iPad Apps in Teaching Programs for Kids with Autism Spectrum Disorder

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Abstract
From day to day, the use of technology as a teaching tool has grown. The presentation of educational exercises through electronic devices reveals itself as more attractive and captivating to the user when compared with traditional methods. The objective of this thesis was to develop an attractive mobile application that would make the development and acquisition of learning skills easier to children diagnosed with autism spectrum disorders. With that in mind, we researched about autism, its impact on children and traditional teaching methods available and used. Also, we researched how technology is used as a teaching tool in order to understand what are the methods and techniques most successful in an application of this kind. After the research was done, and after we concluded that the possibility of customization was one of the keys to success, we designed and architect one first version of this application. This version was then tested and submitted to several changes based on the feedback of a professional specialized in Special Education and Rehabilitation. The last implementation stages of this application were submitted to tests with a user diagnosed with an autism spectrum disorder, in order to test and enhance its efficiency. The results of the evaluation met our objectives given that they show that there is in fact a improvement in reading skills.

Keywords: educational exercises, electronic devices, mobile applications, children, autism spectrum disorder

1. Introduction
According to statistics in the United States of America (USA), 1 in every 68 children (from birth to age 8 years) have been diagnosed with an Autism Spectrum Disorder (ASD), and boys are four to five times more likely than girls to have it. [3]

Although there is no statistics for Portugal, if we take this numbers into account and consider that in the last population census (2012) there were 994835 children aged from 0 to 9 years [7] we can make an estimation of 113.600 children being identified with ASD.

ASD refers to a group of development brain disorders. It is called a spectrum due to its wide range of symptoms and levels of impairment or disability. Most certainly a child suffering from ASD will have difficulties in social interactions and communication, and will engage in repetitive behaviours.

Recent studies [1] [4] show that the use of iPad’s and other related devices in educational and rehabilitation problems can help individuals with ASD, from mildly impaired to severely disabled. [4] Its intuitive and uncomplicated way of use are some of the aspects that make it so helpful and a good tool to approach individuals with such characteristics as the ones with ASD.

2. Background
2.1. Autism
The term “autism”, as it is known today, was first used in a paper [8] in 1943, written by Dr. Leo Kanner, a child psychiatrist and physician at Johns Hopkins University in Baltimore, USA. He observed a group of eleven children (eight boys and three girls) with ages below 11, who were considered by others schizophrenic and feeble-minded, and concluded that all of them had difficulties in relating with other people, communicating and engaged in repetitive rituals, but were all unquestionably endowed with good cognitive potentialities and that although there are many similarities with childhood schizophrenia this condition had different particularities. [8]

Today this disorder still continues to be described by similar symptoms, namely difficulties in social relations and interactions, problems with communication and repetitive behaviours and actions.

Since May 2013, with the publication of Diagnostic and Statistical Manual, fifth edition, (DSM-V)
all autism disorders were merged into one spectrum diagnosis of ASD, no longer being divided into different subtypes. For example, a children that would previously be diagnosed with Asperger’s syndrome would now be diagnosed with ASD without language or intellectual impairment. [2]

ASD is diagnosed by physicians and psychologists, based on behavioural evaluations, but the parents are the ones who usually notice the first signs. [6]

2.1.1 ABA - Applied Behaviour Analysis
This therapy combines decades of research in behaviour modification. In fact, it goes back to 1900’s when Ivan P. Pavlov found what he called conditional reflex and Edward L. Thorndike described the law of effect. This law states that when a behaviour produces a pleasing effect on the surrounding environment, there is a higher probability of it occurring again in the future, under similar circumstances.

This is the main principle behind ABA, which is called positive reinforcement. For example, if a child receives a candy for each time she eats the whole soup, she is more likely to eat the whole soup in the future. To be effective a reinforcement should immediately follow the behaviour.

