

Interaction of children with and without communication disorders using Montessori activities for the Tablet

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Mobile technologies used for education may offer advantages for children with Communication Disorders, among which we can find language disorders and speech disorders, which are identified in DSM-V. In this research, we have introduced two educational activities, “Matching Cards” and “Cards & Sounds”, based on the Montessori Method and which deal with the first stages of reading and writing. We have tested these two activities with children with and without Communication Disorders in order to study how they interact. These groups of children use a Tablet to perform the two activities, which vary in visual and auditory stimuli. The activities employ two touch interactions: tap and drag & drop. Based on Montessori, the activity and the interaction do not produce either positive or negative feedback. The analysis performed with the variables of time, interaction and mistake has shown that children from both groups change their efficiency of use. Differences regarding the interaction of children with and without Communication Disorders have also been observed. Additionally, children with Communication Disorders need additional strategies as explicit indicators in the interaction which may be a guide to be able to carry out specific actions.

Keywords: mobile device, interaction, communication disorders, Montessori Method

Introduction

At present, about 8% of people suffer from communication disorders¹, and within this concept, we can find different problems which people of all ages can suffer, such as Voice, Speech, Language, and Swallowing disorders. Thus, one of the most urgent priorities is to achieve better quality of life and more real and effective inclusion in our society for those who have such needs, working since the early stages by implementing educational strategies [1] for their specific needs.

Within the educational field, one of the methodologies implemented for improving literacy skills which is being fostered at present [2], though it has existed for years, is the Montessori Method [3]. Her method is based on respect towards children with social exclusion risk, as well as on their high level of learning capacity. The didactical tools she developed are based on several manageable devices, which allow children - at the same time they are enjoying the activity - to go through different stages in their learning process. This covers from the basic stages, as the recognition of phonemes, going through the intermediate ones such as learning letters and making words, up to the moment they make and read phrases and sentences. Besides, another advantage of the Montessori Method is that it may be used with people with Communication Disorders (CD) thanks to three important aspects: the first one is that Montessori Method provides them with what they need for success not only in language but for the blossoming of all their human potentials [4]. The second one is that children have greater sensorial stimulation due to the use of different materials, colours and shapes, which are highly attractive for the child and thus, he or she is more interested in the activity to be developed [5]. The third one is the autonomy which fosters that each person follows his or her own learning rhythm according to his or her specific needs [6].

The new technologies may offer them important opportunities [7, 8] specially, in Autism field [9–11]. Research works on children with autism have demonstrated that interactive surfaces offer natural and casual interaction, and removing the complexity of the input interaction mechanism [12], can support the interactions of individuals [13]. Suitable use of visual and auditory stimuli leads to less caregiver's assistance [14] and, in the case of children with autism, it will provide a richer sensory stimulation [13]. Thus, Exergames [15], collaborative games [16] and elastic multisensory surface [13] have demonstrated to be suitable supporting tools to develop specific skills (i.e. eye-

¹ <http://www.worldbank.org/en/topic/disability>

body coordination skills), obtaining good results regarding engagement and attention. Within the sector of mobile devices, used during an average of 5 hours daily [17], there are interventions using tablet devices for children with autism [18, 19] allowing a more personal intervention within the functional area of communication.

Software developers, designers and researchers have been looking for technological solutions in order to help people with CD during more than two decades [12]. There are many examples of apparently successful technology-based products and prototypes, such as applications for mobile devices focussed on communication, which deal with specific aspects of Reading and Writing [20], with positive comments and marks given by users. In addition, there are games, based on Montessori learning method to develop spelling, reading and writing skills using a phonics-enabled Movable Alphabet². Nevertheless, there are only a few studies about the interaction of children with CD with mobile technologies.

Based on two case studies focussed on children with CD and children without CD, we have analysed each group's interaction after training. Two Montessori activities implemented for tablet, which deal with reading and writing skills during the first stages, are the basis for this study. The first activity, "Matching Cards", activity gives a lexical awareness of words. It is not necessary to have a previous knowledge of their spelling as the task is focussed on comparing shapes. The second activity, "Cards & Sounds", develops phonological awareness. The child realizes about the different sounds pronounced in the words, trying to compare them and discover with which sound each word begins.

Motivation and Research questions

The need to customize technology to users with special educational needs has already been present in scientific literature [21, 22] and children with CD have specific characteristics that must be taken into account when designing technologies for this population. Therefore, our purpose is to understand the different interaction ways followed by children with CD and without CD, focussed on generalization of interaction and efficiency of use, for both groups.

²https://lescapedou.com/LEscapedou__Fun_and_Educational_applications_for_iPad_and_IPhone/Montessori_Crosswords.html

We have considered interaction generalization as the similarity of the interactions between both groups within a period of time, once they have been trained. The efficiency of use is defined as how quickly the user can perform tasks [23]. In our study, in order to quantify it, we have taken into account the time each child spends with the task and how the child uses the activity. For this purpose, log files register both the actions carried out by the child with the Tablet as well as the period of time it is used.

“Matching Cards” and “Cards & Sounds” activities combine open-ended and goal-oriented activities to enable children to be independent but, at the same time, allowing the teacher to guide the children when appropriate [13]. The open-ended approach gives children the possibility to work with phonemes and words in different ways. In contrast, the goal-oriented approach promotes the repetition of the activities in order to test generalization in the interaction. These two approaches give teachers the possibility to choose the most suitable training for each child and they may decide about its different features such as duration and repetition of activities to work with phonemes and words in order to achieve learning generalization [24].

Therefore, we have suggested the following research questions:

- a) Does efficiency of use change for each group after training?
- b) Is there any generalization regarding interaction among the groups?

