, contextually relevant sentences for AAC users.

With minimal input required—typically just a few keywords from the user—KWickChat generates intelligent, context-aware responses that significantly improve communication efficiency and speed. Integrating user input, conversation history, and personality traits delivers personalized and meaningful dialogue, bridging the gap between traditional AAC and intelligent dialogue systems.

One of KWickChat's standout features is its ability to minimize user effort. It achieves potential keyboard stroke savings of up to 77%, enabling smoother and faster interactions. Additionally, evaluations by human judges have confirmed the system's ability to produce semantically coherent and contextually appropriate sentences, highlighting its potential to transform communication for AAC users. [12].

Methodological framework

PictoConecta is an application designed for nonverbal individuals or those with severe speech difficulties within the autism spectrum, specifically targeting users from preadolescence onward. It aims to facilitate communication and improve the quality of life for this demographic. The DSM-V manual introduced a classification of three levels for ASD, depending on its severity and the level of support required:

- Level 3 “Requires very substantial support”: Severe verbal and non-verbal social communication deficiencies. Minimal social interaction and minimal responses to others. Example: Use of few intelligible words and interaction only to meet needs.
- Level 2 “Requires substantial support”: Marked verbal and non-verbal social communication deficiencies. Limited social interaction and abnormal responses to others. Example: Using simple phrases and strange nonverbal communication, focused on restricted interests.
- Level 1 “Requires support”: Noticeable deficiencies in social communication without support. Difficulty initiating and maintaining social interactions. Example: Able to speak in complete sentences but with ineffective conversation and difficulty making friends.

PictoConecta is particularly suited for individuals classified under Levels 2 and 3, where communication barriers are most pronounced. Addressing these challenges provides a tool to enhance interaction and autonomy, bridging gaps in social communication.

Design Methodology

Design-Based Research (DBR) was employed as an interventionist research method to understand the communication needs of nonverbal individuals with ASD. This approach enabled the design of solutions tailored to their unique environments and characteristics, ensuring that the developed software is functional and practical for use at home and in external settings.

The model presented in this article results from two prior iterations based on testing and feedback from individuals with ASD and their caregivers. These new evaluations will be applied with input from an autism and childhood specialist psychologist and a special education teacher. This multidisciplinary team will contribute to assessing improvements in users’ communication with their environment and identifying new functionalities. The DBR process consists of several steps illustrated in Fig. 3.

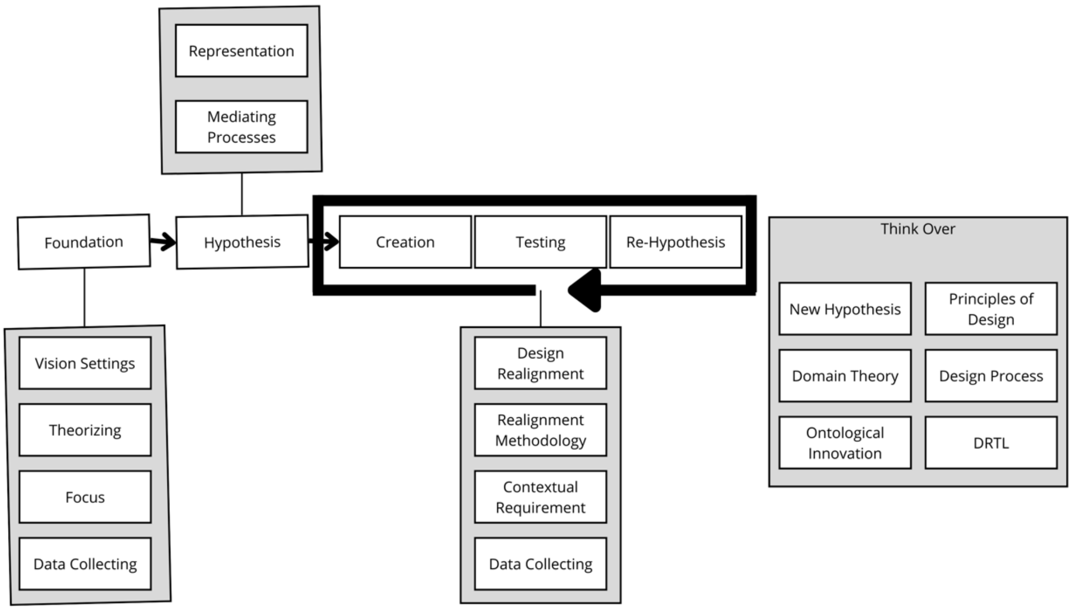

Fig. 3. DBR Design Diagram, Self-Elaboration.

