

iPad Apps in Teaching Programs for Kids with Autism Spectrum Disorder

Cátia Vanessa Alves Braz de Matos Rosa

Thesis to obtain the Master of Science Degree in

Engenharia Informática e de Computadores

Supervisor(s): Professor José Alberto Rodrigues Pereira Sardinha

Examination Committee

Chairperson:	Professor Mário Jorge Costa Gaspar da Silva
Supervisor:	Professor José Alberto Rodrigues Pereira Sardinha
Member of the Committee:	Professora Maria Luísa Torres Ribeiro Marques da Silva Coheur

Maio 2015

"We must believe that we are gifted for something, and that this thing, at whatever cost, must be attained." - Marie Curie

Acknowledgments

First of all, I would like thank my grandmother, Vó Nana. The one that encouraged me to pursue what I wanted.

To my parents, Fátima Rosa and Paulo Rosa, for all the education and support and for putting up with my me, specially in the morning!

To all my family, specially my sister, Raquel Rosa, for caring.

To professor José Alberto Sardinha, for the guidance and knowledge transmitted.

To therapist Célia Cunha, for the willingness to help.

To my good friends, my second family, the ones that seduce me to go home late when I shouldn't and with whom it is possible to forget all worries and enjoy life.

Last, but definitely not least, to the one and only, Luís Santos. The one who always helped me surpass the obstacles and encouraged me to continue. The one that is always there.

This work was partially supported by Fundação para a Ciência e a Tecnologia (FCT) through the Carnegie Mellon Portugal Program and its Information and Communications Technologies Institute, under Project CMUP-ERI/HCI/0051/2013.

Resumo

De dia para dia o uso de tecnologia como ferramenta de ensino tem vindo a aumentar. A apresentação de exercícios educacionais através de dispositivos electrónicos revela-se mais atractiva e mais cativante para o utilizador quando comparada com métodos tradicionais.

O objectivo desta dissertação foi desenvolver uma aplicação móvel atraente que facilitasse a aprendizagem e aquisição de competências de leitura a crianças diagnosticadas com desordens do espectro autista. Para tal foi efectuado um estudo sobre o autismo e o impacto que tem nas crianças, assim como os métodos tradicionais de ensino utilizados com as mesmas. Também um estudo sobre a utilização da tecnologia como veículo de ensino foi efectuado, de forma a perceber quais os métodos e técnicas com mais sucesso numa aplicação deste foro.

Depois de efectuada a pesquisa, e de concluirmos que a possibilidade de customização era um ponto-chave, foi então desenhada e architectada uma primeira versão desta aplicação. Esta aplicação foi depois testada e sujeita a várias evoluções com base em conselhos de uma profissional especializada em Educação Especial e Reabilitação. As últimas fases de implementação desta aplicação foram sujeitas a testes com um utilizador, diagnosticado com uma desordem do espectro autista, de forma a averiguar e aumentar a eficiência da mesma.

Os resultados da avaliação realizada foram de encontro aos nossos objectivos uma vez que demonstram uma maior facilidade de aquisição de competências de leitura.

Palavras-chave: exercícios educacionais, dispositivos electrónicos, aplicações móveis, crianças, desordens do espectro autista

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 an improvement in reading skills.

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

Contents

Acknowledgments	v
Resumo	vii
Abstract	ix
List of Tables	xiii
List of Figures	xvi
Nomenclature	1
Glossary	1
1 Introduction	1
1.1 Motivation	2
1.2 Document Structure	2
2 Background	4
2.1 Autism	4
2.1.1 Therapies	5
2.1.2 ABA and Autism	6
3 Related Work	8
3.0.3 Using an iPad-based video modelling package to teach numeracy skills to a child with an autism spectrum disorder	8
3.0.4 Teaching Functional Use of an iPod-based Speech-generating Device To Individu- als with Developmental Disabilities	9
3.0.5 Effectiveness of Using iPads to Build Math Fluency	10
3.0.6 Using Tablet Computers as Instructional Tools to Increase Task Completion by Students with Autism	11
3.0.7 The Effect of Instructional Use of an iPad on Challenging Behaviour and Academic Engagement for Two Students with Autism	11
3.0.8 Mobile Learning Technology Based on iOS Devices to Support Students with Spe- cial Education Needs	12
3.0.9 Multitouch Tablet Applications and Activities to Enhance the Social Skills of Chil- dren with Autism Spectrum Disorder	13
3.0.10 Vocabulary Acquisition for Children with Autism Teacher or computer Instruction .	14

