Design and Evaluation of ECO: An Augmentative and Alternative Communication Tool

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Abstract

Current technology provides new challenges to improve skills on people with special necessities. In fact, persons with communications needs can take advantage of new devices and mobile applications to interact and communicate easily and in the most straightforward way. Augmentative and Alternative Communication (AAC) systems are oriented to users who cannot use natural language due to temporary or permanent impairments, providing an alternative to natural language for communication. In this paper, we present design guidelines for ECO (Easy Communication Application), an AAC tool designed with a User-Centered Design (UCD) approach to make functional communication easier for individuals with complex communication needs. ECO tool has two well-defined modules: the Communication User and the Communication Manager. The former is thought as an AAC tool, whilst the Communication Manager module provides a way to edit the content and fit the dynamics of use and application design to the user's interests. In addition, we present an evaluation of the ECO tool from two different perspectives. On the one hand, we have achieved a heuristic-based expert evaluation in order to analyse the functionality corresponding to the Communication Manager module of the tool, in order to check main accessibility requirements and improve functionality accordingly. On the other hand, we have evaluated both the Communication Manager and Communication User modules in a real context, carrying out a qualitative evaluation with final users and their therapists to check whether the tool is useful in concrete daily scenarios. Results corroborate research questions, demonstrating that ECO meets the most important accessibility requirements and it is highly valued by experts and end-users.

Keywords: Accessibility; Alternative and Augmentative Communication; Mobile Application; Expert Evaluation; End-user Evaluation

1. Introduction

Augmentative and Alternative Communication (AAC) systems are oriented to users who cannot use natural language due to temporary or permanent impairments, or for whom the use of natural language implies a significant effort. In all cases, this kind of communication tries to provide an alternative to natural language for communication and therefore allow these users to communicate satisfactorily in their daily life. Many different types of people use AAC devices in order to communicate since disorders affecting their ability to communicate can result from physical, intellectual, congenital and acquired disabilities, in addition to progressive disorders. For example, people with Autism Spectrum Disorder (ASD) use AAC devices due to the fact that one

of the keys defining elements of autism is that an individual exhibits impairment in both verbal and nonverbal communication [24].

Various types of AAC tools are available. Some may use unaided techniques, such as gestures and sign language, while others can employ low-technology devices like communication-symbol books and letter/word boards. Additionally, there are high-technology AACs which use technological aids comprised of both peripherals and AAC software, specifically designed to assist with the complex communication needs of certain individuals [32]. Pictograms are one of the most used resources in AAC. A pictogram is a schematic symbol that represents an idea or concept in a manner that allows communication across language barriers. Therefore, for people who have this kind of language difficulties, a pictogram is not only a way to express ideas and feelings, but also a tool to interpret, understand and ultimately transform their ideas into pictures in a schematic and efficient way. Thus, pictograms may represent many types of concept: objects, animals, persons, feelings, actions, or even grammatical elements.

The number of existing AAC applications based on pictograms with the purpose of enhancing the communication and interaction of users with communication problems is huge. Although many of these tools are widely used and easily available, it has only been in recent years that developers have considered following User-Centered Design (UCD) techniques to implement this kind of application. In considering the iterative UCD, it should be clear that people with disabilities can be part of this process so the target levels for accessibility can play an important role in the overall process [30]. However, in many cases, users with disabilities are only considered at the end of the design and development process as evaluators of the final systems, and not in other intermediate phases like requirement analysis or application design. In this sense, this paper presents the Easy Communicator application (ECO), an AAC tool designed using a UCD approach to make functional communication easier for individuals with complex communication needs. ECO has been designed with user participation in the design phase, as well as in the evaluation phase.

The following section presents literature that includes works related to AAC applications and experimental studies carried out with people with disabilities who use AAC applications. Afterwards, the ECO application and its design process are described. Subsequently, an evaluation of the ECO tool from two different perspectives is presented: an evaluation with experts and an evaluation with users with disabilities and their therapists. Finally, conclusions and suggestions regarding new requirements and elements to integrate into this communication tool are presented.

2. Related work

Alternative and Augmentative Communication (AAC) devices are used by people with special communication needs in order to be able to participate in society, with their families and in their schools, among many other everyday situations. A multitude of different AAC devices exists due to the fact that end-users have a wide range of communication needs [38]. Advancements in technology, especially in the mobile technology sector with regard to smartphones and tablets, have greatly improved the customization and portability of AAC devices and provided powerful new communication tools [22]. Mobile technologies, such as touch-screen smartphones and tablets, have become much more commonplace. The wide range of apps offered for these devices includes those that assist in communication, which has helped to transform AACs from low-tech to more high-tech devices. They have provided new symbol sets, layouts, organizations, selection techniques and even output [3]. The creation and prevalence of these digital technologies have, potentially, made it much easier to meet the wide range of communication needs for a large, varied group of people with impaired communication abilities [15]. As mobile technologies have become more readily available, acquiring AAC apps has become easier and taking into account the low price of these devices, relatively speaking, when compared to the cost of traditional

systems, significant changes have occurred with regard to the manner in which AAC solutions are accessed by both individuals with complex communication needs and their families [21][22][33].

In recent years, many AAC developments have used a UCD approach when designing and developing applications [16][27][34]. However, only some works have also performed heuristic evaluations with experts in both accessibility and disabilities of target users. This has proven to be a good idea as many accessibility and usability issues can be found by experts and then corrected before target users evaluate the applications. For example, AraBoard [2] is a set of tools focused on creating pictogram boards using a computer, smartphone or tablet. The aim of this tool is to support the creation and use of communication boards adapted to the particular needs of each user. Accessibility evaluation of AraBoard was carried out in [3] , where accessibility experts evaluated the tool by using two lists of checkpoints extracted from accessibility standards and related work in the domain of AAC. The results from the study indicated a high level of accessibility in AraBoard, and reported some suggestions about new requirements to integrate into the tool. PICTAR [19] is another tool on AAC for people with autism, which has been evaluated by usability experts [20]. PICTAR is a web application based on a service of translation from text to pictograms in order to help teachers and tutors in the creation of new pictogram materials from texts like daily routines, stories or news. In [23] authors present an application for multi-touch tablets to support the improvement of empathy for children with autism. They conducted an evaluation with three academic researchers having skills in software usability and accessibility, who detected a total of 21 problems in the first prototype. The mobile social application presented in [26] aims to aid the children with autism in learning basic interaction skills, which consist of introducing basic emotions and gestures. Five evaluators were involved in its heuristic evaluation, in order to enhance the user interface of the mobile social application. The results from the evaluation concluded that all evaluators agreed with all the applied heuristics. In [3], the authors report on developing collaborative activities to enhance language skills of children with autism. They adopted a multi-touch tablet iPad as a platform to support quiz and storytelling activities. A total of four evaluators carried out the heuristic evaluation. In this work, a simple questionnaire with statements crafted from design heuristics statements was presented.

Experimental studies with users with disabilities in order to evaluate AAC tools have been found. There are numerous AAC tool works evaluated with people with cerebral palsy such as [38], which presents an AAC tool with a "language playground" aimed at users with physical, speech, and language impairments and tested with children with cerebral palsy. [28] presents the development of an augmentative system that allows people with movement disabilities, mostly cerebral palsy, to communicate with people that surround them. An evaluation of the usability was performed, which showed that it can be easily used by any non-trained person. [8] presents the development of an AAC computer-based solution to act as a complement to the therapist's AAC activities in order to help make the lives of children with disabilities better. In the evaluation of the tool, school-age students with cerebral palsy participated. Quantitative reports and qualitative assessments from a speech and an occupational therapist were obtained. This research deals with a set of accessibility guidelines that benefit researchers and practitioners, giving more evidence about the design of AAC computer-based solutions for people with limited speech or language skills. [31] presents the ITHACA framework. This system was evaluated through demonstrations with children with cerebral palsy and severe speech impediments using observational methods. This demonstration showed good acceptance of the ITHACA applications and substantial improvement of the end-users' communication skills.

Another group of users benefiting from AAC solutions are persons with speech disorders and motor impairments. Along this line, we have found works, such as [11], that present the experience of an AAC application with persons with severe language (and motor) impairments

who were treated at an adult day center for people with disabilities. This experience testifies that AAC can be successfully applied to severe disabilities and encourages research in this direction. [4] includes a usability test of an AAC tool (WebAACcess) with participants with motor disabilities to improve accessibility and overcome some of the barriers to navigating the web. This was done by means of a repeated-measures research design carried out with users with motor disabilities who used AAC tools. An evaluation of an AAC tool, customized according to the communication needs of people with speech disorders and motor impairments, is presented in [29]. A system following a pre-defined test protocol was evaluated with people with speech difficulties and motor impairments, and they completed a system usability scale (SUS) questionnaire in order to rate the ease of learning, memorization, efficiency, the occurrence of runtime errors and the level of user satisfaction. The results showed that the software is user-friendly.