Reinforcements can be scheduled to be continuous or intermittent, on the first option, the behaviour is reinforced every time it occurs. If the schedule is defined as intermittent, the person will receive reinforcement while learning or engaging in a new behaviour, which is called acquisition, and once the new behaviour is acquired, the reinforcement will be delivered intermittently, which is called maintenance.

There are four more principles in ABA, namely extinction, punishment, stimulus control and respondent conditioning. Extinction, in opposition to reinforcement, has the objective of weaken a behaviour, if an action is no longer reinforced it is expected to extinguish. For example, everyday John goes to the vending machine at his work and spends a one Euro coin on a beverage. For two days in a row John spent the coin but the machine did not give him his beverage. Since the behaviour stopped, it is not being reinforced, he stopped going to the machine and bought his beverage at the coffee store.

Punishment, such as extinction, is supposed to be used to weaken a behaviour. For instance, imagine that Mary was cooking and whatever she had on the iron pan started burning. Her immediate reflex was to grab the pan, with bare hands, and to take it out of the heat. However, as soon as she felt the pain she dropped it. After this happened Mary always uses something to grab things that are hot. Her behaviour had an immediate outcome that was not desirable and because of that it is less likely that she will repeat it in similar conditions.

All these principles are based on behaviour modification and that a behaviour is controlled by its consequences. Stimulus control is used by analysts who try to understand what outcome a behaviour has and how they can manipulate it in order to modify the behaviour. Reinforcement, extinction and punishment are related to a certain situation, where some behaviours can be reinforced under some conditions and punished under another. For example, Michael always asked his grandparents for candy but only his grandmother would give it to him. As time passed, Michael only asked his grandmother because he knew his grandfather would not give him candy. Basically, his grandmother reinforced his behaviour, while his grandparent extinguished it. We can say this behaviour is under stimulus control because it only happens under a specific stimulus his grandmother.

The last of the basic principles of ABA is respondent conditioning. This can be exemplified as follows: imagine that Anna takes the same way home every night, and in some days, at a certain place, she hears a scary sound that makes her heart beat faster. Now every night, with or without the scary sound, when Anna gets to that specific place her heart starts racing. What first is a normal reaction of the body (reacting to the sound) becomes a conditioned response (reacting to the place where the sound occurs). In other words “a form of learning in which a response is elicited by a neutral stimulus which previously had been repeatedly presented in conjunction with the stimulus that originally elicited the response”. [9]

2.1.2 ABA and Autism
There are several approaches to ABA therapy but all of them use similar methods. A typically ABA therapy is applied twenty-five to forty hours per week and each session lasts two to three hours, according to the child’s needs and skills. There is time devoted to learn specific tasks (usually between three and five minutes) and at the end of each hour, ten to fifteen minutes breaks are taken. These breaks are also used for incidental teaching or practising skills in new environments. Every ABA method uses a three step process that is intended to help determine why a behaviour occurs. This process is known as the ABC:

- **Antecedent** A verbal or physical stimulus, like a request or command;
- **Behaviour** A resulting behaviour, response or lack of response to the stimulus;
- **Consequence** Positive reinforcement, for the desired behaviour or no reaction otherwise.
All of the approaches use a reinforcement when a desired behaviour occurs. This reinforcement has to be seen by the child as a reward, and because of that, it should be continually evaluated if the child still feels like it is worth to work for it. The reinforcement should only be available to the child as a reward or else she can lose interest and it will lose its power.

A variety of reinforcements should be used, not only to keep the child interested but also as a differentiating element. If the child has several reinforcements, the ones that are their favourite should be used as a reward for the most desired behaviours. The reinforcement should be appropriated to the child’s age and, whenever possible, it should be presented in different ways. Surprises are very well accepted and highly motivational.

Social reinforcements, like smiles and compliments, should also be used in association with physical rewards.

Reinforcements should not be used as a bribe, although this works in a short term. In the long term, it can create serious problems.