The DBR consists of four phases:

- Foundation: Collect and analyze challenges faced by individuals with ASD at support levels 2 and 3 who are nonverbal or have communication difficulties to inform preliminary decision-making for the project and specify the roles of stakeholders. Interviews will be conducted with caregivers from institutions whose children exhibit the specified user characteristics. These users must have completed at least the third level of the PECS system.
- Hypothesis: Grounded in theories of visual learning and alternative communication, it was hypothesized that using pictograms supported by natural language processing (NLP) technologies would significantly enhance communication fluency and efficiency. This approach integrates the concept of technology transfer, adapting advanced tools to meet the specific needs of this user group.
- Reflection: The final design of PictoConecta was validated through a collaborative evaluation approach, integrating the perspectives of psychologists, educators, and caregivers. This ensured the application adhered to principles of usability, accessibility, and effectiveness, promoting a positive impact on users' daily interactions.
- Iterations: The iterative design process was rooted in the principle of incremental improvement, where each cycle incorporated direct feedback from users and caregivers. This applied the concept of experience-based learning, utilizing practical tests as the foundation for functional and aesthetic adjustments to the interface.

The design applies the concept of adaptability, offering features that adjust to users' preferences and progress. For example, implementing tools for personalizing pictograms and contextual recommendations reflects a design that addresses initial needs and evolves with its users.

Testing Methodology

The tests will be conducted with individuals diagnosed with Autism Spectrum Disorder (ASD), aged between 10 and 25 years, who are at support levels 2 and 3 and have verbal difficulties or are nonverbal. Additionally, participants must have level 3 or higher knowledge of using the Picture Exchange Communication System (PECS).

The application will be presented to the users and their caregivers during the tests while a multidisciplinary team of specialists (a psychologist and a special education teacher) observes the interactions. Subsequently, a survey based on a combination of the UTUAT and PACMAD models will be administered to the caregivers.

For this research, an adapted model (M-UTUAT) is proposed, replacing the effort expectancy component of the UTUAT model with the usability principles of PACMAD. This combined model enables a more robust application evaluation, where each attribute significantly impacts usability and technological acceptance. Figure 4 presents a descriptive diagram of this methodology.

The ABLLS-R questionnaire (Assessment of Basic Language and Learning Skills-Revised) will also evaluate communication effectiveness during the tests. The specialists will complete this instrument and assess the participants' skills based on observations made during their interaction with the application.

This approach measures the application's acceptance, usability, and impact on improving communication for individuals with ASD in real-world contexts.

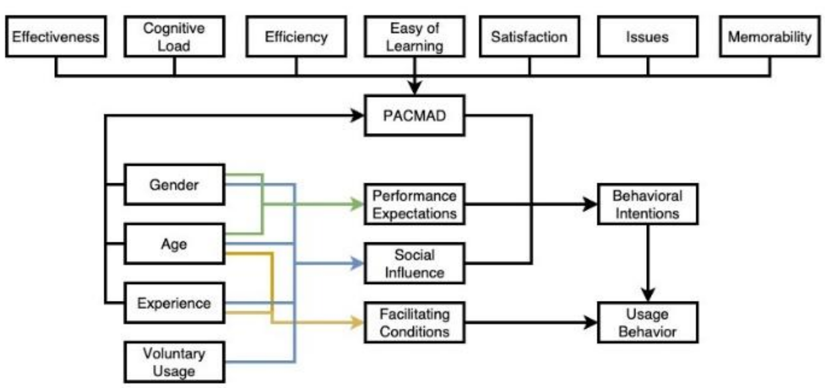

Fig. 4. Description of the testing methodology. Self-Elaboration [13].

