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Supporting self-evaluation for children with mental disabilities through Augmented Reality

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ABSTRACT

Self-evaluation is the ability to assess one's work, and is a key element in the psycho-pedagogical development of children with special needs in their path towards autonomy and self-determination. Acquiring this skill requires explicit training and materials, and it is often cumbersome and time-consuming. In this paper we present a study to ascertain to what extent systems based on Augmented Reality (AR) are a suitable and less expensive alternative to help children with cognitive disabilities to train self-evaluation skills in special education schools. For this purpose, we have developed tablet application (BART) that offers assistance to children with special needs to self-evaluate basic arithmetic operations. The system was designed through the involvement of 2 educators, 2 experts on

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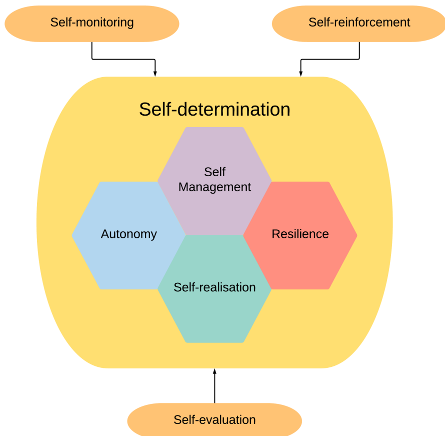

Figure 1: Self-evaluation as a skill to enhance self-determination of people with cognitive disabilities

psycho-pedagogy, and 2 software designers. The contribution of this paper is the description of BART, an innovative system for children with special needs and a concrete plan for an empirical study that is to be carried out on a short-term basis. Here we describe the methodology that is to be applied to the proposed study and outline the main expectations about the results and their implications in the issue of self-evaluation skills acquisition for children in special education.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in interaction design**; **Collaborative and social computing design and evaluation methods**; **Accessibility systems and tools**.

KEYWORDS

Augmented reality; special education; basic arithmetic; self-evaluation

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INTRODUCTION

Individuals with mild cognitive impairment and Autism Spectrum Disorders (ASD) face several challenges throughout their lives in order to obtain a certain degree of autonomy [8]. However, from the psycho-pedagogical point of view, the single concept of *autonomy* does not include the whole set of capabilities that are supposed to make an individual become an autonomous person [7, 10]. Hence, the term *self-determination* is more frequently used for these purposes. It was firstly used by Deci and Ryan [3, 11] as a holistic perspective to describe the psychological mechanisms that rule humanâĂŹs motivation and needs, in order to outline the main aspects of mind that lead to individual development and well-being. This theory encompasses the psychological items that are usually tackled during the education of individuals with cognitive impairment and ASD, since motivation and well-being are the ultimate goal for the development of these individuals . These items are: Self-regulation (or self-management), self-realisation, autonomy and resilience [9, 14]. Moreover, these capabilities are normally obtained by means of training on the following skills (see Fig.1): self–monitoring, self–reinforcement and self–evaluation.

In this paper, we focus on self-evaluation. Regarding cognitive level, it is one of the latest and more difficult abilities that are trained, since they require some level of control in the aforementioned skills and capabilities [1, 14]. Self-evaluating involves minor-scales tasks such as being able to tell themselves if a certain exercise has been carried out properly (provided that their are given a solution) as well as larger-scale activities like estimating the performance of oneself at a certain task after some time has passed within the life of the individual. Examples of self-evaluation tasks are 1) correcting an exercise about arithmetic operations by means of seeing the given solution (small-scale task) or 2) giving oneself rewards for having the chores done every day of a week (larger scale). In the first example, being able to correct the exercise requires autonomy (not needing help or interventions from educators or relatives), resilience (tolerating frustration if the result is not the same as the one in solution) and self-reinforcement related skills (when the exercise is correct).

Likewise, the second example requires the individuals to self-monitor themselves (recording everyday's chores status), emotional self-regulation (not feeling like doing the chores, but doing them anyway), autonomy and self reinforcement (planning rewards every period of time they did the chores properly).