ABA is not only used to modify behaviours but also to teach. The teaching of a new skill is made by breaking a complex task into smaller steps or components. This is called task analysis and is used by everyone on everyday chores, like following a recipe. It is specially useful for children with ASD given their learning needs. This can be used for any skill and the number of steps will depend on the child’s ability.

Prompts are also used when teaching skills. A prompt is a question or instruction given with the intention of directing the individual to engage a certain response or behaviour. As the child masters each step, the prompts are gradually eliminated. This process is called fading.

Another thing that is common to the ABA therapies is the assessment of the child. Frequently the professional responsible for the therapy assesses the child in order to keep track of the child’s learning and efficiency of the treatment plan.

3. Related Work
After analysing works related to this subject, we concluded that the use of technology has shown some proof of being more engaging and motivating than traditional materials. This leads to children paying more attention to what they are learning and consequently to better results.

Results obtained by measurements like A-B-A-B design, show that all sort of skills are improved, or at least maintained, when teaching is delivered through this device. These findings are supported by teachers and therapists observations.

This results are obtained not exclusively because technology is being used but also because of factors like personalization of the APPs, so that it adapts to the child needs. Also, it allows us to conclude that reinforcement can be more effective when using images and sounds.

Although we would like to study more researches that were related to reading skills we find this results are transverse, independently of the skills that are taught. Given that iPads are a recent technology, and given the number of studies made about this subject, there are not enough findings to conclude if it can be more effective teaching one skill or another.

4. Development
Ensina-me a Ler has the main objective of teaching children reading and writing skills, through an effective and engaging interface. To develop this APP we used an agile approach well known in software development, the Incremental Development. This method is based on the idea of implementing a base version, expose it to users and evolve it based on their comments.

4.1. Requirements analysis and definition
In this phase, we defined what were the requirements of this APP, what should it do and what services should it provide to reflect the needs of its users and serve its purpose. To define them, we worked in collaboration with the therapist and narrowed it to the following:

4.1.1 Functional Requirements
Functional requirements reflect how the system should react, behave and what should it provide given a certain condition. [11] We set the following list as the main functional requirements list:

- The user should be able to add words and images.
- The user should be able to turn reinforcements on and off.
- The user should be able to choose between different types of exercises.
- The APP should have different types of exercises. It should cover reading, writing and association.
- The APP should allow customization of both exercises and interface.
- The APP should allow to change between normal and syllabic reading.

4.1.2 Non-Functional Requirements
Non-functional requirements are requirements that are not directly connected to the services delivered to the user but on which such services depend to
better perform their role. Non-functional requirements relate to system properties, such as reliability and response time, and affect the overall architecture of a system. [11] Given that, the following requirements should be met:

- The APP should have a clean interface.
- The APP should have an intuitive interface.
- The APP should allow to store data persistently.
- The APP should easily allow to add and remove data.
- The APP should be scalable, when new data is added efficiency should not be compromised.
- The APP should allow to store several words/images without compromising efficiency.
- The navigation between scenes should be easy and fast.

4.2. Prototyping
After establishing the previous requirements, we designed a prototype that allowed us to test our concept and provide specifications for the next step, for example, of what should consist each exercise.

4.3. Architecture
As mentioned before, the main purpose of this work was to develop an APP that could help the acquisition of academic skills, specifically reading and writing skills. As we could conclude from related works, customization is the key to success. Not only it allows to engage the user visually but also to adapt the difficulty of exercises to his level of knowledge. It is important for this APP that the addition and manipulation of data is easy and efficient. The architecture has to be scalable, so that it is always possible to add and remove new data without compromising efficiency or efficacy.

5. Implementation
5.1. Data Store
We decided to use Core Data framework to deal with our data management.

The implementation of Core Data began when we had already started developing the first exercise, Leitura. In the beginning it was only possible to add a word and its corresponding image. Other attributes were added as needed.

To add new content, we built a settings menu, where we were able to add a new word and to see the list of words already stored.

4In this APP we consider that data is words and images.