Proposed solution

PictoConecta is an app for nonverbal individuals with Autism Spectrum Disorder (ASD) who have severe speech difficulties. It specifically caters to users classified under support Levels 2 and 3 with prior knowledge of the PECS system. The app is compatible with iOS and Android operating systems, ensuring broad accessibility across devices.

PictoConecta integrates advanced AI technologies to enhance communication. It utilizes a text generation AI powered by GPT-3.5-turbo-0125 to assist in crafting responses and a summarization AI based on T5-small to simplify complex messages for better comprehension.

The application employs three APIs to deliver its functionalities:

- An API to retrieve pictograms from the ARASAAC database.
- Two APIs dedicated to the text generation and summarization AIs.

These APIs are hosted on a server running Linux Ubuntu 22.04, with one vCPU and 2 GB of RAM. This provides a secure and efficient platform for resource management and application performance. This combination of technologies and thoughtful design ensures that PictoConecta effectively bridges communication gaps for its target audience while remaining reliable and user-friendly. Figures 5, 6, 7, and 8 are self-elaboration screenshots of the PictoConecta application in use.

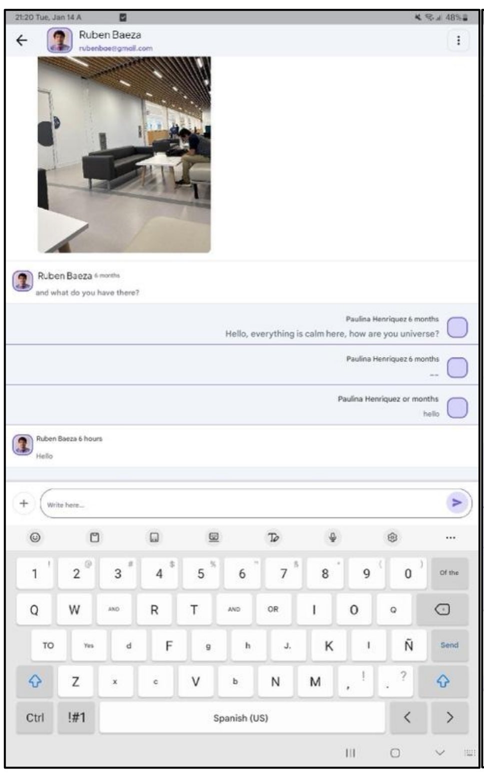

Fig. 5. Chat screenshot without AAC

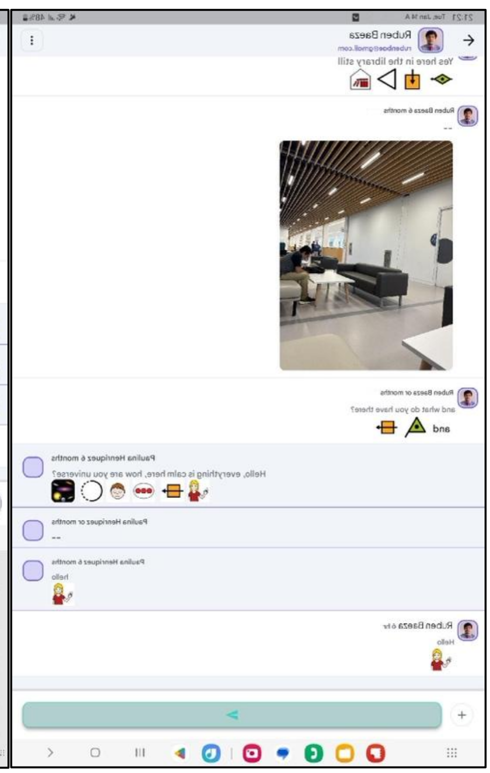

Fig. 6. Chat screenshot with AAC

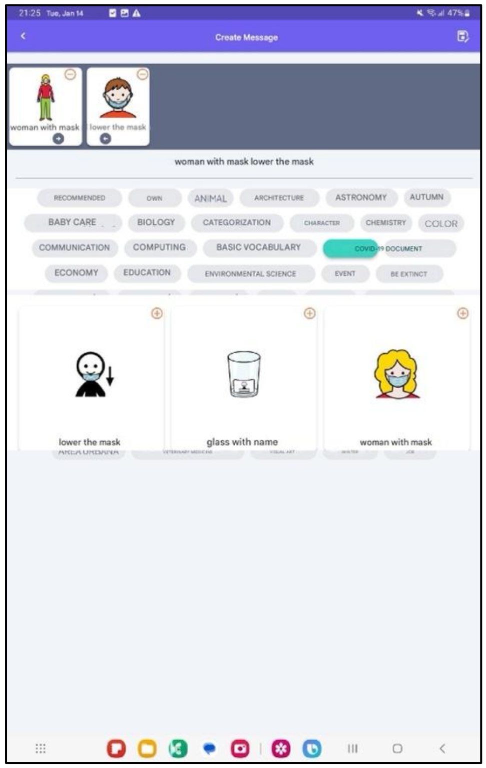

Fig. 7. Creating a message for AAC users with AI assistance

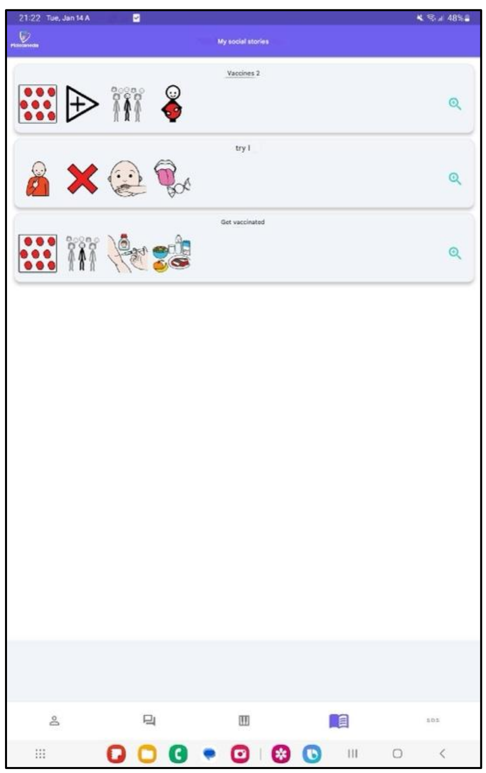

Fig. 8. View of saved social stories

Application results

To assess the effectiveness of the application, two surveys were used:

- To evaluate usability and accessibility, a survey was employed using the Unified Theory of Acceptance and Use of Technology (UTAUT) and the People at the Centre of Mobile Application Development (PACMAD) models.
- The ABLLSR (Assessment of Basic Language and Learning Skills Revised) questionnaire was utilized to measure communication effectiveness.

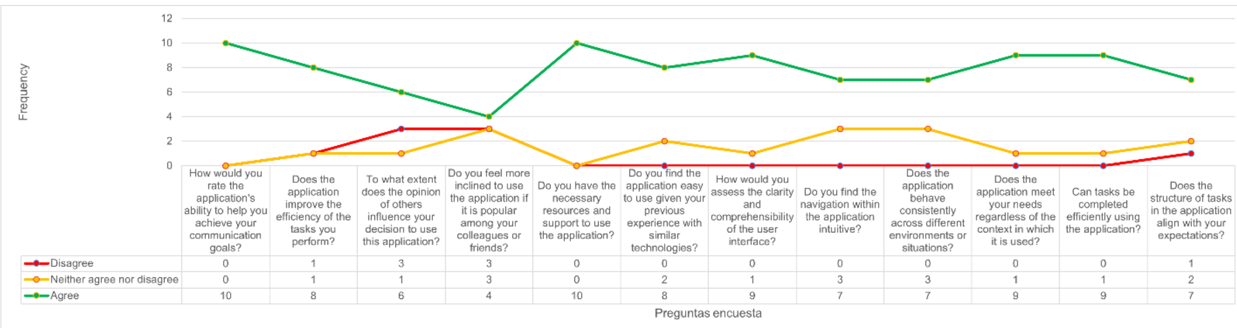

Fig. 9. Frequency of survey results. Self-Elaboration.