In the following sections we describe a piece of research that addresses the smaller-scale kind of tasks in which children with cognitive disabilities learn to self-evaluate. For this purpose, we present a system based on tablets and Augmented Reality (AR) to assist them in the self-evaluation learning process. Usually, the special education schools use intervention strategies to help these individuals self-evaluate themselves. These strategies, as with other intervention strategies in other psycho-pedagogical contexts [6], require an educator or expert to be present to provide the material and store the results of the self-evaluation. However, the presence of experts, as well as the material itself, are often expensive and not available for all individuals with cognitive impairment. Sometimes, these interventions are stressful, cumbersome or excessively demanding for their parents [12]. However, well-known technology such as tablets or smartphones might ease the process, due to their ubiquity and intuitiveness, as proven by means of successful studies that use them for assistive purposes [2, 5, 7, 13].

Thus, 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).

For this purpose, we have developed a system that provides assistance to solve basic arithmetic operations (BART) and designed to be used by individuals of age 10-13 with cognitive disabilities. Furthermore, we propose a study based on experiments with children with cognitive disabilities in a special education school.

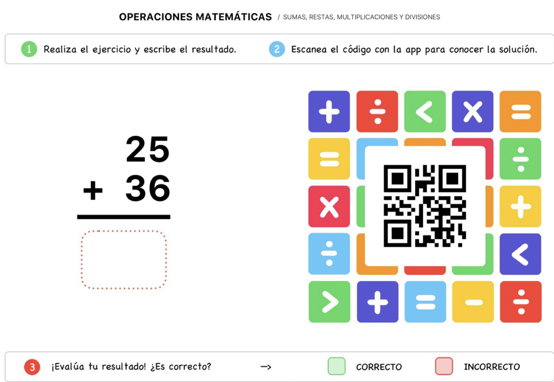

Figure 2: BART sample sheet

BASIC ARITHMETIC OPERATIONS AR TOOL (BART)

We have designed an AR application for Android called BART. It is based on the interactive print paradigm of augmented reality, in which the system represent 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** For this study, we have implemented an interface to store a list of arithmetic operations.
- **Generate exercise sheet** 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).
- **Visualise solution** 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).

We considered that this functionality is enough to carry out the study to answer the research questions stated in the introduction. In the following section, we describe such study.

The development process of the system involved 2 domain experts in psycho-pedagogy and cognitive disabilities, 2 educators from a special education school, 1 researcher and 1 developer. The domain experts stated the main needs about self-evaluation training and shared their expectations about any kind of digital application that might help them provide assistance in this issue. Their needs were later confirmed by the literature, as we did not find specific systems that addressed this problem specifically. We designed two low-profile prototypes that were shown to the domain experts, in the first place, and then to the educators. The former provided functionality feedback, and the latter gave us insight about usability and suitability to the daily class activities. Thus, the application was designed to be used in the normal situation of arithmetic practice in which the children obtain the solutions to the operations they are indicated to do. Furthermore, using this application, the children will be able to correct themselves their exercises without having to generate extra materials on paper or the constant assistance of the teachers. We repeated the process in the implementation phase of the development, showing to the stakeholders the final version of the application. Then, we had a meeting with all of them to discuss the conditions of the empirical study that is to be carried out as future work. We outline such study in the following section.

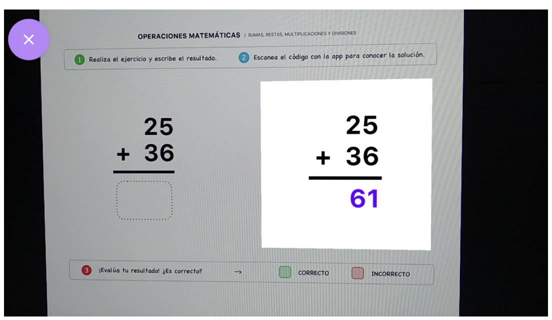

Figure 3: BART screenshot

METHODOLOGY

The study will be a two-treatment comparative analysis. The treatments are (1) paper method and (2) BART. Paper method consists of giving the solutions for the arithmetic operations in a paper to the subjects and letting them check it to self-evaluate their results. This method involves browsing information (solutions to arithmetic exercises are often given in little booklets, along with many other solutions and other information) and handling the paper, in addition to the paper in which the exercise