5.2. Leitura Exercise
The initial idea for the first exercise was to display only the word. The child would read it and when the therapist thought it was correctly spoken, then a reinforcement would be displayed, much like the traditional way where cards are used. But we found that this exercise could be improved, and hopefully more successful with a few changes. With this purpose a new attribute was added to our Palavras entity. We decided to include sound so it was possible to give verbal prompts to the child. Now, when we added a new word, we had to record the reading.

After implementing sound, we applied it to the exercise. This was made by transforming the word displayed on the screen into a button, so that each time this button was pressed it was possible to hear the recording of the word. At the same time, we added the corresponding image to the screen.

Both of this changes failed to succeed, because if a child is exposed to the sound it repeats it without having to look at the word. The same goes with the image, the child identifies what it is supposed to say just by looking at the object displayed and names it. While discussing this with the therapist, it was suggested that we displayed the image as a reinforcement, which at the same time would help the child to make a correspondence between visual and written representation.

With a defined objective, we continued improving our exercise. As suggested, we took the image, but we still thought it would be of help to use the sound, so we went back to related works and related applications to see if there was a way we could make sound useful in this context. As we searched, we came across several applications used to teach emotions, which were never studied by us given that it was a different subject and had a different purpose. This is well documented [5] as one common characteristic of children with ASD. Taking that into account we decided to implement two buttons. A sad smiley button (Fig.1(1)) and a happy smiley button (Fig.1(2)). When the therapist considers that the child is not reading correctly it presses the first button (the sad smiley) and the recording of the word can be heard, stimulating the child to repeat it and associating the feeling of sadness with failure. When the therapist considers that the child correctly reads the word, it should press the second button (the happy smiley) which will display the image corresponding to the word.

The next step was to implement the syllabic reading. To do so, we implemented a new attribute to our entity Palavras and a new text field in word adding. Also, a new settings screen, where it is possible to turn on or off this feature, was added.

As we reached a solution that, from our perspective, was fun and duly substantiated we decided
to implement the reinforcement. To do so, we implemented a particle system, a rendering technique used in game physics and computer graphics that allows to emulate a chaotic system, as fire, water, stars and others.

When the happy smiley button is pressed the image is displayed and this effect crosses the image, from left to right, with a falling star-like effect. We also wanted to make the effects customizable so we decided to create a settings screen that allowed to choose between four different particles. This diversity will also allow to keep the child interested in the exercises.

5.3. *Encaixe* Exercise

Next, we started implementing the second exercise, *Encaixe* (Fig.2). This exercise is meant to teach children how to write a word. The first approach to this exercise was to implement what we decided in prototyping. We display a word divided by letters, which we called tiles (Fig.2(3)), and we display squares, called targets (Fig.2(2)), where tiles are supposed to be dragged to form the word. Because the tiles are shuffled, if a word is big, it might not be straightforward what it is supposed to be written, so we decided to use the sound feature here too. When the word is displayed, the word recording is heard and at any time the speaker button (Fig.2(1)) can be pressed to play the audio. We also implemented a visual prompt that makes it more obvious that the tile was not placed correctly. When the tile is dragged to the wrong target it moves away from its center. The reinforcement was implemented as in the previous exercise. When the exercise is completed, the reinforcement is displayed across the screen.

We showed the exercise to the therapist and there were several annotations. First, the task of dragging the tiles to the corresponding targets should be done in order, it should not accept random placing. Second, when placing the tile it should be more obvious if it was done correctly or not. Third, when the tile is not placed correctly, there should be a prompt that indicated what was the correct tile. And fourth, the way the letters are displayed should be customizable, it should allow to choose between different fonts and different capitalization styles.