Carrying out a comparison of the previous works with our application ECO, we can observe that the main difference is the interaction provided with the user because ECO is designed like a game. ECO includes the possibility of creating and sharing customized content in an adaptable and easy-going way. The communication elements can be photos, pictograms, videos in sign language, texts and voices. For example, the concept of "school" can be represented by a customized photo of the user's school, or using the generic pictogram, or the video in sign language or reading a word or using the text. ECO allows adding external elements and using resources created by the user. It should be noted that the pictograms are not defined in the application, and this makes it more flexible. It is fully adaptable in language and presentation mode. It is an open and free platform. ECO is developed with the service-learning methodology where research is carried out seeking solutions for real cases.

3. ECO: Easy Communicator app

The Easy Communicator application has been proposed as an Augmentative and Alternative Communication tool addressed to achieve a single goal: to ease the communication between people whatever the capabilities they have. Therefore, attending user requirements becomes key for the ECO design and its subsequent deployment [12].

Accordingly, a User-Centered Design approach (UCD) has been used as the guideline for the application design. UCD [16] incorporates user-centered activities throughout the entire development process of a product, from the requirements specification to the evaluations of the prototypes. In UCD the needs, capabilities, expectations and desires of the end user drive each stage of the development process and are considered from the beginning of the product life cycle. The stages involved in the UCD process are: (1) context definition; (2) requirements analysis; (3) application design and (4) evaluation. Feedback from the users is integrated at every stage. This design process is iterative, and like the application design progresses, user testing and user input are used to refine the features.

In the first development iteration of ECO, the tool was developed for a child with ASD and his family. In the next development iterations, users of one special education school, one special work center, one ordinary school, and two geriatric centers were incorporated successively into the process. Then, new users such as students with special needs and their teachers, workers with disability and their tutors, or elderly people with their caregivers were incorporated for testing and proposing further improvements. Once a complete version was published, we also performed heuristic and qualitative evaluations with new final users and their therapists to check if the tool was useful in their daily day scenarios.

The following subsections describe the   first stages of the UCD process: the context definition, the requirement analysis, and the application design. The last phase of the evaluation is presented in section 4.

3.1. Context definition

The first step consists of understanding and specifying the context in which the application is going to be used, i.e. identifying the potential population which the tool is addressed to, how and why they will use the application and in which conditions. Attending the goal of ECO, the context is defined according to the following aspects:

- Addressing a wide range of potential users. ECO is thought as a wide spectrum AAC tool. Therefore, its design must be addressed to attend a wide range of users, with noticeable different communication capabilities: from people with severe communication issues (e.g. users framed in the autism spectrum) to teachers specifically skilled in working with this kind of tools;
- Simple user structure. To ease the user interaction with ECO, two main roles are proposed: Communication User and Communication Manager. The former is set to the users who are the natural target of the application, i.e. those with some kind of communication handicap. The counterpart is the Communication Manager, responsible for setting up the application so that it fits the requirements of all the Communication Users under their care;
- Deployment in several contexts. Since ECO will support a wide range of users, it is reasonable to think that it will be used in multiple and diverse scenarios as well. For instance, ECO is proposed to be used in elder people centers, special work centers or simply the family environment;
- Targeting professional and regular Communication Managers. Communication managers have deep knowledge about the Communication Users under their care. However, they often have different goals when using the application, which are indeed tied to the specific needs of communication users. For instance, parents could just want a way to communicate with their children effectively, whilst a professional educator could be interested in calibrating the degree of communication disability a user has. Furthermore, not all Communication Managers will have the same skills when it comes to dealing with a computer application;
- Accordingly, ECO design has to produce a flexible tool capable of 1) providing any kind of content and 2) fitting the needs, skills and goals of both the communication users and managers.

3.2. Requirements analysis

The second step in the UCD process is to detail the requirements, i.e. all the aims of the potential users and all the restrictions of the system provider, according to the context definition. The requirements that ECO has to fulfill have been grouped in Table 1.

Table 1. System requirements

Identifier	Explanation
REQ1	A message has to be considered as the minimum communication unit. Thus, a message has to consist of both a content to be shown and the way the user interacts with that content.
REQ2	The structure of the information has to match the context in which the application is going to be used. This means not only the environment but also the goals, needs and skills of the users dealing with the application.

REQ3	Content cannot be tied to the application. Thus, content can be taken either from external sources (e.g. network repositories, USB drives, etc.) or device sensors (e.g. camera, microphone, etc.).
REQ4	Content and dynamic of use must be coordinated.
REQ5	Communication user and manager areas have to be clearly differentiated.
REQ6	Content and dynamics of use can be created, stored, reused and shared.
REQ7	Content and dynamics of use can be adjusted according to the Communication Manager interests.
REQ8	Maximizing the usability according to the specific context and users involved.
REQ9	The application has to work with any media useful for communication purposes, which involves at least images, photos, audio and video files, avatars and texts.
REQ10	The way in which the content is presented must be able to adapt according to the communicator user. This involves at least the color, size, position and way to interact with the content.
REQ11	Simplicity must rule the application in all activities related to communication users.
REQ12	The interaction with the application has to be intuitive.
REQ13	The application design has to be appealing to all communication users.
REQ14	The application has to support multiple languages.
REQ15	The application has to be fault-tolerant.

3.3. Application design

The next step in the UCD approach is to propose solutions for the application. These design solutions are iteratively proposed until reaching a definitive solution, which will be assessed in the last step to check if the requirements are properly fulfilled.

REQ8 and REQ13 demand that the application can be used by any kind of user, whatever their capabilities are. To do so, the ECO application was designed to structure the information in three levels: users, categories and messages. This three-tier design is aimed at organizing the information presented by the application, boosting the creation of new content and easing the usage of the tool, as required by REQ1, REQ2, REQ4, REQ8, REQ11, REQ12. Messages are the basic pieces of content used for communication, so that REQ1 is fulfilled. They consist of a joint picture and text label, which multimedia content (i.e. video and audio) can be added to. Although messages provide a rich way to create wide-spectrum communication items, they might limit the capabilities of an AAC tool when used standalone. Therefore, categories were introduced in the design of the ECO application to group messages dealing with a common and shared concept. Thus, instructors (or parents) can group pieces of information that are related one to each other (i.e. messages) and set up specific communication environments to their pupils (or children). Thus, categories allow the users of the tool to switch the communication environment according to their needs. The third tier of the ECO design introduces the concept of users, which are the people that actually use the software, i.e. the instructors, who set up the categories and conduct the communication experience; and the communication users, who make use of the tool to communicate with someone else.

Categories and users morph into several concepts according to the context the application applies to. For instance, in a home environment, the users are the children and the categories can be sets of actions these children want to take (e.g. eating related actions); in an educational center, user can be lectures (e.g. learning, diary, emotions, etc.) and categories can be sets of concepts (e.g. colors, continents of the word, numbers, days of the week, etc.). This capability to adapt the information structure to both the user and the context is addressed by requirement REQ2.

Figure 1 shows the main activity of the application, which leads to the two well-defined areas in which the application is divided: the Communication User and the Communication Manager. The former is thought as an AAC tool, whilst the Communication Manager area provides a way to edit the content and fit the dynamics of use and application design to the user's interests, i.e. requirements REQ3, REQ5, REQ6, REQ7, REQ8.

As can be seen in Figure 1, the plain and direct design of the sections, with simple and appealing images aiming to make the application both intuitive and appealing to the user, addresses the requirements REQ12 and REQ13. Only a few actions are thus allowed: changing the language (to attend the requirement REQ14); accessing the Communication User area by selecting any of the users defined by the Communication Manager; and logging into the Communication Manager area by pressing the customize button.
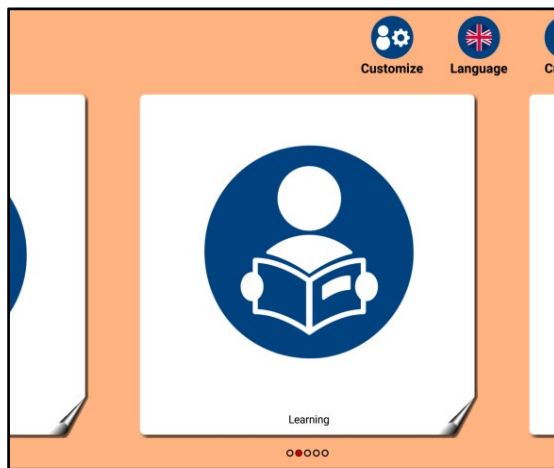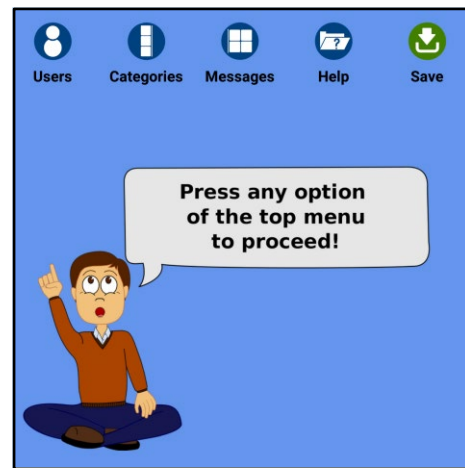

Figure 1. The main activity of the application

Figure 2. Communication Manager area

3.4. Communication Manager

The Communication Manager area follows the same design criteria, as shown in Figure 2. Options are structured in the same way for users, categories and messages. This covers requirements REQ2, REQ8 and REQ12. The users section allows the Communication Manager to manage the application users, i.e. to create new users or to remove or edit those already included in the application.