This survey to evaluate usability and accessibility was administered to a sample of 10 individuals with ASD aged between 10 and 25, including those with support levels 2 and 3 and with knowledge of PECS. The results obtained are summarized and presented in the graph in Fig. 9.

Based on the results presented in 9, the application is highly rated across several key aspects. Most users believe that the application is practical in helping them achieve their communication goals (100%) and enhances the efficiency of their tasks (80%). Additionally, ease of use stands out, with 90% of users positively evaluating the clarity of the interface and the application's consistency across different contexts. The application also meets users' needs regardless of the environment and supports efficient task completion (90%). However, regarding social influence, only 40% of users feel more inclined to use the application if it is popular among their peers or friends, indicating that while popularity holds some weight, it is not a decisive factor. Furthermore, while most users positively rated the intuitive navigation and consistency of the application, there is still room for improvement in these areas. Overall, the application meets user expectations regarding performance, usability, and efficiency, though certain aspects, such as social influence and navigation, could benefit from adjustments to enhance the overall user experience.

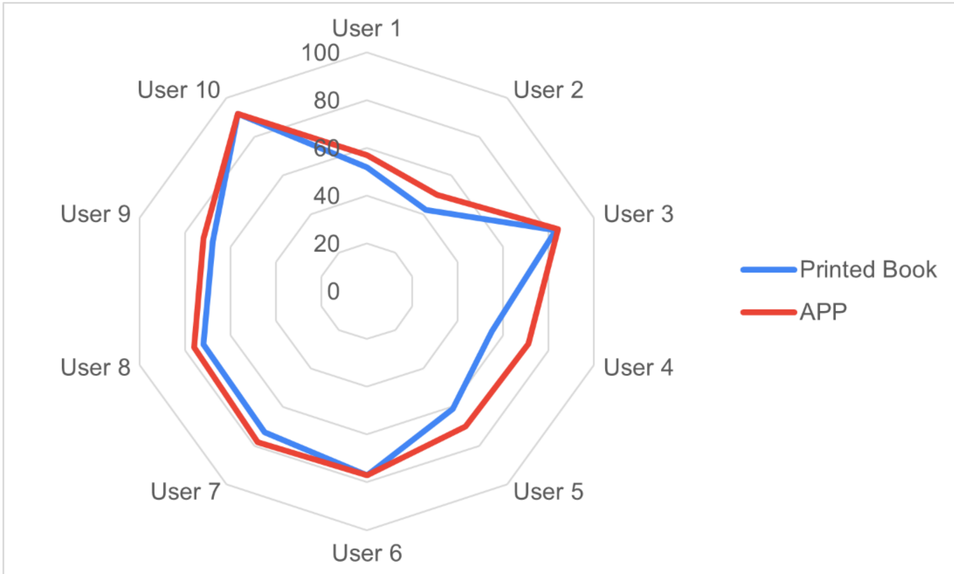

Fig. 10. Total scores per user. Self-Elaboration.

The analysis of Fig. 10 reveals that users with Level 2 tend to achieve higher scores on both the printed book and the app. However, their performance when using the app is consistently superior, suggesting that the digital platform facilitates faster and more efficient communication. In contrast, users with Level 3 (requiring more substantial support) generally obtain lower scores, highlighting their need for additional assistance to utilize either platform fully. Nevertheless, the app demonstrates a slight but consistent advantage for specific users, such as User 1 and User 2, who achieve notably higher scores with the app than with the printed book. Additionally, users without a disability certificate, like User 7, perform well on both platforms, with the app providing smoother interaction and easier access to pictograms. In summary, the analysis underscores that while children with fewer support needs generally perform better across both platforms, the app offers significant advantages in efficiency, accessibility, and ease of use, positioning it as a more effective alternative to physical pictograms.