To solve these problems we made a few changes to the exercise, except for the first problem, that was solved right away without major changes. In order to solve the second problem, of making the matching of tiles and targets more intelligible, we improved the visual aid. We implemented a new effect using our particle system. Every time the tile is placed in the correct target a explosion-like effect is displayed. Though this visual reinforcement helped, it was only applied when the correct match was made, so we decided to add sound indication of what happened, in other words, we implemented sound to give positive and negative reinforcements. To do this, we added three different kinds of sounds: when a single tile is placed correctly, when a single tile is placed incorrectly and when all tiles are placed correctly, solving the problem. The third kind of sound was also applied to the first exercise and it is played at the same time as the visual reinforcement.

The next problem to be solved was the displaying of a prompt when the tile was not placed correctly. It was implemented using a simple effect of scale that will shrink and enlarge the target and tile(s) that are to be matched next.

Lastly, to solve the fourth problem, we implemented a new settings screen where we can choose between four different fonts and 3 different styles of capitalization.
5.4. Ligaç~ao Exercise

The third exercise (Fig.3) is intended to help children associate the word with its visual representation, and its implementation is similar to the writing exercise. In this exercise, the words are the tiles and the images are the targets. The child must drag the words to the corresponding image which, like the second exercise, will generate visual and sound reinforcements. Based on similar applications we have a counter that increases the number of possible matches on screen. At first, the exercise would start with one match and at every three correct answers it would add one more, with a maximum of five possible matches. But, after presenting the exercise to the therapist, we decided that it should start with two matches. With only one match the child would not have to read or understand what was presented to her. Knowing that the objective was to drag the tile to the target, she would simply realize the automatized gesture without giving it any meaning.

![Figure 3: Matching Exercise.](image)

Since every child has a different learning curve, the therapist also suggested that it would be better if there was the possibility to choose with how many matches it should start and how many correct answers the child has to give to add a new one. With that in mind, we implemented a new settings screen. This screen allows to choose from two to five matches to start, being that five is always the maximum of matches possible on screen, so that the words do not become too small to read. It also allows to choose the number of correct answers needed to add a new match, with a range from one to ten.

5.5. Improvements

When we reached this state of the APP, where the three exercises were implemented, we added the possibility of recording three personalized sound reinforcements. This allows to use different sounds and, for example, use a voice that is known to the child to praise him.

The next step was to show it to the therapist, to have feedback of the APP as a whole. She tested it for some time and reported to us details that could be improved. From the user perspective there were some technicalities we had to solve. When adding a word, and respective image, we resized the image before saving it, but, if a image was big, it would still cut off some details. This was solved by readjusting the size to which the image is scaled.

Another problem was that it was not possible to add the same word with different images, a feature that allows to understand the generalization of a term. In other words, it allows to understand the word as a name to different representations of the same object. It would always assume the first added image for different entries of the same word. This happened because we were saving the image with the word as its name. To solve this we changed the saving name of the image to the date and hour of when it is added.

Regarding the words that were added, it was pointed out that as the list of words was getting bigger it would become slower and less fluid and even crashed one time. This happened because the image displayed in the list was loaded at its full size and shrunk, overloading memory. The solution we found to this problem was to save the image with two different sizes, so, by the time the user saves a new word, a thumbnail is also saved. This thumbnail is used in the word listing and prevents the memory overload.

From the exercise perspective, Encaixe exercise was being executed by trial and error, so we added a model prompt. A model prompt is used to let the child know what it has to do and, in this case, it consists of displaying in the targets the letters supposed to be dragged (Fig.4). This prompt can be turned on and off on settings.

Another problem, regarding every exercise, was that the words displayed were chosen randomly. Since there is a specific word that is worked at a time during therapy, while others are used as diversions, the probability of the wanted word to be featured on exercises was very small. To solve this problem we first had to implement the possibility of choosing a given word to be featured more, which is done in word listing simply by touching the row of the word.

Next, we implemented an algorithm that would allow us to solve this problem. In the Leitura and Encaixe exercises, every time a new exercise is displayed, we create an array of three words. This new array is filled with the selected word and two other
random words. We then choose a random position of this array to be displayed in the exercise. This will augment the probability of the selected word being displayed to 33.3\%.