Background

Different studies show the use of new technologies for the Special Education Needs. In [25], it may be observed the possibilities of using information technology in the education of the disabled, taking into account different types of functional diversity as, for example, deafness, blindness, problems regarding mobility or communication. Other studies try to establish which technologies are most useful for other profiles, such as the one carried out in [26] in which the authors mention some examples of the positive impact on students’ engagement, as they could hear the instructions and see the text more clearly with the use of visual and hearing technology. Besides, the use of software allowed them to keep up with the class by easily taking down notes while, for others, doing tests were easier using a laptop as their hands were not sore from writing.

Inside the Special Educational Needs area, we can find a division of these people affected by communication disorders. Taking DSM-V into account [27], we

observe two groups in this kind of problems. On the one hand, we find language disorders; difficulties in learning and using language, which is caused by problems with vocabulary, with grammar, and with putting sentences together in a proper manner. These disorders can both be receptive (understanding language) and expressive (producing language). On the other hand, we observe speech sound disorders, for those people with problems with pronunciation and articulation of their native language. We can highlight studies that, by using games, help children with speech disorders [28, 29] to improve their skills adapting to their specific needs.

Interaction with educational applications and games on computers is something that has already been studied in scientific literature. Within this context, it is imperative to mention the works prepared by [30, 31]. In [31], Plowman & Stephen have assured that interaction by using games since early stages is a limited experience for most children because computer play does not always act as a support for learning. Ellis & Blashki study children's behavioural interaction with customized children's software [30], discussing the advantages and disadvantages children have to face when using a mouse and when they have to press a button, make double-button clicks or have to make a “dragging and dropping” of an object.

During the last years, great development has taken place regarding mobile devices that allow a different interaction type than the one offered by traditional technology, based on the use of the keyboard and the mouse. Specifically, basic interaction is based on the use of the child's finger with which he or she carries out the tap and the drag & drop actions. In [32] the authors study the development during the stage between 3 and 6 years old regarding this type of interaction, and the differences between children and adults when interacting with these devices. Other studies compare the direct interaction of children in the kindergarten, with a Tablet and the one on a sheet of paper when painting with their fingers [33], coming across both quantitative and qualitative differences in types of touch across these two environments. These studies suggest that each child demonstrate different repertoires of interaction, which may be linked to family practices and familiarity with technologies, such as touch screen and handheld devices.

Currently, there are different methods for literacy skills learning, and each teacher implements the one he or she considers more suitable depending on the learning context. One of these systems is the one designed by Montessori. This method is based

on the use of manipulative materials and on the use of sounds and visual aids, thanks to children's sensitive receptivity at their early life stages. Besides, it was one of the first methods to determine that writing skills come before reading skills, and this is the more natural order for children [34]. Implementing this method with young children, an efficient development of manual writing may be observed and, at the same time, it offers several benefits such as the cerebral ones, development of motor skills, memory and independence and, obviously, quasi-immediate reading once the writing skill has been acquired [35]. Another interesting aspect of this method is the possibility to use it outside its classical learning environment, such as the classroom, and the child may even learn in a more autonomous way, taking into account that, at the early development stages, children's interest towards discovering new things is one of the key elements for motivating learning [36].

Montessori Method regarding literacy skills [37] is based on a set of manageable elements which stimulate the child arising his or her interests. Among these elements, we could find sandpaper letters, with which the child will hear the sound, see its representation in the form of a letter, and feel the way it is written as the child feels the letter with his or her fingers, learning a motor pattern since the first time he tries it. Another outstanding element within this literacy method is the movable alphabet, the main aims of which are to help the child with the analysis and exploration of the language, to reproduce words with graphic symbols, and the preparation for writing and reading. All the analyses previously carried out lead us to conclude that the method developed by Montessori may be implemented with children with communication disorders, because students in the Montessori program wrote more sophisticated and creative stories and showed a more developed sense of community and social skills [38].

Within the technological field, there are several prototypes based on Montessori that have been not tested on wide samples. An example of this is the TriPOD [39], an app that connects the tablet feedbacks with a main controller (i.e. a PC) with a Wi-Fi connection. The prototype is addressed for educational applications and it is designed in order to exploit the central role of the manipulation and the multisensory approach in education, then to be applied with Montessori-like exercises. Another example is the one developed by Raffaele Di Fuccio [40], the aim of which is to overcome material

limitations by exploiting a TEL (Technology Enhanced Learning) methodology to connect activity books and Montessori-like educational materials.

“Matching Cards” and “Cards & Sounds” Activities

Considering the benefits that the Montessori Method would offer in children with CD, thanks to the characteristics of the activities related with Sensorial stimulation and interaction [33], we have designed two activities for Tablets. “Matching Cards” is based on Picture Exchange Communication System (PECS) [41], and uses cards with pictures and words. “Cards & Sounds” also applies the philosophy developed by PECS to facilitate the communication. In this case, it involves images with their corresponding sounds.

A key consideration for any technology to be deployed in a real setting is to design activities that closely match teachers’ and students’ goals [21, 42]. This requires a joint work to be carried out by a multidisciplinary team made up of experts in the field of knowledge in the same line suggested by [16]. Thus, the design of our activities is made up by a multidisciplinary team in which experts in ubiquitous computing that have developed the activities with the constant support of a Montessori guide, who specifies how to adapt real materials to an application. After several revisions of the activities, we have reached a final version accepted by said guide and experts from the associations. Following [43], we have tried that children’s interaction with Montessori materials be implemented in a Tablet. Our activities are based on the handling of materials suggested by Montessori. Though a child cannot touch the pieces or cards with a Tablet, he or she may choose, drag and release the elements. Thus, the different elements which are part of these activities will be:

- High-quality **pictograms**, it is used graphic resources obtained from ARASAAC³ with license from Creative Commons (BY-NC-SA); this resources have been made by Sergio Palao for CATEDU and with CPEE Alborada's help, as well as with funds of Department of Science, Technology and University from Aragon's Government and Teruel Digital's program which copy objects from the daily life.