Any user can be exported or imported, which allows the Communication Manager to back up their users, move them to another device or take benefit from the contents created by other Communication Managers. The same applies to categories, which can be created, removed, edited, imported and exported, thus fulfilling requirement REQ6.

Once a user is selected, a new left-sided slide bar appears. This bar shows all user categories, so that the Communication Manager can select the one which he/she is interested to work in. Tapping one category loads all associated messages, as shown in Figure 3. As shown in Figure 4, a message can include a text, a sound, an image and a video, just as demanded in requirements REQ4 and REQ9.

All the content included in the message is shown sequentially, with a defined lapse of time between each piece of media, so that the user has enough time to process the information properly. Thus, firstly the image and the text are shown and after a while, the video and audio (if present) are played. Media (audio, image and video) can be taken by means of the device sensors (e.g. camera) or provided as a file, according to requirement REQ3. Moreover, the font (family, size

and foreground and background colors) and the image background can be tuned according to the manager's interests, satisfying thus requirement REQ10. The same applies to user and category elements, where any media can be added and tuned according to the purpose of the element.

Figure 3. Messages loaded after tapping a category

Figure 4. Message details

Message dynamics can be changed according to the user's needs and the manager's goals, which fulfills what is requested in requirements REQ7 and REQ11. This dynamic tuning is achieved by:

- Changing the message layout. The message layout can be changed according to the user's skills and the nature of the category. The layout represents the amount of messages shown at once on the screen. If the category includes more messages than those shown in the screen, they can be reached by scrolling up or down. As shown in Figure 5, the layout follows a matrix shape of size from 1x1 message up to 6x6 messages, which, according to the screen size of regular devices, fits most of user's and manager's necessities;
- Sorting the information elements. Users, categories and messages can be sorted according to the manager's interests. And both manager and user requirements. Thus, messages can be shown in the specific order the manager sets them or place those messages randomly to avoid the user to develop patterns according to the place the messages are settled;
- Message dismiss. When the Communication User picks a message in the Communication User area, ECO draws it in the screen and presents sequentially all its contents. Once all the contents are finished the message is dismissed. The Communication Manager can decide the way in which messages are dismissed according to the communication user's skills and the purpose of the category where the message is included in: automatically by the system (according to a certain timeout) or manually by the Communication User (by clicking over the message). In the case of automatic dismissal, the manager can set the timeout according to the user's skills.
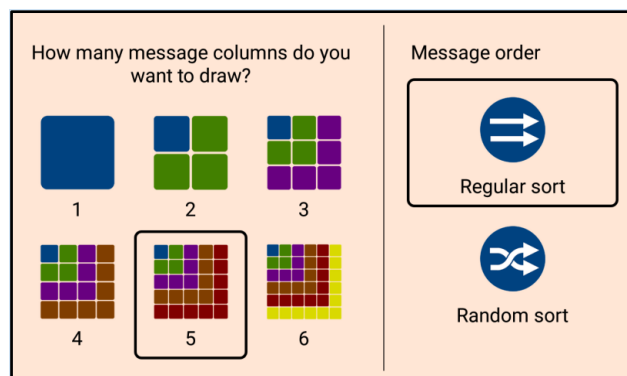

Figure 5. Message layout and display order

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3.5. Communication User

As previously introduced, the Communication User is thought of as an AAC tool. This tool has been structured in three working areas: the message board, the category list and the message viewer. Any other concept has been wiped out from the interface, thus simplifying the use of the tool and fulfilling the requirements REQ5, REQ8, REQ11 and REQ12.

The message board provides a grid that shows all the messages associated with the currently selected category, as shown in Figure 6. This working area is conceived as the key section of the Communication User since it is where the user is expected to spend most of the time interacting with. The main features of the message board are the following:

- It provides the way to get to the other working areas: the message viewer and the category list. The former is accessed by swiping (or pressing on, so as to fulfill the REQ15) the vertical sidebar on the left. The message viewer is raised upon a message of the message board is selected;
- Only one message can be selected at a time;
- Pressing repeatedly a message runs a single instance of the message viewer. This allows precise movements not to be a requirement for using the tool, fulfilling what demanded in REQ15;
- The message board takes most of the screen room. The vertical sidebar on the left, that let the user to access the category list, is the only item that overlaps the message board;
- The amount of messages in the grid and the order in which they are shown depends on the configuration set by the communication manager;
- Whatever the configuration, the amount of messages is expected to be larger enough to exceed the grid visual dimensions. Hence, communication users will be able to scroll up and down over the grid, as they usually do in list-like elements, to show messages that are not currently being shown in the grid.
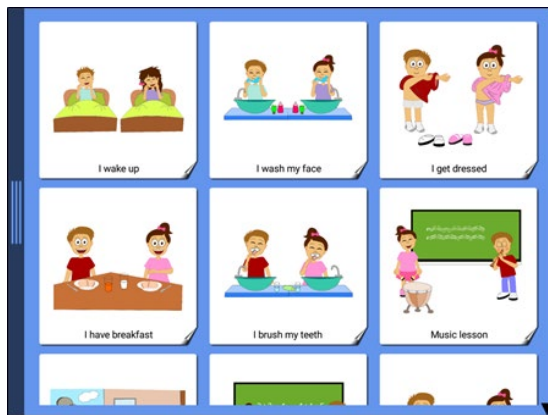

Figure 6. Message board   **Figure 7.** Category list

The category list is shown as the communication user presses on (or swipes, so as to fulfill the REQ15) the sidebar on the left. The goal of this working area is showing the categories addressed to the current user and letting the communication users (by themselves or assisted by the communication manager) select the one in which they are interested on. The main features of the category list, illustrated in Figure 7, are:

- It updates the content of the message board according to the selected category;
- It is settled permanently on the left of the screen, so that the communication user can change the category whenever they want;

- It is shown and hidden at will by the communication user;
- As in the case of the message board, the amount of categories are expected to exceed the screen dimensions. Accordingly, they cannot be shown all at once, except a few of them. The communication users can scroll up and down on the list anytime to reach the category in which they are interested on;
- The last category, labeled as "exit", lets the communication user finish the current session and go back to the main screen of the application. There, they will be able to select any other active user to access a different set of categories or login into the Communication Manager's area;
- Whenever a category is tapped, the message board loads all the messages related to that category and the category list is automatically closed, moving to the message board working area.

The message viewer (see Figure 8) aims to show in detail the message contents. The main features of this working area are summarized next:

- The message viewer magnifies the message basic information (i.e. the picture and a text working as caption) up to fill all the screen. This basic data is mandatory for every message in the application. This procedure is addressed to fulfill the requirements of REQ8 and REQ13;
- The message viewer plays the multimedia content that comes with the message, satisfying thus the requirements REQ4 and REQ9. This content can involve audio and/or a video track, but its presence is not mandatory;
- Whenever an audio track needs to be played, the message viewer will show the picture and the text that acts as a figure caption, as background for the sound. The purpose is to keep the communication user focused on the concept associated with the message;
- Once all the multimedia contents of the message are played, the message basic information (i.e. the picture and caption) will remain for a while on the screen. The time the message basics remain on the screen depends on the setup made by the Communication Manager. It can be either a fixed time after the message contents have been played or an undefined time that concludes with the communication user tapping the message (i.e. anywhere in the screen). Finally, once the message viewer's job is over, the message is progressively shrunk until it disappears. This procedure attends what is demanded in the requirement REQ13.
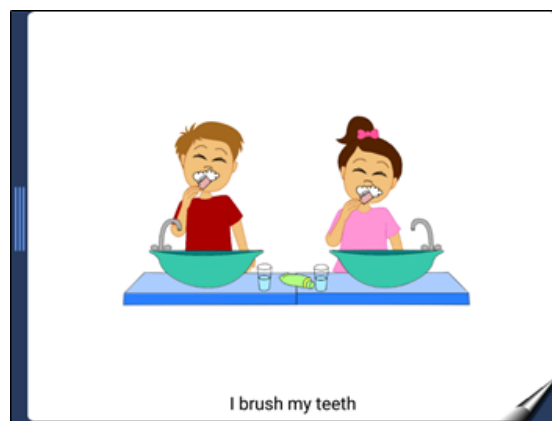

Figure 8. Message viewer

4. Evaluation

Following a DCU approach, an evaluation of the ECO tool has been carried from two different perspectives. On the one hand, we have achieved a heuristic-based expert evaluation in order to

analyse the functionality corresponding to the Communication Manager module of the tool, in order to check the main accessibility requirements and improve functionality accordingly. On the other hand, we also wanted, later on, to study both the Communication Manager and Communication User modules in a real context, carrying out a heuristic-based evaluation and a qualitative evaluation with final users and their therapists to check whether the tool is useful in specific daily scenarios.