In the third exercise, we used a different method. The chosen word is always displayed and, according to the number of matching pairs, we randomly choose the rest of the words.

6. Evaluation and Results

6.1. Evaluation Metrics

Single-subject designs are research designs, most often used in ABA research studies, in which the subject serves as his own control, rather than using individual or group control.

Single-subject designs are used to monitor a subject progress and test the effectiveness of an intervention.

This research has different designs composed by the conjugation of different phases. Each phase can be one of the following:

- **Baseline phase** (abbreviated by the letter A) Refers to the status of the subject prior to intervention. Repeated measurements of the dependent variable are taken to serve as a control and enable to see the changes that occur with intervention. This phase is conducted without the use of prompts or reinforcements.

- **Intervention or training phase** (abbreviated by the letter B) Represents the implementation of the intervention. During this phase, repeated measurements of the dependent variable, using the same measures as before, are obtained to help determine if any change has occurred in comparison to baseline phase. This allows to determine if the intervention is effective or not.

These phases are chained, one or more times, and each conjugation, or design, allows to obtain different results. The possible combinations are:

- A-B Design
- A-B-A Design
- A-B-A-B Design

6.2. Evaluation

The evaluation of our APP was made with the help of the therapist and a male child. Typically these tests are done with several subjects (e.g. three to eight) but they can be made with only one. In this case it was only tested in one child due to lack of available children who would fit the criteria.

6.2.1 Procedures and Experimental Design

The APP was tested with a male child of seven years old diagnosed with ASD (hereafter called tutee) and with the therapist (hereafter called tutor).

The sessions took place in the tutee natural learning environment, his classroom, at a table, where both trainer and participant would sit next to each other.

Our APP was installed in an iPad2 and, given the availability of both tutor and tutee, for the purpose of evaluation, it was only collected data from *Encaixe* exercise. We chose this exercise given that it requires more interaction than *Leitura* exercise and more reading/writing knowledge than *Ligao*.

The sessions were carried everyday, two per day, using the A-B-A design. Each session consisted of writing the same unknown word to the tutee, "Foca".

For purposes of evaluation, every session consisted of five trials.

6.2.2 Baseline

As explained before, baseline is meant to collect data to serve as control and, in this case, determine the ability of the tutee to write the word "Foca". This phase only ends after four consecutive stable sessions.

This phase consisted of four sessions (two days) and, in each trial, the tutor would handle the iPad to the tutee and ask him to write the word. Based on observation, the tutor would evaluate if the tutee had given a correct or incorrect answer.

If the tutee tried to drag the wrong letter, or the right letter to the wrong target, the answer would immediately be considered *Wrong* and a new trial would be performed.

To better assess the capability of the tutee to write the word, the exercise was presented without any prompt.

A child diagnosed with ASD in the process of learning to read/write.
6.2.3 Intervention

The intervention phase was applied to evaluate and register the performance and evolution of the tutee. The duration of intervention was dependent of the tutee performance.

As in the previous phase, in each trial, the tutor would handle the iPad to the tutee and ask him to write the word. The first trial of the first session was made with the model prompt enabled (see Fig.4). If the tutee performed the exercise correctly\(^3\) the answer would be considered a Right answer with prompt and in the next trial the tutor would choose, based on the tutee performance, if the exercise should be displayed with or without a prompt.

If the tutee responded correctly, in the trial without the prompt, the answer was considered Right and the next trial was performed in the same conditions. On the other hand, if the exercise was considered Wrong the next trial would display once again the prompt. This approach was followed throughout every session and every first trial of a session would be based on the outcome of the last trial of the previous session.

Unless the first five trials were completed with a Right answer the tutee would perform a total of twenty trials. Being that the the extra fifteen trials are considered as training and not part of evaluation.

This phase ended when the tutee performed correctly the first five trials of two consecutive sessions (i.e. one day sessions).