³ <http://www.arasaac.org/>

- **Written words**, depending on the activity, it may also be possible to have words with a configurable type of handwriting (linked features, capital letters, etc.)
- **Boxes**, they are rectangles in which the children could drop an image, or a word; depending on the activity; these boxes may have a graphic label or a written graphic.
- **Speech**, apart from the visual elements, there are utterances which describe the action the child must carry out in order to carry out the activity.

Activities have two main types of interactions:

- **Drag & drop**, which means to drag an element since the position in which it appears up to the destination box and then, drop it, either rightly or wrongly.
- **Tap**, which gives the user the possibility to press with his or her finger on different elements on the screen which will reproduce the sound related with the elements. Depending on the element the child presses, it reproduces either the name of the object or the sound of the related phoneme.

Montessori Method avoids any type of feedback [44], either negative or positive, as it may determine the child's development. Besides, in her approach, children are given an opportunity to search, try, make mistakes and correct their own mistakes on their own. Besides, Montessori materials are designed to help children find these mistakes. Taking this into account, the feedback of the activities has been designed in such a way so as the child is not over-stimulated. When it is right, the name of the object is reproduced and, depending on the activity, the image will remain fixed in the box and, in case of mistake, the image returns, with a slight animation, to its initial position, in order for the child to be able to repeat the action.

The activity "Matching Cards" shows two cards about a chosen topic (image and name in letters) (Fig.1). They will remain fixed on the left side of the screen. On the right side, each of the elements will appear (image and name, but separately). The challenge of this activity is for the child to match the appearing elements with those fixed on the screen: firstly, image with image, then word with word. When images appear, an utterance will be heard which will briefly inform the child what he or she must do: Match the images and when the first word appears, then, match the words. To

achieve this, the child will need to use a drag & drop interaction and to move the appearing elements towards some boxes located next to the fixed elements. The child will have a second type of interaction: tap, to hear the name of the element chosen. There are two fixed cards and two boxes. Therefore, in this activity, children will only have two options (one which is right and the other one which is wrong) in order to move the only movable element which is on the screen on that moment.

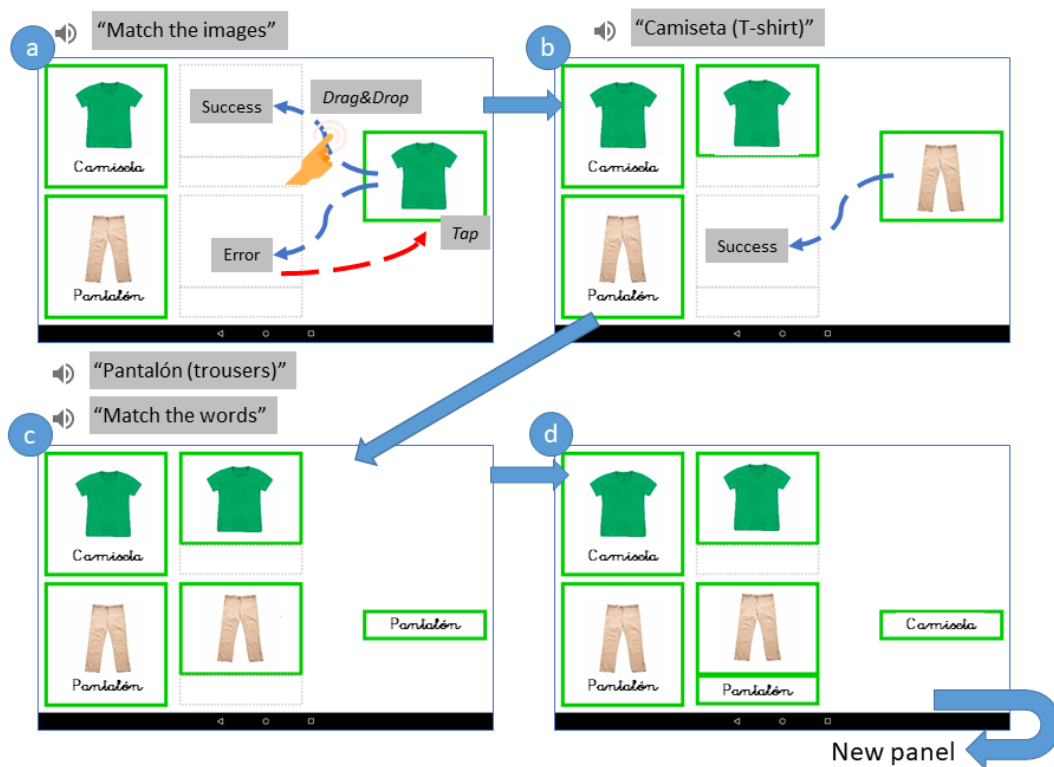


Fig 1. How “Matching Cards” activity works. The blue arrow shows the possible drag & drop and labels show if the action is correct or not. The red arrow is for the return of the image to its original place. The tap interaction is shown with a label. Besides, utterances and text to speech are also represented with a loudspeaker image. The thick blue arrows refer to transitions within the same panel or towards a new panel.