Both evaluations were carried out in accordance with the recommendations of national and international ethics guidelines, i.e. the Código Deontológico del Psicólogo and American Psychological Association. The study does not entail any invasive procedure, and it does not carry any risk to the participants' mental or physical health, thus not requiring ethics approval according to the Spanish law BOE 14/2007. All subjects participated voluntarily and gave written informed consent in accordance with the Declaration of Helsinki. They were free to leave the experiment at any time.

4.1. Expert Evaluation

In this case, the idea is to determine the perception of usability and accessibility based on the best practices in AAC systems, and according to expert criteria. This is a formative evaluation where the main aim was to detect the main usability and accessibility problems that will be revised later on.

4.1.1. Research Questions

In order to conduct our evaluation, we propose the following research questions that will be answered through the evaluation results:

- RQ1.1: Can the ECO Communication Manager module be considered usable according to expert criteria?
- RQ1.2: Does the ECO Communication Manager module fit the most important accessibility requirements based on the best practices in AAC systems, according to expert criteria?

4.1.2. Method

The evaluation consisted on a controlled experiment accomplished with a set of experts that were asked to carry out an inspection evaluation [6][17][18] based on an interaction with the ECO Communication Manager module, and the completion of two different questionnaires that will be described down below: a SUS (System Usability Scale) questionnaire [5][9] and a heuristic checklist on accessibility requirements with regards to AAC systems [3].

This way, we provided experts with an initial overview of ECO, download guidelines and instructions for the evaluation (about 10 minutes). Then, we provided experts with a set of usage scenarios so they could walk through the ECO Communication Manager module and explore the main functionalities intended for expert users, educators and therapists. We also measured the time that every expert spent to complete each usage scenario to have an idea of efficiency. Once they finished, we asked participants to fill in the two questionnaires and report some additional questions about strengths and likely improvements focused on the analyzed tool.

Finally, we carried out statistical analysis to compare the results obtained from the questionnaires filled in by experts. To carry out this task, we analyzed the results from the SUS questionnaire and also utilized an inter-rater reliability (kappa-value) technique to measure expert agreement with respect to the heuristic checklist. Moreover, we analyzed other qualitative information obtained from experts, comparing and discussing the results obtained.

4.1.3. Evaluation Questionnaires

We used a SUS questionnaire to measure perceived usability from experts after they interacted with the ECO Communication Manager module. SUS is a valuable questionnaire with a high psychometric validity to measure perceived usability. It consists of 10 questions (half of them are positive, while the others are negative) that experts rated using a 5-point Likert scale (where 1 means *strongly disagree* and 5 means *strongly agree*). Also, SUS provides a method for combining the 10 scores obtained on a wider scale between 0 and 100. The result from the evaluation of the 10 questions has to be interpreted as a whole, and not separately [36]. The outcome obtained represents a measure for the perceived usability.

In addition, we utilized a heuristic questionnaire based on a checklist of 16 checkpoints to validate accessibility in a specific domain such as AAC systems. This questionnaire has been inspired by different works and standards to analyze and capture accessibility requirements that AAC tools must meet for people with special communications needs. The checklist is shown in Table 2, where checkpoints are gathered into categories (a total of 6). Measurable checkpoints should be evaluated by each expert using the following values: "No" when the checkpoint is not satisfied, "Yes" when the checkpoint is satisfied, "Partial" when the checkpoint is partially satisfied, and "NA" when the checkpoint does not apply.

Table 2. Checklist proposed to evaluate accessibility requirements in a specific domain such as AAC systems

#	Checkpoint categories and evaluable checkpoints
Categories, profiles and configuration settings	
1	Allows users to create and edit different semantic categories
2	Allows users to create and edit profiles for different types of use
Theme communication boards and configuration settings	
3	Permits box sizes to be changed
4	Permits box layouts, positions and orientations to be changed
5	Provides a different background color for each semantic category
Content: Pictographic symbols and configuration settings	
6	Allows for the upload of external pictures
7	If it allows external pictures, users are informed about which sizes and formats can be used
8	Allows the inclusion of: a picture along with a caption/text; the pictures are distinguished from the caption/text; only a picture; only a caption/text
9	Pictures and captions/texts must be easy to understand
Output: Messages and configuration settings	
10	Provides flexibility regarding the number of messages
11	Provides speech output, digitized speech output or synthetic speech output
12	Provides flexibility with regards to the size and editing of messages
13	Allows users to select and adjust the volume
Input: Access and configuration settings	
14	Permits access via a haptic interaction. Enough space is provided to allow for the movements needed to reach all boxes. Accuracy (boxes are large enough to click comfortably)

15	Allows access via Assistive Technology
Online documentation, help and support services	
16	Provides understandable and accessible documentation and help

4.1.4. Participants

We recruited 5 experts with an expertise in accessibility to participate in the evaluation. They consisted of two men and three women with ages between 37 and 49 years old (M=42.6, SD=5.2). As for their background, they are university researchers having advanced skills and years of experience in accessibility (M=5, SD=4.6) and autism spectrum disorder (M=9, SD=6.7).

According to existing bibliography, formative evaluations can be achieved with a more reduced set of participants than summative ones. Although there is not a fixed number, recruited participants should be selected according to the objective of the evaluation and the kind of problems expected to be found [7]. In this case, five experts can be considered as a representative figure   [25] to find the most important usability problems (over 85%) that will be considered to refine the ECO tool in following iterations.

4.1.5. Usage Scenarios

We proposed the following usage scenarios in order to evaluate ECO. Those can be meant as walkthroughs including different tasks intended to cover the principal functionalities that the Communication Manager module provides for experts:

- Scenario 1: Create, export and share a new user;
- Scenario 2: Configure the tool's settings according to the new user created in Scenario 1;
- Scenario 3: Create two different messages and associated categories according to the settings provided in Scenario 2.

All scenarios are interdependent, so they have to be performed in strict sequential order for all participants.

4.1.6. Apparatus

To perform the different usage scenarios, we asked experts to utilize their own tablets. In general, experts utilized Lenovo and Samsung Galaxy tables, featuring different models (Tab4, Tab S2 and Tab S4) and screen sizes (10" and 10.5"). Android OS version ranged from 7.0 to 8.1.

4.1.7. Results and Discussion

Figure 9 shows the results obtained from the SUS questionnaire for each expert. In general, an average value of 86 was obtained (SD=5.5), denoting high perceived usability [34] for ECO Communication Manager module.

As for the heuristic checklist, an inter-rater reliability analysis using the kappa statistic was accomplished to determine agreement among experts. Specifically, a Fleiss' kappa [14] was calculated to evaluate the agreement with the ratings obtained from the heuristic questionnaires filled in by the 5 experts. In contrast to other statistics, such as Scott's pi or Cohen kappa, which are suitable only for two raters, Fleiss' kappa works for any number of raters. The kappa value comprises a real number between 0 to 1, where 1 means agreement and 0 means disagreement. A significant kappa=68% at p-value < 0.05 was obtained, denoting a substantial agreement among experts [14] . Figure 10 depicts the agreement among expert in a graphical way, where option 1