6.2.4 Follow-up

To determine if the intervention phase was successful we applied once again a baseline phase. Unlike the other phases, that would start as soon as the previous phase was finished, this new phase was conducted only after three days. This is done to help determine if the effect of the intervention persists.

This phase had the duration of one day (two sessions) and was conducted like the baseline phase. The tutee had to complete five trials without prompts and, based on observation, the tutor would consider the answers Right or Wrong.

6.2.5 Tutor Feedback

In order to evaluate the APP from the tutor’s perspective we constructed a questionnaire (see Appendix A) and conducted an interview with the tutor. This was done after the tutor completed the A-B-A research.

6.3. Results

6.3.1 Baseline

During baseline, the tutee never performed the exercise correctly. Occasionally he would drag the first letter (F) to the correct target but no more than that. Also, he never dragged more than one letter correctly, or did it in two consecutive trials.

This leads us to conclude that the correct placement of the letter was random and that the tutee was not familiar to this word or had any knowledge of how to write it.

6.3.2 Intervention

As we can see from Fig.5, the ability of the tutee to write the word evolved throughout this phase. Although we present the complete results and data collection, for the purpose of evaluation we only consider the first five trials of this phase, in order to have equal samples from different phases.

Reading the results (Fig.5), and considering always the first five trials, we can see that in the first session of the first day (day 3), all trials had the prompt model enabled. Which tells us that although the tutee was able to give a correct answer, his performance was not good enough to present him the exercise without the prompt. By the second session, of the same day, his performance improved and he was given, once, the exercise without the prompt but failed to give a Right answer.

On day 4, the second day of this phase, the first session was completed without changes on the tutee performance. It is on the second session of this day that we could see a major improvement of his ability to write the word. He performed the five trials with five Right answers.

Although it was a good result, it can mean that he memorized the answer from the previous session, and that is why we stipulated that there had to be two correct sessions in one day two consider the word as acquired.

On the first session of the next day (day 5), and

\(^3\)An answer is consider correct when every letter is placed in the correct order at the first try.
based on the outcome of the previous session, the first trial was presented without prompt, and the tutee failed to answer correctly. Only two of the five trials were completed with the Right answer which, although it was a step back from the previous session, also shows us that there was an improvement in comparison to the first session of the previous day.

The second session of this day was completed correctly with five Right answers.

On the fourth day of this phase (day 6) the tutee performed both sessions correctly, the word was considered acquired and the intervention phase was complete.

6.3.3 Follow-up
Reading the Results Graphic (Fig.5) we can see that the tutee was able to give four Right answers in the first session and five Right answers in the second session. Given that, as mentioned before, this phase was performed three days after the intervention phase was completed, we can conclude that the intervention was successful and that the tutee learned how to write the word "Foca".

6.3.4 Tutor Feedback
Based on the questionnaire we asked the tutor to answer, we could draw several conclusions.

- The interface of the APP was very adequate to target users.
- The amount and variety, as well as the type, of the exercises were also very adequate.
- The tutee did not show any difficulty in performing the exercises and practically none in understanding what was the supposed type of interaction.
- The tutee paid more attention and learned more easily to write a word using the APP when compared to the traditional methods.
- The amount of prompts were sufficient but there should be more reinforcements.
- The visual reinforcements were much more relevant than sound reinforcements.
- The level of possible customization of the APP is very adjustable to children with different needs.
- The tutor considered that this APP was also easy to use by herself.
- She also considered that this APP could be used professionally as a learning tool and it was better than most available APPs she had used.

In the interview, the tutor referred that this APP is very versatile and, in contrast to other APPs, has the advantage of having several types of exercises based on the same information. She also mentioned that what makes this APP a good improvement, when compared to the existing APPs, is the fact that it is very customizable and allows the tutor to choose what to display and when to display it.