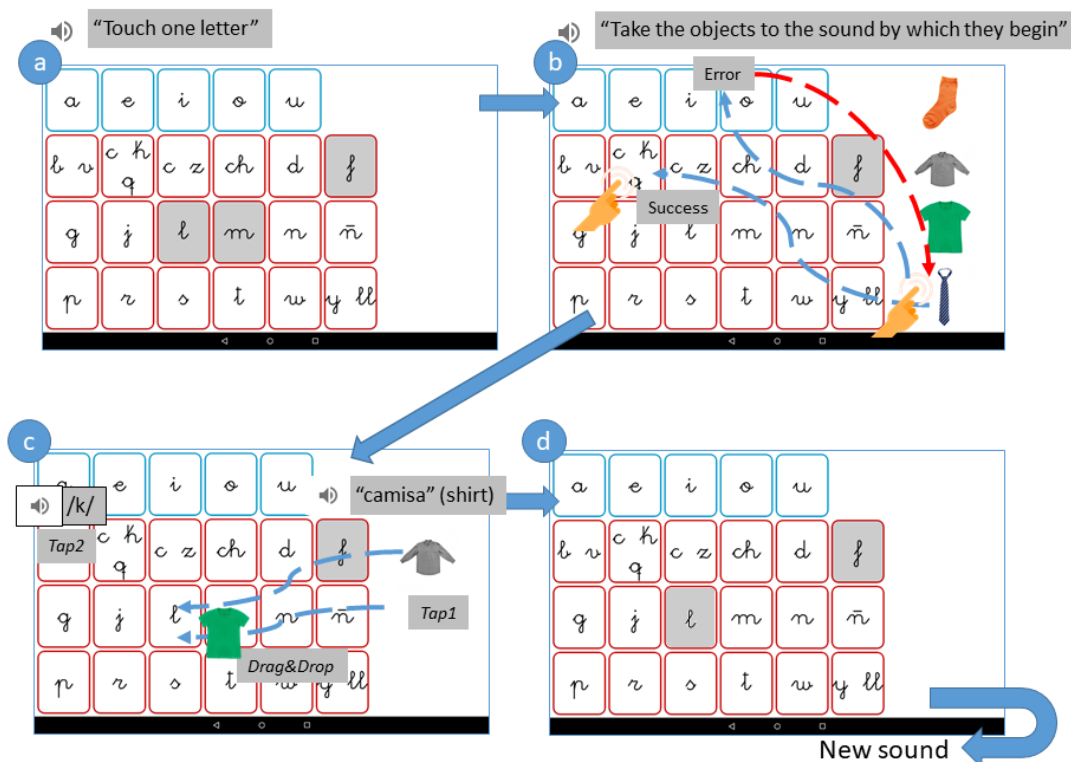


Fig. 2. “Cards & Sounds” activity. The symbols used in this activity are analogous with those included in Fig. 1.

The second activity, which is called “Cards & Sounds”, shows a screen with different “drawers” in each of which there is a graphic of one or more letters which represent the same sound in Spanish. The child will press on one of the drawers and on the right part there appear four objects the name of which begins with the sound pressed. The challenge is that the child must put the images inside the corresponding box. When it starts, the following audio will play: “Tap a letter”, and when the child presses a box and the images are shown, the following will be heard: “Drag the objects towards the sound with which they begin”. In this way, the child may begin to drag & drop the different images. In this activity, the child may tap on the image in order to hear how each object is pronounced (Fig. 2). The child may also press on each box to listen to the sound of that phoneme. When the child drops the four images on a drawer, such drawer will turn to be in grey colour and the child will be able to begin again with a new set of four objects.

Methodology

This study used a mixed research method. We collect both quantitative and qualitative data to assess our research questions. Quantitative data are obtained from the logs with the child-activity interactions. Such data give us the possibility to carry out a statistical analysis to assess, in each activity and for each group, the change in the efficiency of use, as well as to find out findings about generalization during the interaction between both groups. Qualitative data are collected in meetings held with teachers as “proxies” to children’s [45]. In these meetings, by means of teacher’s experiences with Montessori activities, we could learn more about the process of using “Matching Cards” and “Cards & Sounds” activities on a tablet-computer in a preschool setting.

Sample

Following the research line suggested by Druin in [46], we wanted to know how children interact with the Tablet in a natural way. Therefore, we decided to send the activities to Montessori associations and public schools in the North of Spain, where in both cases, nursery education was addressed to children with and without CD.

The sample is formed by children with CD specifically diagnosed of language disorder and speech sound disorder. The diagnosis is supplied by the schools and is based on DSM-V. Caregivers were responsible for installing the specific activity for the children and, for such purpose, gave their consent. In the “Matching Cards” activity, a total number of 166 children finished the training (age: $M = 5.44$, $SD=1.16$ years old), 81 with CD and 85 without CD. Following the same line, for the “Cards & Sounds” activity, a total number of 186 children finished the training (age: $M = 5.32$, $SD=1.32$ years old), 89 of them were with CD and 97, without CD.

Procedure

During the first three-month period of the academic course, we carried out two case studies during 12 sessions. The procedure followed for data collection was the same for both groups. It was made up of two clearly-defined stages which are detailed below:

First stage:

We consider that generalization in interaction is the consequence of promoting generalization in learning [24] with the training and observation strategy. In our study,

teachers and caregivers are the ones who chose the personalized training for each child and they observe if they have acquired such generalization while learning. This is the reason why we only collect data from the interaction at the beginning and at the end of the specific activity for each group, thus implementing the pretest – posttest methodology.

All the children have carried out at least 9 sessions. Attendance reports evidence that some children, due to being ill, could not attend all the 12 sessions. For each session, each child is given 15 minutes [47] to complete 4 panels. The groups of children work independently with each activity; there is no interaction between them or between the children from both groups, and each of them has focused only on his or her specific activity, without using the other activity at any moment.

Second stage

We have interviewed two teachers for 2 hours following a semi-structured interview format. During these meetings, we have identified some themes [48] which have allowed us to discover findings that have answered our research questions. Teachers analyse “Matching Cards” and “Cards&Sounds” giving us their points of view about adaptation of the activities to the Montessori methodology and their own practical experiences with such activities to work with phonemes and words. Besides, we have also asked them their own opinions about the possibilities of using the Tablet in class as an additional technological device, as well as their own perception about the children’s experience with the activities.

The variable extraction process

We collected the interactions of each student who has finished, at least, 75% of the training (9 sessions). Our research team processes the logs with each child’s actions to obtain the variables. Thus, variables obtained have a direct relation with Montessori methodology. They may be classified into three sets: time, interaction and mistakes.