(no), 2 (partially) and 3 (yes) are represented in axis Y, whereas the different checkpoints shown in Table 2 are represented in axis X; "NA" was never selected by experts for any checkpoint.
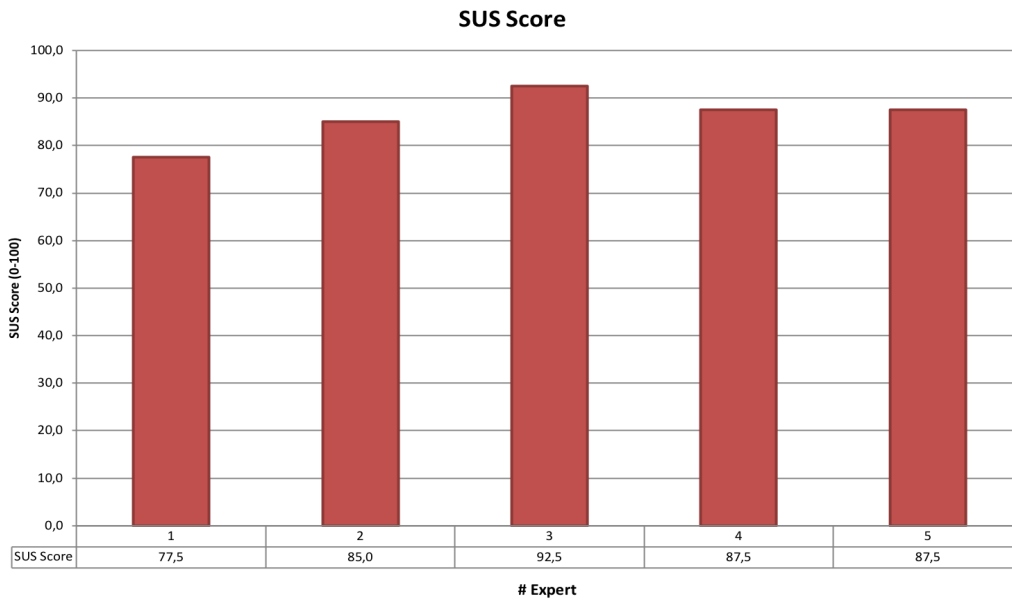

Figure 9. SUS score by expert

As shown in Figure 10, all the experts agreed that the categories, user profiles, and configuration setting requirements are perceivable in the evaluated tool. Users have complete freedom when creating categories and user profiles for different types of use. ECO provides flexibility with regards to the number of messages and external pictures that can be displayed on screen, in addition to offering either digitized speech output or synthetic speech output for messages.
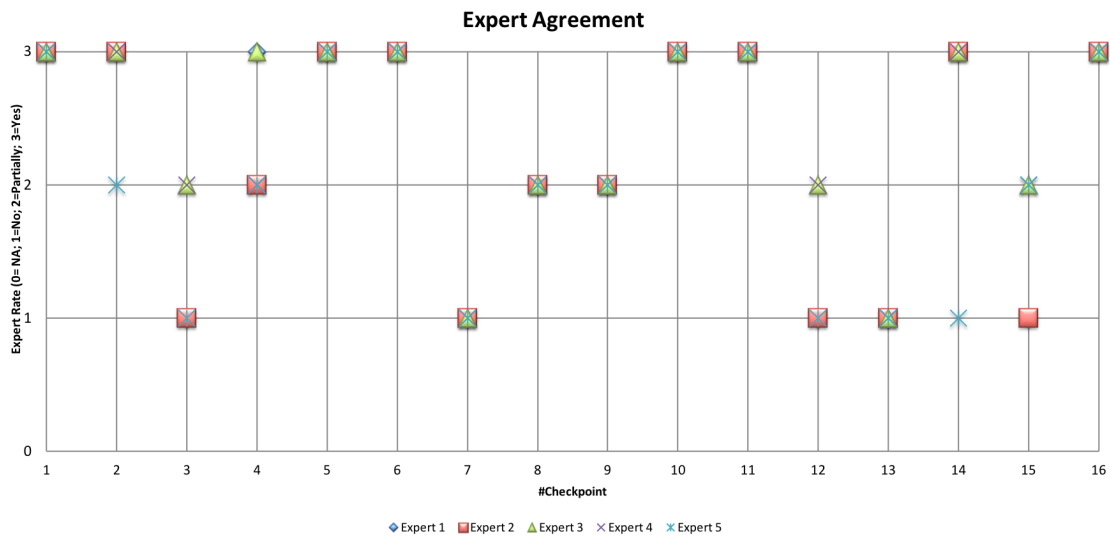

Figure 10. Expert agreement with respect to the 16 checkpoints analyzed

On the contrary, the experts agreed that some requirements related to permitting changes in box sizes are either not included or only partially included. Moreover, the experts observed that the tool does not fully comply with some of the requirements. One example of this is the fact that users are not given information as to which sizes and formats of external pictures can be used. Additionally, users are not forewarned that the pictures and captions introduced should be easy to understand. What is more, users are not allowed to select and adjust the volume within the application itself and it can only be adjusted through the volume settings of the device. The experts observed only partial compliance with other accessibility requirements with regards to the size

and editing of messages, which can be moved within the grid but the size cannot be changed. Furthermore, while access via assistive technology is allowed using the magnifier, the voice assistant is not well-supported.

Compliance with the remaining requirements has been observed in the tool, according to expert criteria. The ECO Communication Manager module permits access via haptic interactions and enough space is provided to allow for the movements needed to reach all boxes. Finally, a help menu with comprehensive information is offered.

We also measured efficiency values according to the average time on usage scenarios during the walkthrough sessions with experts [37] (see Table 3). As shown, Scenario 3 required the highest average time, while Scenario 2 required the lowest. In general, Scenario 2 was achieved by all experts presenting no specific problems. It consisted in configuring the tool according to the new user created in the previous scenario. As for Scenario 3, users spent some time identifying how categories and messages have to be created. This took more time than the rest of tasks, as experts realized that categories should be created before messages, in contrast to the order specified in the scenario statement. As for Scenario 1, it involved initial tasks concerning creation, exportation and sharing of a new user. It is worth mentioning that experts found difficulties in finding the sharing option, which is executed together when the user is exported and saved in a folder of the tablet, needing some additional time to correctly identify the task and carry it out. As for strengths identified in each scenario, the experts highlighted the intuitive and easy creation of users, together with the help mechanism that provides the corresponding support to carry out the task successfully. In addition, all experts appreciated the mechanism to configure the tool's settings according to the new user created, where the tool provides visual help and support to carry out the task easily. As for functionality affecting messages and categories, all experts agreed that both messages and categories are well structured, providing visual feedback to complete the tasks.

Table 3. Statistics corresponding to efficiency in seconds for each scenario analyzed

Measure	Scenario 1	Scenario 2	Scenario 3
Mean	199.60	80.60	314.60
Min	153.00	56.00	231.00
Max	246.00	102.00	390.00
SD	40.61	19.84	63.75

With respect to improvements, experts identified that the user management should be improved in order to provide visual feedback accordingly, as a new user has to be created from an existing one, which may result confusing as all user options appear together. On the other hand, one expert identified that the editor does not correctly interact with the Android Voice Assistant accessibility option, presenting problems for blind parents and teachers. In addition, experts identified another improvement related to messages and categories. This way, visual feedback should be improved to distinguish options affecting all categories or just only one. Moreover, options related to message configuration should be improved in order to correctly identify how to remove messages and the relationship among the different options provided for it, which should appear clearly enough. In addition, menu options affecting categories and messages should be restructured in order to better identify the creation sequence and split up help and management options in a much clearer way.

All these concerns will be considered in the next improvement round to refine and include new requirements. All in all, the ECO Communication Manager module provides evidence of initially being a usable and accessible communication tool according to the expert criteria. This helps answer research questions RQ1.1 and RQ1.2, concluding that the ECO Communication Manager

module can be considered usable, fitting also the most important AAC accessibility requirements according to expert criteria, respectively.

4.2. End-User Evaluation

In order to test the real benefits that users with disabilities and their therapists could obtain from the ECO application, we carried out a qualitative evaluation of the Communication User module with children and young adults with cerebral palsy and related disabilities. People with cerebral palsy face specific challenges, which arise due to motor dysfunction and communication disorders. In this sense, augmentative and alternative communication (AAC) systems are solutions to supplement spoken communication or to replace it completely   [35].

This evaluation was performed not only with children and young adults with disabilities but also with their therapists who are also end-users of the ECO Communication User module. Therapists used the ECO tool during their sessions as they use other types of materials (for example, communication boards), so their opinion should be considered.

4.2.1. Research Questions

The aims of this experimental study were to evaluate the ECO Communication User module from the perspective of users with communication disorders, and their therapists.

The users that participated in the evaluation of the ECO Communication User module were quite heterogeneous in their cognitive levels and communication disorders, and the scenarios of use had to be completely personalized to be useful for them, so we performed a qualitative evaluation focused in how the ECO tool could improve the users' therapy sessions and how both patients and therapists could benefit from it. This qualitative evaluation was designed to address the following research questions:

- RQ2.1: Does the ECO Communication User module fit the needs, skills and goals of users with disabilities?
- RQ2.2: Does the ECO Communication User module fit the needs, skills and goals of therapists?
- RQ2.3: Is the ECO Communication Manager module a flexible tool capable of providing any kind of content?

