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Designing Educational Supports for People with Intellectual Disabilities

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ABSTRACT

In this paper we present two applications that have been designed to investigate the potential of mobile technologies to improve the educational tasks of people with intellectual disabilities. Specifically, we describe Leo con Lula, a mobile app that assists people with autism spectrum disorders to train global reading skills, and BART, an app based on augmented reality that assists people with intellectual disabilities to train self-evaluation skills through math exercise sheets. From the experience of designing the application and the studies to evaluate their efficacy, we come up with some design guidelines aimed to inform the creation of similar educational tools.

KEYWORDS

Intellectual disabilities, educational technologies, mobile application

1. INTRODUCTION

Educational technologies have been a hot topic in the recent years and are becoming even more important with the lockdown situation and online teaching these days. Appropriate methods and new tools are necessary to provide a ubiquitous and high-quality learning experience. Besides online and remote learning, unsupervised activities are also relevant, in the case of special education. In these schools, classes are often limited to a certain number of students (typically 4 to 6, depending on the country's regulations) due to the constant need of support and assistance of these students. Moreover, in addition to the teacher, assistants are very common to help with some duties, such as reading, caring or during the breaks. Despite of these efforts, additional supervision and help is needed, but this involves more human and time resources which are not available in most situations. Under these circumstances, educational technologies provide a new frame and opportunities to provide an unsupervised learning experience without losing teachers' track, support, and analysis. By means of interaction recording, adapted media and tools, students can receive activities and training to be done autonomously and teachers are provided with the appropriate data to analyse students' performance. Furthermore, educational technologies add a new level of personalization and adaptation in different aspects. Not only can contents be adapted to the student, but also the presentation and the interaction can be personalised to fulfil user's needs. The aim of this paper is to present our vision and guidelines of how educational technologies for people with intellectual disabilities should be designed. Particularly, we present two educational mobile applications: Leo con Lula (a tablet app to introduce reading to children with Autism Spectrum Disorders) and BART (a mobile app to practice basic arithmetic operations and self-evaluation through an augmented reality experience).

2. RELATED WORK

There is a plethora of studies about introducing technology to assist people with cognitive disabilities throughout their learning stages (Gillespie, Best, and O'Neill 2012). However, when it comes to self-evaluation of exercises and deliverables, the technology employed is expected to work with the material that is going to be evaluated, which is normally paper. For instance, designing a system to help children to get their writing exercises corrected and revised must be able to receive the writing exercises as input. Exercises about numerical operations also need the self-evaluating assistant to work with the paper in which the exercise has been solved. Issues that require combining physical objects with technology are often solved by using Augmented Reality (AR) (Milgram et al. 1995) This technology has become recently popular for educative purposes (Wu et al. 2013) given its potential to enhance the information about the real world by inserting virtual objects and information through a screen or visual representation device .

In contrast, communication is one of the widest areas explored among technologies for education of people with cognitive disabilities. Particularly, as it is one of the limitations many people with ASD have and, due to its imperative

necessity for an autonomous and proper life development, many researchers focused on developing and evaluating tools to provide augmented and alternative ways of communication (AAC) (Shanne 2012).
Related to communication we find literacy. Introducing reading to children with ASD is challenging, but researchers such as Grindle (2013) studied the suitability of an specific software for early reading access (MimioSprout® *Early Reading*, MER) with children with autism. In their study, 4 children (aged 4 to 7 years old) participated in 80 online sessions that took place during the academic year. From the data collected and consequent analysis, authors found that participants presented an improvement in their word recognition skills after completing the sessions.

3. EDUCATIONAL MOBILE APPLICATIONS

In this section we are going to propose two educational mobile applications aimed to help children with intellectual disabilities in two issues: global reading skills and self-evaluation skills. The former is called Leo con Lula (Gomez et al. 2018), and the latter is BART (Torrado, Gomez, and Jaccheri 2019).

LEO CON LULA

Leo con Lula ("reading with Lula", in Spanish) provides an introduction to reading for children with ASD. Learning methods, user's interaction and game mechanics have been designed to adapt to these users. Particularly, the learning method is based on global reading (Segers 1958) and error free learning. As opposed to syllabic reading method, global reading is based on visual skills and begins with the picture-word identification, then the word is divided into syllabus and so on. Regarding error-free learning, users have to choose the correct answer in order to advance. This mechanism has been implemented by means of a customizable feedback, in order to help the user hit.
The game is divided into three levels, increasing the difficulty. Each one is also divided into three sub-levels and, finally, each sub-level consisted on a (configurable) set of exercises. Additionally, the vocabulary is divided into groups of three words, so only a reduced number of words was trained at a time. Depending on the level and sublevel, the user is presented with a set of words and pictures and has to link them. In the lower levels, the amount of options is limited while in the higher ones (syllabic decomposition) there are more elements to connect.
Regarding the interaction and interface design, it is as simple as possible, and consist on drag and drop actions and clear and customizable elements. As an example, teachers can choose among different font types (specifically oriented to ASD teaching), amount of decorative elements and customized feedback.
In order to encourage autonomous work and require less supervision from the teacher, the game records all the interaction so teachers can analyze the user's performance afterwards. At the moment, only the basic information is provided in the app, such as number of sessions, cumulative number of hits and errors per user and level is showed in the game, however, further analysis can be included as more information is recorded.