In the first set, we have taken into account the variables of total time and mean time between interactions. Montessori wants to give the child time autonomy, as he or she may spend the necessary time to carry out the activity. When dealing with simple activities, the maximum duration established is of 15 minutes and we collect such

variables in order to observe the children's times within the freedom offered by Montessori.

In the set of interaction variables, we have included the taps and drag & drop. To design "Matching Cards" as a Table application, we have considered two interaction types, the tap when pressing on an image/text, and the drag & drop to drag it to the card side. In the case of the "Cards & Sounds", the design for this activity is based on two types of taps, the one carried out on each drawer in order to know which phoneme is, and the one carried out on the object in order to listen to the phoneme it begins with. The action of moving the object to the drawer is implemented with a drag & drop interaction.

Finally, the set of mistakes contains the "Mistakes" and "ConsecutiveMistakes" variables. Taking into account that Montessori avoids any type of feedback, the "Mistakes" and "ConsecutiveMistakes" variables were used as progress indicators of each child. Therefore, we define the following variables:

- **TotalTime:** The time, expressed in minutes, the student spent for finishing the activity.
- **AverageTime:** The average time, expressed in seconds, between all the student's interactions during the session.
- **Tap:** Amount of taps the student made. In the activity "Cards & Sounds", this variable is divided into:
 - **PhonemeTaps:** Number of taps of the phoneme type.
 - **WordTaps:** Number of taps of the word type.
- **Drag & drop:** Number of drags made by the student during the session.
- **Mistakes:** Number of mistakes made by the student during the session.
- **ConsecutiveMistakes:** Maximum consecutive mistakes made by the student during the session.

Data Analysis

To analyse the data, an expert of data analysis and another expert of Human Computer Interaction coded the variables in a worksheet and carried out the analysis with SSPS Statistics 24. Such variables give us the possibility to carry out a statistical analysis. An intra-subject study with a pretest and a posttest, allows us to assess the change in the efficiency of use in the activities within the same group. For each activity and in each

group, we implement the Paired T test between the variables of the pretest and posttest. An inter-subject with Unpaired T test of the variables between the groups has given enough results to be able to assess if there is or there is no generalization in the interaction after having used the activities. For each activity, we have made a comparison of the variables for pretest between students with CD and students without CD by using the Unpaired T test, also we carried out the comparison between the groups, but taking the posttest as reference. In addition, to determine statistical significance, we estimate Cohen's d. To interpret the effect size, we use the traditional criteria established in 1988 by Cohen [49] where $d = 0.20$ is a small size, $d = 0.50$ is a medium size and $d = 0.80$ is a big size.

We have analysed the teachers' interviews with qualitative methods [50]. An attendant helping us with the research has transcribed the interviews. The authors have worked independently with the transcription of the interviews following the thematic analysis approach [51], in order to find out evidences supporting the aim of our research. Besides, the authors have carried out member check with the teachers to confirm the interpretation and discussion of the results and thus, the study reliability may be achieved [52].

Results

After having carried out the data analysis and having processed the interviews, we have obtained some results with which we have tried to determine the validity of our research questions. In table 1 and 2, the statistics described for the "Matching Cards" and "Cards & Sounds" activities are presented for each group (with CD and without CD) before and after training. Besides, we have shown a bar comparative diagram with the values of the standardised variables ($M = 0$ and $SD = +-1$) for each group and activity (Fig 3 and Fig 4).

Table 1. Descriptive statistics for “Matching Cards” activity. It shows the Mean values (M), Standard Deviation (SD) and Range (Maximum- Minimum) for each variable, each group, in the pretest and posttest.

	Group with CD (N=81)			Group without CD (N=85)		
	M	SD	Range	M	SD	Range
Pretest						
<i>TotalTime</i>	1.55	1.10	0.43 - 7.37	1.40	0.86	0.45 - 6.75
<i>AverageTime</i>	2.41	1.75	0.77 - 13.81	2.22	1.40	0.77 - 11.91
<i>Taps</i>	39.49	7.68	32 - 78	38.99	7.05	32 - 76
<i>Drag & drop</i>	20.57	6.00	15 - 51	19.82	5.02	15 - 46
<i>Mistakes</i>	1.93	2.39	0 - 11	2.16	2.40	0 - 13
<i>Consecutive Mistakes</i>	0.99	1.23	0 - 8	1.16	1.04	0 - 6
Posttest						
<i>TotalTime</i>	1.16	0.71	0.45 - 4.84	1.33	1.21	0.42 - 7.69
<i>AverageTime</i>	1.86	1.03	0.64 - 6.29	2.14	1.66	0.75 - 11.18
<i>Taps</i>	38.07	5.80	32 - 59	37.26	7.06	32 - 87
<i>Drag & drop</i>	18.95	4.22	15 - 38	18.79	6.34	15 - 68
<i>Mistakes</i>	2.12	2.16	0 - 8	1.47	1.52	0 - 8
<i>Consecutive Mistakes</i>	1.15	1.15	0 - 7	0.86	0.80	0 - 3

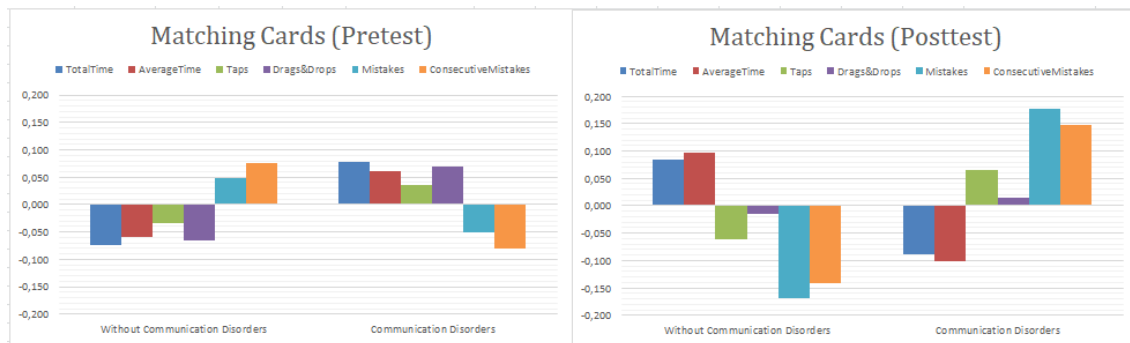


Fig. 3: Bar Chart of “Matching Cards”. Standardised variables are represented (M = 0; SD = +-1)