Table 1: Dependent variables

Dependent variable	***Description***	***Type***
Exercise comprehension	Although the treatment is applied to the self-evaluation moment, treatment failure might be strongly related to a poor comprehension of the exercise in which they are performing self-evaluation. Thus, stating the degree of understanding of the self-evaluated exercise may give some insight about further measurements.	Qualitative. It can be *No comprehension* if the subject is not able to solve the exercise, *Partial comprehension* if the subject seems to understand the exercise despite seeming confused or needing repeated explanation, and *Full comprehension*
Exercise solving	Similarly to exercise comprehension, the fact of having solved the exercise successfully might be related to the ability to self-evaluate.	Qualitative. Boolean (y/n).
Exercise performance	Time spent doing the exercise.	Quantitative (s).
Self-evaluation comprehension	Degree of understanding of the self-evaluation activity.	Qualitative
Material handling	This variable aims to measure to what extense the respective self-evaluation material (paper or AR application) represents a hindrance to the subject. Data bifurcation in this variable will be decisive to ascertain which treatment is more beneficial to these individuals.	Qualitative. It can be *Poor* if it is completely impossible for the individual to use the material, *Strongly Assisted* if the individual needs major help to use it, *Partially Assisted* if the individual can use the material with a reasonable degree of help, and *Good* if the individual does not show meaningful issues using it.
Self-evaluation correctness	This measures if the subjects have given themselves a correct evaluation or mark on the exercise. This variable corresponds to the error rate, as it is called in most of user experiments.	Qualitative. It can be *Correct* or *Incorrect*.
Self-evaluation performance	Time spent on self-evaluating.	Quantitative (s).

is written (it cannot be the same paper, since that way they would be able to see the solution before solving the exercise).

We will split the subject sample (expected size regarding to initial meetings: N=30) into two groups and then assign one treatment to each group randomly. Being both treatments the independent variables of the experiment, we identify the corresponding dependent variables as described in Table 1. Exercise performance and self-evaluation performance will give us data about the efficiency of each treatment, whereas the rest will provide information about the treatment efficacy. Concerning satisfaction, we will use the questionnaire made by Estapa et al. [4], based on the Instructional Materials Motivation Survey to measure the motivation of students after an AR activity. However, since answering these questions might be cognitively demanding for these subjects, the educators will answer on behalf of each subject. Data bifurcation in the aforementioned variables might give us insight about which treatment is more helpful for training self-evaluation skills, providing answers to the research questions stated in the introductory section.

Ability to read and solve simple arithmetic operations, as well as previous experience with tablets will suffice as inclusion criteria, since the experiment will be conducted in a special education school called Alenta, in Madrid (Spain), in which all students have cognitive impairment (from severe to mild and Down Syndrome) and/or autism spectrum disorders. Given that we are dividing the subject sample in two groups of the same size, the comparisons that would lead us to answering the research questions will be based of carrying out between-subjects measurements.

Regarding experiment procedure, the experiment will begin with a previous learning phase in which the educator and investigator show the treatment to the subjects (paper solutions or AR application) and teach them how to use it to self-evaluate. Then, the subjects would solve the arithmetic exercise. Finally, they would self-evaluate the answer by means of the randomly assigned treatment. In order to attain certain degree of data reliability about qualitative data retrieval, both educators and investigators are supposed to measure the qualitative data from the dependent variables included in Table 1. This way, observer inter-agreement will be calculated by subject, attending to the number of agreements and disagreements when taking qualitative measurements.

CONCLUSIONS

In this paper we present BART, a self-evaluation helper for arithmetic operations that generates interactive prints with the solutions of the exercises. These exercises can be created by means of a straightforward interface by the educators, and the application generates the exercise sheet and the AR solution as well. The system has been built using the easyAR library.

In order to ensure the validity of this system, we also propose a comparative study of an AR application to help cognitive-impaired children train their self-evaluation skill. The study follows the alternative treatment paradigm, comparing paper method (giving solutions in paper to the individuals so they can check it out and correct their own exercises) versus BART. Thus, we expect to obtain measurements concerning the efficacy, efficiency and satisfaction of both treatments. Efficacy variables rely heavily upon qualitative measurements, whereas efficiency is calculated through performance times. As for satisfaction data, we have applied a 20-question survey specialised on obtaining subject opinion on AR application for education.

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