As improvements she suggested that the enabling and disabling of prompts should be made on the exercise, or before an exercise begins, because, as we can see in the tests made, it is necessary, from trial to trial, to turn them on or off and to do so she always had to go back to settings to perform the action, which can make the tutee lose interest in the activity.

Also, referring to the visual reinforcements, and as concluded from the questionnaire, she mentioned that at the beginning, the tutee did not pay much attention to the reinforcement. She suggested, that it should be possible to choose the amount of particles that are displayed, to create more or less impact accordingly to the sensibility of the tutee to the visual stimuli.

6.4. Discussion
The results of this study showed that, using our APP, the tutee made a rapid acquisition of how to write the word "Foca". In 3 days the tutee went from absolutely no knowledge of how to write a word (zero correct answers) to complete a session with five correct answers. And, even after the intervention phase, without any help, he was still able do write it 90% of the times.

These findings suggest that the use of our APP is effective as a teaching tool and are consistent with the outcomes of the research we conducted previously.

7. Conclusions
The main goal of this thesis was to fill a market gap. It had the objective of developing a tool that could help Portuguese children diagnosed with a condition of the Autism Spectrum Disorder. This tool should help in the process of learning to reading and to writing skills and preferably make it easier and fun. Each children with such diagnostic has special needs, that need to be addressed in different ways, so our tool had to be well supported by theory and other works.

With that motivation, we created an iPad Application, Ensina-me a Ler, where most of the features available are based in concepts of Applied Behaviour Analysis, a field of study well documented and with scientifically proven results. The research we conducted helped us understand how some of these concepts had been applied in teaching through technol-
ogy and if they were effective. After this review of literature, we defined what would be expectable of such application by mimicking traditional materials that are used with the same objective. When we though we had a solid foundation, we prototyped it and started implementing the application.

During implementation, and given that we chose to use an incremental design, we found that our planning had a complexity lower than what would be required. All three exercises developed were, at the end, different from what was initially planned.

To test if the achieved solution fulfilled our goals, we conducted a study with two possible users of this application.

This research showed us that our application was an improvement to traditional methods and that the concepts applied were also effective when delivered through technology. The child showed interest in using the application and made a fast acquisition of a new word.

The visual reinforcements proved to be captivating, but should allow even more customization. On the other hand, the sound reinforcements did not work as expected and the explanation we found for this is that, although it is possible to customize the sound that is presented in a given situation, it is always the same sound making it dull after several displays.

Although the outcome of the tests were mainly positive, this application should be tested with more users. The fact that it was only tested in one child does not allow us to conclude that it would be an effective tool in every children, or in most of them.

7.1. Future Work

Although we consider this application successful and that it fulfilled our goals, there are improvements and upgrades that can be made to this solution and that can make the process of learning reading and writing skills even more efficient.

On a first approach, the issues that were found should be corrected. For example, concerning the visual reinforcements, maybe it would be a good approach to develop a mini-game where several effects would be displayed and the child would interact with them. The effect that the child most interacted with would be the one displayed during the exercises.

To solve the lack of interest in the sound reinforcements there could be the possibility to record several audio files to the same action, that would be displayed randomly.

Another issue that should be corrected is the location of the button that allows to enable and disable the use of prompts. It should be placed in a screen, or position, of fast access avoiding the need to go through several screens to change it.

Also, regarding the actual solution, it should be tested with more subjects in order to have enough data to conclude that this application was also effective in other individuals.

One upgrade that we think would benefit this application is the implementation of speech recognition in the Leitura exercise. This would make the exercise less dependent of the tutor and, consequently, more captivating to the child.

Also, instead of choosing only one word, it could be possible to choose a variable set of words to work with. This would allow to have a big collection of words and at the same time work one singularity present only in some words. For example, if the therapist would like to work the pronunciation of "ch", like in the words "cho" or "chinelo", she could choose only the words that contained it.

Even though this upgrades suggestion would benefit this application, we consider that the first approach should be to test the application with more users. This would allow to better assess the possible issues of this solution before implementing new features.

References