Table 2. Descriptive statistics for “Cards & Sounds” activity. It shows the Mean values (M), Standard Deviation (SD) and Range (Maximum- Minimum) for each variable, each group, in the pretest and posttest.

	Group with CD (N=89)			Group without CD (N=97)		
Pretest	M	SD	Range	M	SD	Range
<i>TotalTime</i>	1.88	1.55	0.41 - 9.25	1.55	0.99	0.47 - 5.92
<i>AverageTime</i>	2.25	1.74	0.53 - 11.81	2.00	1.08	0.71 - 6.84
<i>PhonemeTaps</i>	5.61	5.00	0 - 25	7.96	7.69	4 - 65
<i>WordTaps</i>	24.44	8.91	16 - 63	21.02	5.93	16 - 51
<i>Drag & drop</i>	49.52	13.53	33 - 103	46.48	12.19	36 - 116
<i>Mistakes</i>	3.47	3.54	0 - 14	1.51	2.38	0 - 11
<i>Consecutive Mistakes</i>	1.49	1.53	0 - 7	0.89	1.22	0 - 6
Posttest						
<i>TotalTime</i>	1.30	1.44	0.41 - 11.78	0.97	0.71	0.41 - 4.09
<i>AverageTime</i>	1.79	2.14	0.57 - 18.13	1.33	0.77	0.55 - 5.58
<i>PhonemeTaps</i>	4.57	4.15	0 - 25	5.82	3.79	4 - 31
<i>WordTaps</i>	21.55	5.78	16 - 46	19.67	5.58	16 - 48
<i>Drag & drop</i>	44.89	9.44	34 - 81	43.02	10.68	36 - 103
<i>Mistakes</i>	2.76	3.38	0 - 15	1.53	2.50	0 - 13
<i>Consecutive Mistakes</i>	1.12	1.06	0 - 5	0.98	1.51	0 - 9

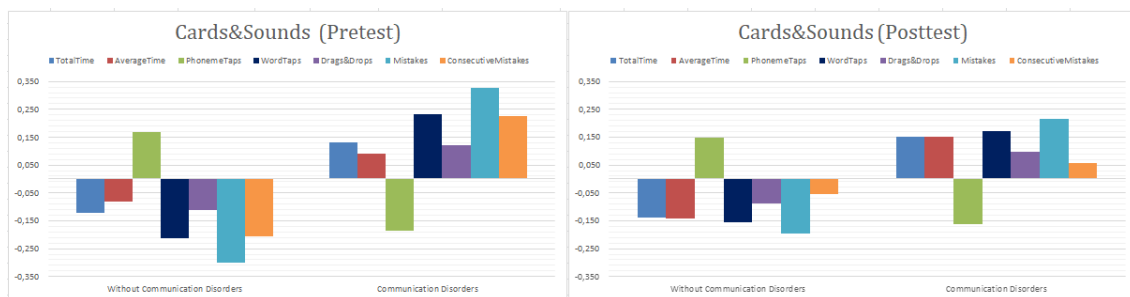


Fig. 4. Bar Chart of “Cards & Sounds”. Standardised variables are represented (M = 0; SD = +-1)

Research Question 1: Change in the efficiency of use for each group

In the “Matching Cards” activity for the group without CD, the T test for related samples found significant differences in the variables: Mistakes [$t(84) = 2.478$; $p < 0.05$; $d = 0.27$] and Consecutive Mistakes [$t(84) = 2.34$; $p < 0.05$; $d = 0.25$]. The same

test carried out with the group with CD showed significant differences in the following variables: TotalTime [t(80) = 4.074; p < 0.05; d = 0.45], AverageTime [t(80) = 3.649; p < 0.05; d = 0.41] and Drag & drop[t(80) = 2.384; p < 0.05; d = 0.33].

In the “Cards & Sounds” activity for the group without CD, the T test for related samples showed significant differences in the variables: TotalTime [t(96) = 5.702; p < 0.05; d = 0.58] AverageTime [t(96) = 6.094; p < 0.05; d = 0.62], PhonemeTaps [t(96) = 2.417; p < 0.05; d = 0.25], WordTaps [t(96) = 2.036; p < 0.05; d = 0.20] and Drag & drop [t(96) = 2.377; p < 0.05; d = 0.24]. The same test carried out with the group with CD showed significant differences in the variables: TotalTime [t(88) = 2.906; p < 0.05; d = 0.31], WordTaps [t(88) = 2.85; p < 0.05; d = 0.30], Drag & drop [t(88) = 2.967; p < 0.05; d = 0.40], Mistakes [t(88) = 2.141; p < 0.05; d = 0.23] and ConsecutiveMistakes [t(88) = 2.024; p < 0.05; d = 0.21].

Research Question 2: Generalization of interaction between both groups

In the “Matching Cards” activity, no significant differences were found in pretest between the groups. Nevertheless, the T test in posttest showed significant differences in the Mistakes variable [$M_{withCD} = 2.12$; $M_{withoutCD} = 1.47$; $t(143.28) = -2.241$; p < 0.05; d = 0.34].