4.2.2. Participants

A total of 3 therapists and 10 children and young adults with different cognitive levels as well as special communication needs participated in the study. All of them come from the ASPACE Segovia Association[1]. ASPACE Segovia is the Association of Parents and Tutors of People with Cerebral Palsy and Related Disabilities, located in Segovia (Spain). It is an open and non-profit organization. They promote the study, information, research and dissemination of problems affecting people with cerebral palsy, and they develop actions that make possible the prevention, rehabilitation, recovery and social integration of people with cerebral palsy and related disabilities. Therapists participating in the evaluation hold different positions within such an association.

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[1] www.aspacesegovia.com

Table 4 shows a detailed description of the three therapists that participated in the study, including gender, age, position in the association, their experience in Special Education, and their familiarity with the use of assistive applications. They were all women with ages between 25 and 34 (M=28.7, SD=4.7), having years of experience in special education (M=3.3, SD=0.6) and familiarity with the use of assistive applications with their patients (M=4.3, SD=1.2).

Table 4. Information of the professionals participating in the evaluation

ID	Gender	Age	Position	Experience in Special Education (in years)	Familiarity with the use of assistive applications
T1	F	34	Occupational therapist	> 3	Medium
T2	F	25	Pedagogue	Between 1 and 3	Very high
T3	F	27	Speech therapist	> 3	Very high

Table 5 shows the description of the 10 participants with cognitive impairments and with special communication needs who interacted with the application as part of the study, including gender, age, disability, cognitive level and the therapists who worked with them during the experiment.

Table 5. Information of the children and young adults participating in the evaluation

ID	Gender	Age	Disability	Cognitive level	Therapists
U1	M	10	Propionic acidemia	Medium	T2/T3
U2	F	9	Koolen-de Vries Syndrome	High	T2
U3	F	9	DiGeorge Syndrome	Very low	T2
U4	F	9	Developmental delay	High	T2/T3
U5	F	19	Infantile Cerebral Palsy	Low	T1
U6	F	9	Lissencephaly, West Syndrome, Epilepsy	Low	T1/T3
U7	F	9	Microdeletion Syndrome	Very low	T1/T3
U8	F	5	Angelman Syndrome	Very low	T1/T3
U9	F	15	Wolf-Hischorn Syndrome	Low	T1
U10	M	12	Angelman Syndrome	Low	T3

Of the total of 10 participants in the study, two were male and eight were female. Mean age was 10.6 (SD = 3.89). As the range of disabilities was diverse, we asked the professionals to classify the cognitive level of the participants for easier comparison. Most of them had a very low (30%) or low (40%) cognitive level, with only two participants with a high cognitive level (20%) and one with a medium one (10%). It is also important to note that some of the participants had therapy sessions with more than one of the professionals, as each therapist has a different role inside the association.

4.2.3. Method

The evaluation was divided into three stages. Firstly, professionals recruited the users with special communication needs from the people they work within the association. For each specific user, the therapists who treat him/her formalized the goals that will be worked using the ECO Communication Manager module, and for each of these goals decided what new categories had to be created and which messages should be included in them. For example, for working the goal of "increasing their vocabulary through real images", a new category of Places with real photos (completely personalized for this user) had to be created.

In the second stage, once all the required categories and their messages had been created, the professionals used the ECO Communication User module for 2-3 weeks in their usual therapy sessions, where they worked on the previously defined goals. In this way, the experimental sessions were completely adapted to each participant, so they did not get confused by unknown environments or dynamics. Each session alternated usual activities with the use of the categories created in the ECO Communication Manager module for the subject by the professional. The use of the ECO tool in the sessions depended on the disposal and attention of the patients since they associate the use of the tablet with the music videos or drawings that the parents present them in other day-to-day situations. The number of sessions and hours was variable depending on their usual routine. It is also important to remember that some participants were treated by different therapists, as we can see in Table 5.

In the third stage, the professionals were asked to complete two types of questionnaires. The first one was a personalized questionnaire for each of the participants, with questions about participants' reactions to the tool and the degree of achievement of the corresponding goals. This questionnaire should be answered by users with disabilities who participated in the study, though children and young adults who interacted with the tool during the evaluation did not have the ability to respond directly to the questionnaires, so we needed the help of therapists to do it. This is an extended recommendation in studies involving users with disabilities [1][10][13]. Then, a second questionnaire about the therapists' perception of the utility and usage of the tool during the sessions was performed. More details about the goals, scenarios and questionnaires are given in the following sections.

4.2.4. Usage Scenarios

As commented previously, the design of the evaluation was completely personalized and adapted to the needs, requirements and goals of each participant. Therefore, for each user, the therapists defined several goals that could be fulfilled working with the ECO tool, and each of these goals defined the categories that had to be created in order to work with the users during the therapy sessions. Table 6 shows a list of goals and categories created for each user.

Table 6. Specific goals and categories defined by therapists for each participant

USER	SPECIFIC GOALS	ECO CATEGORIES
U1	Associate objects by colour or by their image	Colours
	Discriminate visually between different animals	Animals
	Discriminate auditive between different animals	Animals (with sounds)
	Increase vocabulary related to Christmas	Christmas

	Encourage expression through everyday actions	Daily life actions
U2	Understand and respond appropriately to "no" and "yes", and use it correctly	Selection (yes and no)
U3	Learn the numbers up to 10	Numbers from 1 to 10
U4	Discriminate between different places	Places
	Discriminate between different everyday objects	Everyday objects
	Discriminate between different daily life actions	Daily life actions
U5	Discriminate between different colours	Colours
U6	Discriminate between different colours	Colours
	Discriminate between different basic actions	Basic actions
	Discriminate between different body parts	Body parts
U7	Discriminate between different basic actions	Basic actions
	Discriminate between different everyday objects	Everyday objects
	Discriminate between different real places	Places (real photos)
U8	Discriminate visually between different colours	Colours
	Discriminate visually between different animals	Animals
	Increase vocabulary related to Christmas	Christmas
	Discriminate between different body parts	Body parts
U9	Recognize colours	Colours
	Recognize animals	Animals
U10	Increase vocabulary related to Christmas	Christmas
	Discriminate between different basic actions	Basic actions
	Discriminate between different food	Food
	Discriminate between different clothing	Clothing
	Encourage expression through everyday actions	Daily life actions
	Acquire basic requests (*I want*, *Close*, *Give me*)	Basic requests

As can be seen in Table 6, the goals assigned to the different users are personalized and adapted to their cognitive levels, but are similar or coincident in several cases. For example, goals such as to discriminate between colours or animals, or to increase vocabulary related to Christmas, are important for several users. In this way, once the therapists had defined the new categories they had to create, they were encouraged to share efforts and divide the work among them. For

example, one of the professionals could create the Colours category, and it could then be shared with the others who were going to use it. The export/import capabilities of the ECO Communication Manager module allowed to do this in an easy way.

Figure 11 shows the "Numbers" category created for user U3, where we can see the messages in the category. Other categories contained real-life images that some users find easier to understand than pictograms. An example can be seen in Figure 12 where the "Places (real photos)" category for user U7 is showed.

In addition to the specific goals for each participant, therapists listed a series of transversal goals (see Table 7) that were common for all users but did not require new categories to work on them.

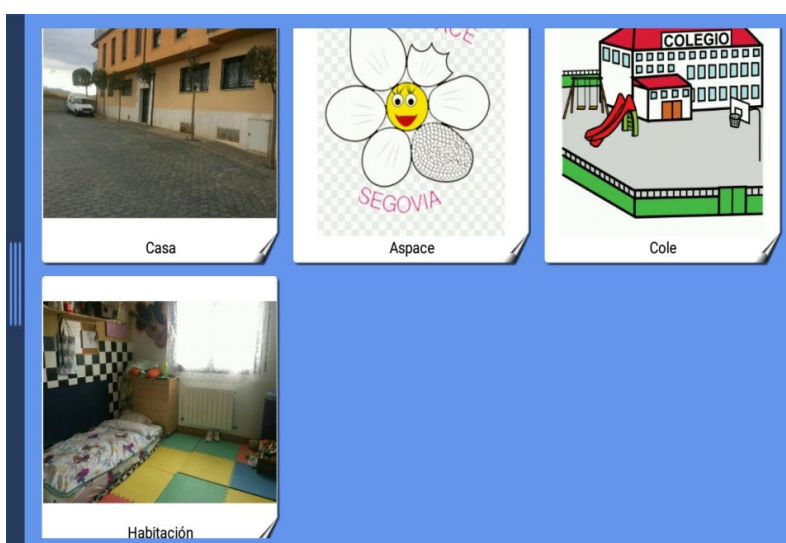**Figure 11.** "Numbers" category created for user U3

Figure 12. "Places (real photos)" category created for user U7

Table 7. Transversal goals defined by therapists for all users

ID	TRANSVERSAL GOALS
TG1	Increase their interest in the tasks worked during the session
TG2	Improve their willingness to work on the goals set in each session
TG3	Work passive movements
TG4	Work sensory stimulation
TG5	Work basal stimulation
TG6	Work on the categorization of concepts
TG7	Work on the cause-effect relation
TG8	Develop listening sequential memory
TG9	Work the imitation
TG10	Improve attention
TG11	Improve fine motor skills
TG12	Reduce impulsivity
TG13	Promote sustained attention times
TG14	Promote oral expression
TG15	Improve communication
TG16	Improve eye contact
TG17	Increase vocabulary

4.2.5. Evaluation Questionnaires

Once the therapists had finished their sessions with the participants of the study, they were asked to complete two different end-user evaluation questionnaires: one containing information about the usage of the tool by each user with disabilities (Questionnaire 1), and another about their own perception as therapists (Questionnaire 2). Both questionnaires were based on Likert-scale questions ranging from 1 (*strongly disagree*) to 5 (*strongly agree*), except for a yes/no question in Questionnaire 2 and a blank space that was left to be filled freely with feedback or suggestions for improvement.