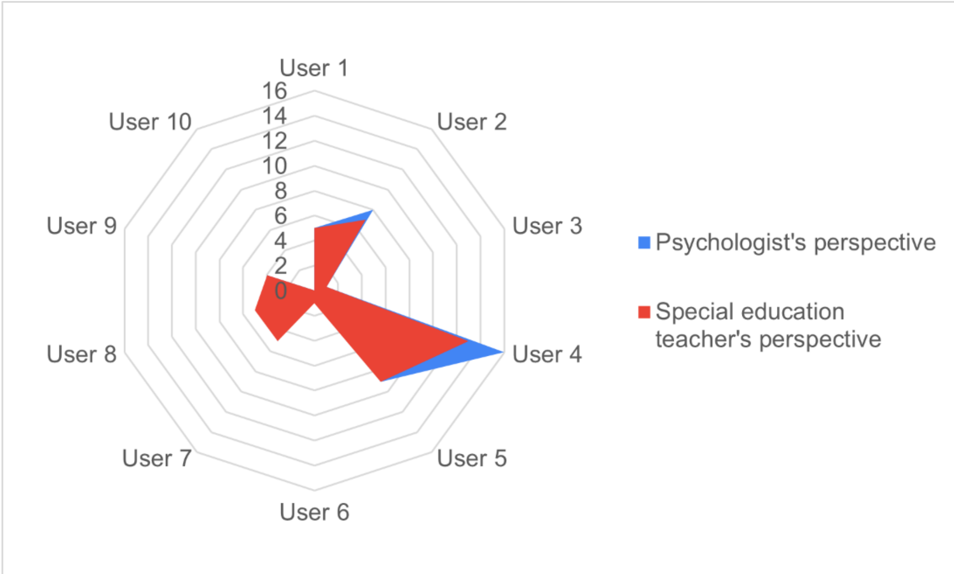

Fig. 11. Total score difference between APP and Printed Book per user according to each specialist. Self-Elaboration.

Fig. 11 shows the score differences between the app and the printed book evaluated by two professionals, a psychologist, and a special education teacher. In general, the score difference between the app and the printed book tends to be more significant in the scores evaluated by the psychologist compared to those by the special education teacher.

For example, User 4 shows the most significant score difference, with a 16-point difference in the psychologist's evaluation and a 13-point difference in the special education teacher's evaluation, suggesting a more significant advantage of the app over the printed book in their case. Similarly, User 5 has a 9-point difference for both the psychologist and the special education teacher, indicating that both professionals agree on the greater effectiveness of the app over the printed book.

On the other hand, there are cases like User 6 and User 10, who show no significant differences between the app and the printed book, with a score difference of 0 in both evaluations, suggesting that there is no notable difference in their performance on both platforms.

Overall, the score differences vary between users, but psychologists and special education teachers usually find that the app offers a slight advantage over the printed book.

Regarding the application’s performance, response times for text generation and summarization AIs and metrics such as epochs, ROUGE, and BLEU were used.

GPT-2 was considered for text generation, but its high space requirements and pre-training costs made its use on a 2 GB server impractical. Instead, OpenAI’s GPT-3 is used, which, although consuming more energy (1.287 MWh compared to 0.12 MWh of GPT-2), avoids pre-training and maintenance costs.

In summarization AI, epochs are used to adjust pre-training, and the ROUGE metric evaluates the quality of summaries, with data such as ROUGE-L Recall (0.9167), ROUGE-L Precision (0.3548), and ROUGE-L F1-score (0.5116).

BLEU is used to evaluate the text generation AI, which measures the precision of responses relative to a reference response. Table 1 shows the evaluation metrics for the AI.

Table 1: Text generation AI results. Self-elaboration.

IA	BLEU	Response time
GPT-2	0	480 seconds
GPT-2	0.12251	420 seconds
GPT-2	0.09821	407 seconds
GPT-3	0.48974	20 seconds
GPT-3	0.58122	15 seconds
GPT-3	0.59245	3 seconds

The text generation AI improved from an average of 4 minutes with GPT-2 to 3 seconds with GPT-3, significantly enhancing the responses. The summarization AI also improved by transitioning from a convolutional-based AI to one based on T5, providing more accurate and coherent summaries.