In the “Cards & Sounds” activity, the T test in pretest showed significant differences between the groups in the Mistakes variables [$M_{withCD} = 3.47$; $M_{withoutCD} = 1.51$; $t(152.12) = -4.412$; p < 0.05; d = 0.65], PhonemeTaps [$M_{withCD} = 5.61$; $M_{withoutCD} = 7.96$; $t(184) = 2.448$; p < 0.05; d = 0.36], WordTaps [$M_{withCD} = 24.44$; $M_{withoutCD} = 21.02$; $t(151.18) = -3.052$; p < 0.05; d = 0.45,] and ConsecutiveMistakes [$M_{withCD} = 1.49$; $M_{withoutCD} = 0.89$; $t(168.37) = -2.974$; p < 0.05; d = 0.43,]. The T test in posttest showed significant differences in the variables: TotalTime [$M_{withCD} = 1.30$; $M_{withoutCD} = 0.97$; $t(184) = -2.008$; p < 0.05; d = 0.29], PhonemeTaps [$M_{withCD} = 4.57$; $M_{withoutCD} = 5.82$; $t(184) = 2.15$; p < 0.05; d = 0.31], WordTaps [$M_{withCD} = 21.55$; $M_{withoutCD} = 19.67$; $t(184) = -2.256$; p < 0.05; d = 0.33] and Mistakes [$M_{withCD} = 2.76$; $M_{withoutCD} = 1.53$; $t(161.35) = -2.821$; p < 0.05; d = 0.42].

Findings obtained during the teachers’ interviews

During the interviews, teachers have confirmed us the use of the activities as supporting material to work with phonemes and words:

“Matching cards provides consciousness of the word, without being necessary, at this level, to know its spelling, as it is only necessary to compare shapes. With Cards&Sound, children may realise the consonant and vocal sounds each word has and thus, they will discover the different sounds”.

With reference to adaptation of the different activities to the Montessori methodology, teachers declare that both activities follow the Montessori Method, underlining learning with no mistakes:

“It is impossible to physically touch Montessori materials, but it is possible to choose, drag and drop elements. Feedback is natural and minimally invasive, and the object returns to its initial position in case of mistake”.

Teachers consider that “the experience children with and without CD had with both activities was positive”. They appreciate “the autonomy given by the Tablet in comparison with the traditional method”, though they underline that this result depends on each child’s specific situation. They declare that the Tablet is a supporting device to be used in class but not as the only and exclusive one.

“The Tablet should be used together with other types of traditional strategies and materials so the child may generalize his or her learning”.

Discussion and interpretation of results

In order to analyse the results obtained, it is necessary to take into account that there are differences in the complexity of both activities. At the theoretical level, the second activity (“Cards & Sounds”) is quite more complex because, firstly, its methodology implies to choose out of 23 drawers but in the first one (“Matching Cards”) only out of 2 cards. Besides, “Cards & Sounds” requires matching the image by means of the initial sound of its name with the drawer corresponding to this sound, while the “Matching Cards” activity only requires matching the same pictures and the words with the same spelling.

Despite the differences in the complexity of both activities, both the children with communication disorders as well as those with no problems, finish both activities. This result may be because children without CD and who are 5 or 6 years old are more precise and quick in the interactions carried out due to their cognitive and motor skills development [32]. With this study, we have realized that, in the case of children with

CD, interactions have also improved, especially in the Drag&drop. Additionally, the teachers' comments during the interviews have shown that "activities help to develop the Montessori Method, which involves not only materials but the way of using them as well". Within this context, it is considered that "Montessori materials are cards or boxes and in the activity there are cards and drawers with a similar analogy to the real materials" and that interaction modality with taps and drag & drop is useful for the children [33] and to simulate the "behaviour which is quite next to the child with the Montessori materials". Besides, the teachers emphasised the way in which the (no) feedback in the activities is carried out, observes Montessori methodology for which "mistake possibility does not exist and the child's self-esteem is preserved".

Research Question 1: Change in the efficiency of use for each group

Results for this first question show that for the "Matching Cards" activity, efficiency of use changes for both groups. Studying the variables in detail, we have discovered that, after training, the group without CD makes fewer total and consecutive mistakes but with a small effect size. Reduction of mistakes is the result of children's acquisition of vocabulary after the training; but the small size has shown that no additional strategies were needed to achieve it. This is evident because they do not have communication problems. Results in the type of mistake variables show that the interaction pattern suggested in the activity and based on tap, drag & drop actions and without a feedback according to Montessori Method, for the group without CD fosters some improvement in vocabulary acquisition.

Nevertheless, the group with CD finishes the activity sooner, having less reply time between interactions and a lower amount of drag & drop. This result shows that, for children with CD, visual and auditory stimuli have positive impact, as referred to by Cibrian et.al in [13] for autism and that the group of CD may provide them with richer sensory stimulation. Besides, the fact that there are no significant differences in the mistakes is an evidence that children with communication problems may find the multi-sensory nature overwhelming, in the same line shown by other studies [12, 53]. Therefore, in the group with CD, it may be observed the change of the efficiency of use and that they have developed the necessary strategy to use the activity as it is mentioned by the teachers during the interviews.

Regarding the “Cards & Sounds” activity, after the training, the group without CD spends less time both making the activity as well as between the actions, with a medium effect size. Besides, they also carried out a lower number of drag & drop and of taps both for the phonemes as well as in the words with a small size. Regarding the variables of mistakes, there are no significant differences. These results show that said children have a similar number of mistakes, but they are more accurate at the time of interacting with the activity both regarding the time they spend as well as considering the interactions they carry out, i.e., there is a change in the efficiency of use for the group without CD. Children with CD spend less time, make fewer taps in words, make fewer drag & drop and make fewer mistakes, and in all cases with a small effect size. For this group, there is also a change in the effectiveness of use, but with different features than the one observed in the group without CD. Specifically, reduction of mistakes show that children acquire the vocabulary, the reduction of the taps and drag & drop confirms such acquisition, but they also spend less time, i.e., children are more accurate using the application. Therefore, there is a change in the effectiveness of use. The small size in all the variables and, specifically, in drag&drop, has made us think that, for this activity, children have had to develop additional strategies but not with the same effect size than in the case of “Matching Cards”. This result may be explained due to the existence of the suitable auditory and visual stimuli as mentioned by Cibrian et.al in [13] for autism.