Questionnaire 1 captures information about the use of the tool by each participant with disabilities, with the idea of knowing more about the work done with the tool and the improvements achieved during the sessions, if any. The first research question (RQ2.1: Does the ECO Communication User module fit the needs, skills and goals of users with disabilities?) is associated with this questionnaire. A part of this questionnaire is common to all participants and contains questions about the transversal goals shared among all users (one question for each goal in Table 7, and an additional question "The user shows interest in the application"), and there is another part which contained specific questions for each participant about each of their personal goals, the ones

presented in Table 6. Therefore, we created a total of 10 different questionnaires, one for each user. This is the typical questionnaire that participants in a study must answer with their personal responses. However, as our participants do not have enough cognitive level to understand the intended questions and to perceive their improvements in each specific goal, therapists filled this questionnaire for them. In the cases where a user was treated by two different professionals, we received two copies of the filled-out questionnaire corresponding to this user, where each therapist had answered the questions corresponding to their work with the user.

Questionnaire 2 (see Table 8) captures the perception of the professionals about the use of the tool. It contained questions about the use of both the ECO Communication Manager module and the ECO Communication User module. Each therapist filled out this questionnaire at the end of the evaluation. Research questions RQ2.2 (Does the Communication User module fit the needs, skills and goals of therapists?) and RQ2.3 (Is the Communication Manager module a flexible tool capable of providing any kind of content?) are associated with Questionnaire 2.

Table 8. List of questions in Questionnaire 2

#	Question
Q2.1	The application allows to easily create a new user
Q2.2	The application allows to easily export users
Q2.3	The application allows to easily share users
Q2.4	The application is easy to configure for a new user
Q2.5	The application allows to easily create new categories
Q2.6	The application allows to easily export categories
Q2.7	The application allows to easily create different messages and associate them to the categories
Q2.8	I have learned to use the tool easily
Q2.9	I save time in my usual tasks by using the tool
Q2.10	I would like to continue using the tool
Q2.11	I would recommend the tool to other professionals
Q2.12	In general, the application is more useful than others I had already used
Q2.13	The application allowed me to work all the proposed goals (yes/no)
Q2.14	If not, what goals could not be worked with the application? Why?
Q2.15	General comments

4.2.6. Apparatus

In order to carry out the assessment, the therapists used devices available in the association, which were two Bq-Aquaris tablets and one Lenovo tablet featuring different models (M10 and TB-X304F), and a 10.1" screen size, with Android OS versions 6.0 and 7.1.1, respectively.

4.2.7. Results and Discussion

Figure 13 shows a chart including individual box plots related to each transversal goal posed to all subjects (see Table 7), according to the therapist's answer to the question associated with each goal in a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). As shown in Figure

13, goals TG3, TG4, TG5, TG6, TG7, TG8, TG9 and TG16 have median values greater than or equal to 3.5 and lower variability -i.e.,   IQR (Interquartile Range) <=1   . This means that such goals were easier to achieve according to the distribution of answers, as they have median values closer to agree onwards in the aforementioned Likert scale. More specifically, TG7 and TG16 were achieved by all subjects (median=4, IQR=0). Moreover, TG13 has one of the highest variabilities (IQR=1.375), but also a higher achievement value (median=4). By contrast, TG14 and TG15 have the lowest median values (median<=2.5, IQR=1), also TG1 with a higher variability (IQR=1.375), denoting that such goals were the more difficult to achieve. Some outliers can be also identified in TG7 (above Q3+1.5*IQR), TG8 (below Q1-1.5*IQR) and TG16 (two above Q3+1.5*IQR and one below Q1-1.5*IQR) that does not specifically affect the interpretation of results.
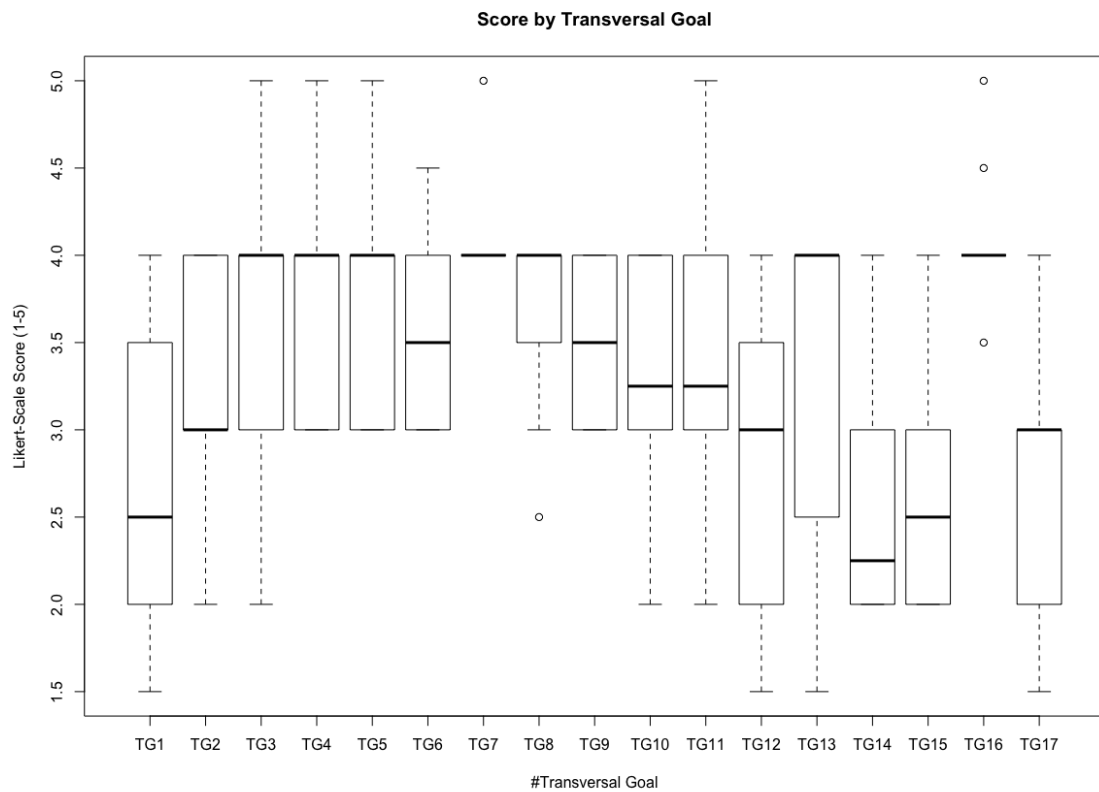

Figure 13. Distribution of results for transversal goals obtained from Questionnaire 1

Figure 14 shows the percentage of specific goals achieved by each participant. As can be seen, there are four participants (U2, U5, U6 and U9) who did not achieve any of their specific goals and three participants (U3, U4 and U7) who achieved all the specific goals that the therapists set out to work with them.
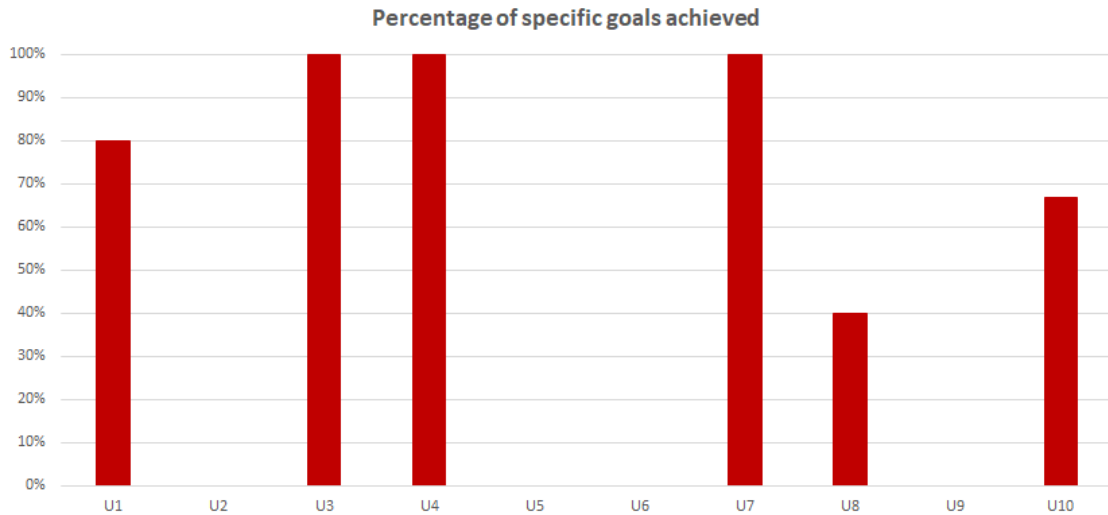
23