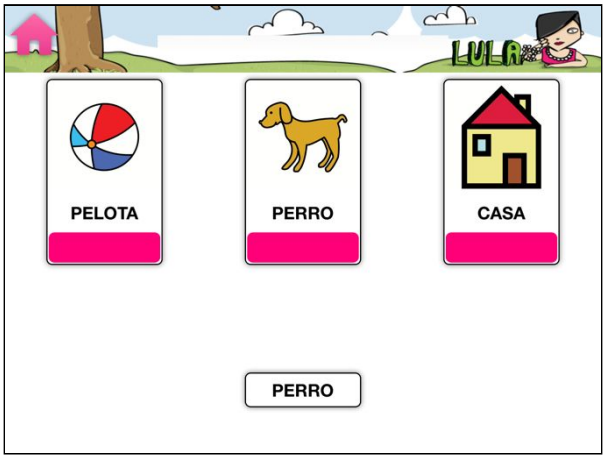

Figure 1. Leo con Lula screenshot. The user has to drag the word "perro" (dog) to the suitable space

BART

Regarding BART, our goal is to check to what extent AR technology is suitable to help children with cognitive impairment in their self-evaluation learning process, in terms of efficacy (if they can self-evaluate successfully),

efficiency (within a reasonable time) and satisfaction (taking advantage of the motivation that children usually show when technology is involved). We also wanted to explore the development of self-evaluation skill in a context of maths exercises, since this is one of the fields that requires a higher intensity of evaluation in the learning process. For this purpose, we have developed a system that helps solving basic arithmetic operations (BART) and designed to be used by individuals of age 10-13 with cognitive disabilities. The system represents virtual surfaces on the real surfaces to provide information by recognising QR codes, instead of detecting shapes or representing virtual 3D models. By means of a simple and straightforward menu, it allows the following functionality:

- Create exercises: so far, we have implemented an interface to store a list of arithmetic operations.
- Generate exercise sheets: it creates a .png or .pdf with the exercise belonging to a certain mathematical operation. It contains the operation to be solved and the QR code to virtually print the solution afterwards (see **Figure *2*. BART exercise samplesheet**)
- Visualise solutions: It opens the camera of device and waits for the user to point towards an exercise sheet to virtually print the solution on the right side of the work of the student. Users may view this information as much time as they want, although it is intended for making agile checks and correcting the operation if it is incorrect, or perform positive reinforcement otherwise (see **Figure *3*. AR solution visualiser**).

Figure 2. BART exercise samplesheet. On the left part the operation is placed, with a blank space to fill the solution. On the right side, a QR code is placed. It will be replaced with the solution through AR capabilities of the app. At the bottom of the page the user is asked to self-evaluate the result

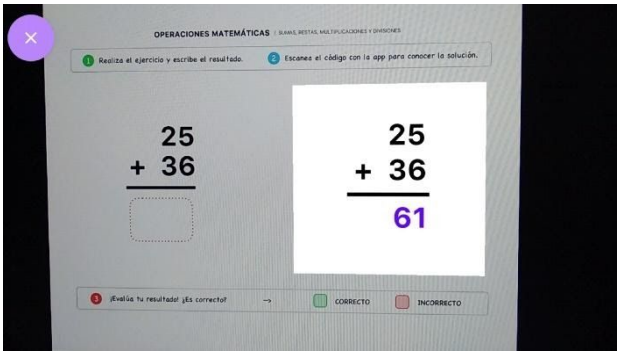

Figure 3. AR solution visualiser. Once the QR code is scanned with the app, an AR version of the result is displayed.

In addition to train self-evaluation and math skills, this application is aimed to challenge the fine-motor skills of children with intellectual disabilities, since it makes them use a tablet, paper material and writing gear. Fine-motor skills is a term that refers to the coordination eye-hand that has todo do with manipulating small objects, doing precise movements or manipulating more than one object simultaneously.

4. DESIGN GUIDELINES

The two applications share design features due to the needs of the target population they have been tailored for. In this section we provide a short insight of these common features:

- Gamification: around 65% of digital tools for people with intellectual disabilities are abandoned or not successfully adopted by them or their families (Dawe 2006). Many researchers have studied the reasons behind that, being motivation to keep using technology on a daily or regular basis is motivation (Torrado et al. 2020). Gamification is a design approach that focuses on the entertainment side of the application. Achievement metaphors such as badges, trophies, medals and progress tracking mechanisms such as bars or level system and smooth learning curves contribute to the engagement of the users and make them feel more motivated to keep using it. In BART, we used visual cues that provided with positive reinforcement when the evaluation is correct, and Leo con Lula tracks the progress by challenging the user with new exercises that build on top of each other.
- Interactive and cognitive customization: the UX requirements of people with intellectual disabilities are not straightforward. Language is a barrier for many users, whereas strong colors or inappropriate visual cues might jeopardize the experience of others. Therefore, the visual interface must allow customization to some realistic extent.
- Error-free learning paradigm: the correct-wrong binary narrative for evaluating results has proven not to be adequate for many users with intellectual disabilities, due to their difficulties to tolerate frustration.
- Multimodality: due to the communication requirements of different individuals with intellectual disabilities, the visual interface must be able to provide information
- Comprehensive activity record

5. CONCLUSIONS AND FUTURE WORK

In this paper we present a set of guidelines for educational applications for people with ASD. These ideas are based on the empirical work carried out during the design and developed of Leo con Lula, a tablet game to introduce reading to children with ASD, and BART, an AR app to work son self-evaluation skills. Despite of the different objectives of both applications, they share a set of common points which support the creation of these guidelines.

As future lines to work on, further evaluation of both applications is proposed, in order to detect possible inconsistencies or interaction difficulties, as well as to analyse users learning processes.

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