Research Question 2: Generalization of Interaction between both groups

Before the training, in the “Matching Cards” activity, results show that there are no differences between both groups. After training, the variable Mistakes shows significant differences between both groups; children without CD make fewer Mistakes. This result confirms that children with CD need additional strategies to use the activity. This information is confirmed in the interviews, during which one of the teachers told us about the need to provide explicit indicators in the interaction. For example, one of the teachers told us about the need to give explicit indicators in the interaction, such as, “to leave the application when they have finished because children without CD do it but children with CD perhaps, do not do it”.

In the “Cards & Sounds” activity, before training, the group with CD interacts more with the words and less with the phonemes, making more total and consecutive

mistakes in comparison with the group without CD, with a medium effect size in the Mistakes variable. This result is explained in the interviews with the teachers, who comment that children with CD make more taps on words and fewer on phonemes because of “their lack of vocabulary and because of the same reason, they make more mistakes”. After training, the group with CD spends more time and makes more mistakes, though its value is reduced, they make more taps on words and fewer on phonemes. Results show that they continue making more mistakes due to the lack of vocabulary and because they spend more time. Therefore, in comparison with children without CD, children with communication problems need more time to carry out the activity due to the level of difficulty regarding vocabulary acquisition and the need of additional strategies [54] to overcome their language difficulties [55]. In the case of children with CD, the acquisition of vocabulary with the Tablet should be complemented with other type of intervention strategies, as suggested by the teachers during the interviews. The association of phonological sounds and words with images has proved to be a valid strategy to deal with language difficulties of children with CD [28, 56]. Our activities implement this type of association with the support of the Tablet, together with a set of closed contents referring to daily life objects instead of proposals including more open contents adaptable to each child [57].

The evidences found in “Matching Cards”, make us consider that there is a generalization in the interaction, except the mistakes variable. But, in “Cards & Sounds” we have only found the drag & drop as an interaction variable to be generalized. Each group has some specific characteristics and it seems to be necessary to adapt the interface to such needs. Interviews with teachers give more information about this matter, though the Tablet allows enjoying a higher level of autonomy and visual and auditory stimuli lead to less caregiver’s assistance [14]. Nevertheless, in the case of children with CD, it is necessary to provide them with more guidance because they need additional strategies to interact, as it may be possible that they “do not know how to abandon an activity”. Teachers consider that “activities for children with communication problems facilitate a type of intervention which helps to solve their problems and for those without CD, they allow working with skills that help to prevent communication problems from appearing in the future”.

Conclusions and future work

Despite about 8% of the population suffer from Communication Disorders, there are only a few studies which analyse how children with communication problems interact with mobile technologies. In this work, based on two case studies with children with and without CD, we have analysed the interaction of the groups. For this purpose, we have developed two Montessori activities that deal with reading and writing skills with the support of a Tablet. The “Matching Cards” activity works with words without being necessary to know their spelling. “Cards & Sounds” provides phonological awareness with the purpose of making the child be aware of the different sounds present in words.

A child cannot have sense of touch of the pieces or cards of the Montessori materials with a Tablet, but he or she may choose, drag and release the elements in a mobile device. Thus, our activities include contents with visual and auditory stimuli, two ways of interacting based on the tap and drag & drop. It also avoids any type of positive or negative feedback in such a way that, in case of failure, the image automatically returns to its initial position and, in case of being correct, the object will be anchored in the correct position. The interaction is defined and measured with variables of the type of time, drag & drop, taps and variables of the mistake type. Then, a comparison of the two groups of children for both activities was performed. The activities carried out have evidenced that it is possible to work the Reading and Writing skills with the support of a Tablet.

The research has made us conclude that direct interaction and without intermediate elements offered by mobile devices is suitable to work specific skills of children with CD and to carry out interventions in the functional area of communication in the cause of children with autism [18]. For children with communication disorders, the correct use of visual and auditory stimuli provides richer sensory stimulation as it happens in the “Cards & Sounds” activity. Nevertheless, our work demonstrates that in the case of children with Communication Disorders it may even fill them up as it happens in the “Matching Cards” activity.

After working with “Matching Cards” and “Cards & Sounds”, children from both groups show a change in the efficiency of use in both activities, i.e., the change is regarding the time spent by each child and how he or she uses the specific activity. Results in generalization of the interaction for both activities have made us think that there is no clear and defined similarity in the interactions between both groups. Besides,

the analysis of the efficiency of use and of the generalization give evidences that children with communication problems require additional strategies, needing explicit indicators in the interaction, which may be a guide, for example, to “leave an activity when they have finished”.

Results discussed previously have shown us that there are several future lines. Firstly, to develop Montessori activities (for example, the Movable Alphabet) with a similar interaction to the ones herein described and to check all the activities with the same amount or with more samples in order to generalize the results obtained. The inclusion of new activities will give rise to new variables of interaction that will give clues for the development of more complex activities from the point of view of usability. Secondly, to analyse more parameters of use of the activities that will give information about the cognitive processes of people with communication problems. This approach would allow us to develop more usable interfaces for this group and besides, more adapted to their characteristics, needs and even interests. Thirdly, to suggest a cross-cultural study in the same line proposed by authors such as [58] in order to investigate the similarities and differences in the interactions and in the implementation of the Montessori activities among different countries. Finally, we have suggested the creation of an open content management that may adapt the aims of each activity to each child’s specific needs and, in this way, the teacher’s work will also be supported.

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