Figure 14. Percentage of specific goals achieved by each participant

Figure 15 shows the percentage of goals (transversal and specific) achieved by each participant. We can see that, although there were participants that were not able to fulfill their specific goals, all participants achieved at least some goals if we consider together the transversal and specific ones. All participants achieved at least 30% of their goals, and six of them achieved 50% or more. If we analyze these results we can see that the number of goals achieved does not depend on the subjects' cognitive level. If we analyze the cognitive level of the four users who have not reached 50% of their goals, we find that two of them have a very low cognitive level, another has a low cognitive level and the last one has a high cognitive level. The same applies to the two subjects who have achieved the highest percentage of their goals: one of them has a medium cognitive level while the other has a very low cognitive level.

Figure 15. Percentage of goals (transversal + specific) achieved by each participant

Differences in the achievement of specific and total goals can be observed in Figure 16. We can clearly appreciate that, although there is high variability in the percentage distribution of specific goals (IQR=0.95), results become less variable (IQR=0,26) when considering all goals together - i.e., transversal and specific ones, obtaining also similar Q2 values (median≈0.5) in both cases.
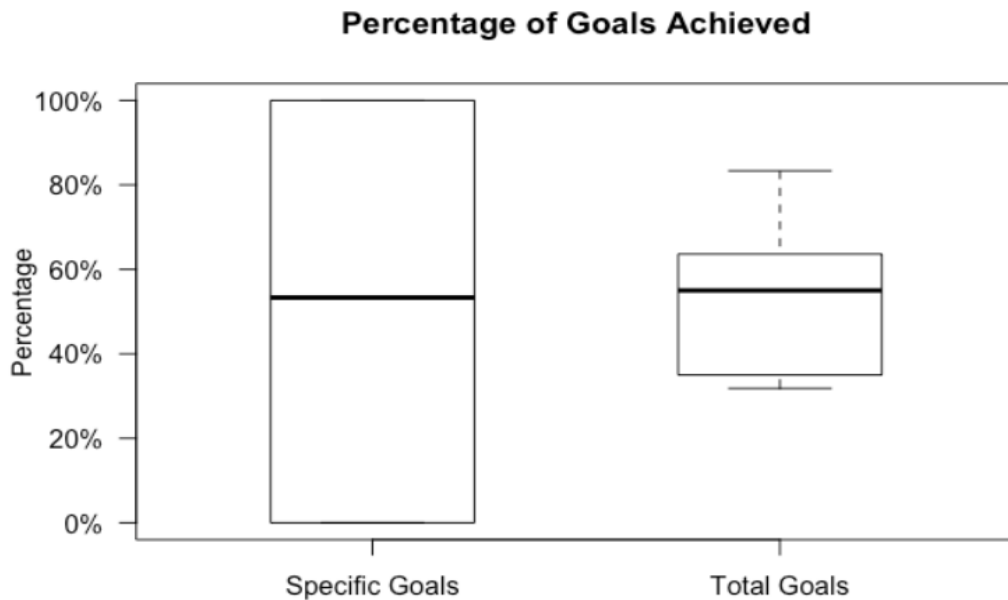
Percentage of Goals Achieved

Figure 16. Comparison between the percentages of achieved specific and transversal goals

Taking into account these results, the research question RQ2.1 (Does the Communication User module fit the needs, skills and goals of users with disabilities?) is corroborated, we can affirm that the ECO tool fits most of the needs, skills and goals required by users with disabilities, as all of them were able to fulfill some of their goals, and most of them were able to achieve most of their goals.

Responses to Questionnaire 2 (perception of the professionals about the use of the tool) were, in general, positive and are detailed in Table 9. The only two questions with answers below 3.5 are questions Q2.2 ("The application allows to easily export users") a Q2.12 ("In general, the application is more useful than others I had already used"). Regarding the option of exporting users, it is a fact that professionals had many problems with this task, and it was necessary to record a video to show them how to export and import users from one device to another. The answers to question Q2.13 ("The application allowed me to work all the proposed goals (yes/no)") were unanimous: the tool allowed all professionals to work the goals set at the beginning of the evaluation.

Table 9. Responses to Questionnaire 2, including mean and standard deviation.

Question	Mean	Std. Dev.
Q2.1	4,00	0,00
Q2.2	3,33	0,58
Q2.3	3,67	0,58

Q2.4	3,67	0,58
Q2.5	4,33	0,58
Q2.6	4,33	0,58
Q2.7	4,00	0,00
Q2.8	3,67	0,58
Q2.9	3,67	0,58
Q2.10	3,67	0,58
Q2.11	4,00	0,00
Q2.12	3,33	0,58

Regarding the comments left by the therapists in the last question (Q2.15), it must be noted that the following observations were highlighted as strengths of the tool:

- Messages can be created with any image;
- Any voice can be recorded (they especially valued the function of recording the voice of the therapist or the patient himself);
- Profiles adapted to each user can be created;
- The possibility of exporting profiles to other colleagues, allowing to carry out multidisciplinary work;
- The possibility of incorporating auditory and visual stimuli to the messages, which allow to capture and encourage the attention of the patients;
- The application helps patients to learn new vocabulary, and helps therapists to create adapted material.

On the other hand, the following weaknesses of the application were also extracted from the answers to this last question:

- Sometimes the tool has worked very slowly or erroneously and therapists have needed to uninstall the application and reinstall it;
- A bug preventing the patients with fine motor problems from interacting properly with the tool, was reported. When this type of patient touched the screen more than once the messages disappeared without reproducing the associated sound and the application returned to the main menu. This performance collides with the requirement REQ15, which states that the application has to be tolerant to multiple clicks on a single message. The bug, which was affecting certain devices only, has been identified and fixed, so the current version of the tool fulfills the REQ15 again.

Regarding the overall evaluation itself, the therapists told us at the end of the evaluation period that they would have needed a little more time to work with the patients since most have low cognitive levels and some of them have only one therapy session of 45 minutes per week.

All in all, answers to Questionnaire 2 indicate that therapists, in general, are quite satisfied with the ECO tool. They stated that the tool had allowed them to work all the goals that they proposed at the beginning of the evaluation ("RQ2.2: Does the ECO Communication User module fit the needs, skills and goals of therapists?"), and the tool has allowed them to create and share users, categories and messages associated to the created categories ("RQ2.3: Is the ECO Communication Manager module a flexible tool capable of providing any kind of content?").

In addition, therapists think that ECO has saved them time and would like to continue using the tool in the future, although the answers to Questionnaire 2 also revealed that there are things that need to be improved so that the tool covers all aspects in an efficient way.

5. Conclusions

While current technology provides new challenges to facilitate communications, new applications intended for people with special needs must follow a UCD approach in order to feature usability and alignment to the most important accessibility requirements.

In this work, a mobile AAC tool that facilitates functional communication to people with complex communication needs has been presented. ECO has been conceived under a UCD approach, providing functionalities for both final users and therapists/educators. As part of the UCD approach, we have carried out two different kinds of evaluations.

First, a formative evaluation with experts was performed to provide usability and accessibility data based on the Communication Manager module included in ECO. More precisely, we have enumerated research questions focused on discovering usability and accessibility indications according to expert criteria. Second, we have evaluated the Communicator User and Communication Manager modules through a qualitative evaluation with final users (individuals with cognitive impairments and communication disorders and their therapists). More specifically, we have defined research questions based on validating the benefits of using the tool in their daily therapy sessions and how this specifically benefits their patients, considering that personalization is essential for this kind of user.

The results obtained from the experts in the usability evaluation provided evidence of perceived usability and the achievement of the most important accessibility requirements, in addition to providing an answer to the stated research questions. On the other hand, regarding user evaluation, most of the participants, who were users with cognitive impairments and communication disorders, were able to achieve many of their goals using ECO. Moreover, therapists were able to use it as a support device in their regular sessions, thus corroborating the research questions.

Evaluation results also provided relevant clues to improve the application and refine requirements. All these findings together with the results obtained in the evaluation with real users will product in a new release of the tool.

6. References

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