Discussion

Efficiency and Infrastructure Costs

The decision to outsource text generation using OpenAI's GPT-3 rather than pre-training GPT-2 locally illustrates how infrastructure limitations and costs can influence technological choices. Although GPT-3 consumes more energy, outsourcing reduces the costs and complexity associated with pre-training and maintenance. This decision reflects a critical evaluation of available resources and the search for the best solution within those constraints.

Response Quality and Metric Evaluation

Metrics such as ROUGE and BLEU are essential for evaluating the quality of responses generated by AI. High ROUGEL Recall and F1-score values indicate that the generated responses and summaries capture important elements and are relevant. However, the relatively low precision (ROUGE-L Precision: 0.3548) suggests there is still room for improvement in reducing the amount of irrelevant content in the generated responses. This observation underscores the importance of a Critical and ongoing approach to evaluating and improving AI models.

Improvement in Response Times

The significant improvement in response times when switching from GPT-2 to GPT-3 (4 minutes to 3 seconds) is crucial for the application's usability and efficiency. This enhances the user experience and makes the application more practical for everyday use. This change demonstrates the importance of balancing response quality with generation speed, especially in applications where quick interaction is essential.

Energy Considerations and Sustainability

The comparison of energy consumption between GPT-2 and GPT-3 (0.12 MWh vs 1.287 MWh) raises reflections on sustainability and the environmental impact of AI solutions. Although GPT-3 was chosen for its operational advantages, it is important to consider strategies to minimize energy impact and explore more sustainable alternatives in the long term.

Reflection on Technology Choice

The transition from a convolutional AI to one based on T5 for summarization shows how choosing the right technologies can significantly improve outcomes. Using the T5-small model for summaries balances performance and efficiency, critical for mobile applications with limited resources.

In summary, the critical discussion of this implementation highlights the need for continuous evaluation of both operational efficiency and the quality of AI solutions. Technological decisions must balance costs, infrastructure, response quality, and sustainability, always seeking continuous improvements and adaptations according to the specific needs and limitations of supporting solutions to expand the horizons of individuals with communication limitations while striving to enhance their reach.

Reflection on Technology Priority

Tablets and smartphones should be exclusively used as communication tools for children and young people with autism, avoiding their perception as reinforcers. This approach fosters the development of functional skills by utilizing apps and programs designed for expressing needs, social interaction, and learning. By emphasizing their communicative purpose, autonomy can be promoted, emotional dependency reduced, and these devices can effectively support active participation in their environment and overall development.

Conclusions

Studies on the use of pictographic language technologies for individuals with Autism Spectrum Disorder (ASD) have revealed the need for more efficient communication systems. The proposed solution addresses this need by improving sentence construction with pictograms through advanced Natural Language Processing (NLP) techniques. It employs recommendation algorithms based on semantics and context, facilitating faster and more accurate search and selection of pictograms.

For People with Communication Difficulties (PCD), a mobile platform with functionalities for chat, message creation, social stories, and emergency calls has been developed. The application, with a simplified and accessible interface, has been positively validated by users, who noted significant improvements in their communication and task efficiency. This indicates that the system effectively addresses communication barriers and provides adequate support.

PictoConecta, as a communication alternative for individuals with ASD in Spanish-speaking contexts, can benefit from NLP approaches and techniques such as semantic recommendation algorithms and contextual analysis. Developing intuitive mobile applications tailored to the specific needs of these users is essential, with continuous validations to ensure effectiveness and satisfaction in various contexts.

Future work

It is proposed that the usability analysis of PictoConecta be expanded through studies with more extensive and diverse samples, including different support levels, age groups, and geographical contexts. Additionally, integrating advanced artificial intelligence technologies is recommended to enhance the application's precision and efficiency and develop adaptive and customizable tools to meet individual user needs. Longitudinal evaluations are also suggested to assess its impact on social, emotional, and cognitive development and explore multilingual and multicultural adaptations to ensure its relevance and inclusivity in various global contexts.

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