3.1 Discussion	15
4 Development	17
4.1 Requirements analysis and definition	18
4.1.1 Functional Requirements	18
4.1.2 Non-Functional Requirements	18
4.2 Prototyping	19
4.3 Architecture	20
4.3.1 Development Tools	20
4.3.2 Design Pattern	20
5 Implementation	23
5.1 Data Store	23
5.2 <i>Leitura</i> Exercise	25
5.3 <i>Encaixe</i> Exercise	27
5.4 <i>Ligação</i> Exercise	29
5.5 Improvements	31
6 Evaluation and Results	34
6.1 Evaluation Metrics	34
6.1.1 Single-Subject Designs	34
6.2 Evaluation	36
6.2.1 Procedures and Experimental Design	36
6.2.2 Baseline	37
6.2.3 Intervention	37
6.2.4 Follow-up	37
6.2.5 Tutor Feedback	38
6.3 Results	38
6.3.1 Baseline	38
6.3.2 Intervention	39
6.3.3 Follow-up	40
6.3.4 Tutor Feedback	40
6.4 Discussion	41
7 Conclusions	43
7.1 Future Work	44
Bibliography	47
A Questionnaire	49

List of Tables

3.1 Articles Reviewed	15
---------------------------------	----

List of Figures

3.1	Post-Training Phase	10
3.2	Picaa Activities	13
4.1	Incremental Development Model	17
4.2	Available exercises.	19
4.3	Settings.	19
4.4	Model-View-Controller Design Pattern	20
4.5	Storyboards	22
4.6	Adding word to Core Data	22
5.1	Core Data	23
5.2	Managed Object Model	24
5.3	Add Word	24
5.4	Words Added	25
5.5	Reading Exercise	26
5.6	Syllabic Reading	26
5.7	Stardust	27
5.8	Visual Reinforcement Settings	28
5.9	Writing Exercise	28
5.10	Single Reinforcement	29
5.11	Writing Prompt	30
5.12	Customization	30
5.13	Matching Exercise	31
5.14	Matching Exercise Settings	31
5.15	Sound Reinforcements Settings	32
5.16	Model Prompt	33
5.17	Word Selection	33
6.1	A-B Design	35
6.2	A-B-A-B Design	36
6.3	Data Collection	38
6.4	Results	39

A.1 Questionnaire part one 50

A.2 Questionnaire part two 51

A.3 Questionnaire part three 52

Chapter 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[10] 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.

What was previously classified as five different disorders: Autistic disorder (classic autism), Asperger's disorder (Asperger's syndrome), Pervasive developmental disorder not otherwise specified (PDD-NOS), Rett's disorder (Rett syndrome) and Childhood disintegrative disorder (CDD), are nowadays denominated as ASD.[2] The exact causes of ASD are not yet known but research suggests that both genes and environment can be related.

Even though there is no known cure for ASD, there are several therapies that can help children overcome some difficulties and improve or give them new skills. However, no two children are the same and the best approach for one individual is not necessarily the best for other. Some of these therapies include Floortime, SonRise, Training and Education of Autistic and Related Communication Handicapped Children (TEACCH), among others.[9]

One treatment that is commonly used is Applied Behavior Analysis (ABA). ABA is a "natural-science approach to understanding the behaviour of individuals"[6], whereby the treatment is designed for changing behaviours in a long term, rather than changing a personal characteristic or trait.[17] This natural-science is based on the assumption that a behaviour is the outcome of the surrounding environment (which can be physical or social) and if a behaviour is followed by some sort of reward it is more likely to be repeated.

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.

It is already possible to find a great number of applications (APP's), with different purposes, made to be used by children with ASD. There are APP's, like Proloquo2go¹, made to be used by children who can not speak or have language delays. By teaching children to build sentences through images and symbols, and allowing children to use the iPad as a communicating device. There are other APP's that help develop fine-motor skills, like writing and manipulating small objects, for example, Balloonimals², a simple touch-and-respond APP that helps teaching about cause and effect. The problem with these APP's is that the majority are made for children whose first language is English.

1.1 Motivation

This work was developed with the purpose of giving Portuguese children, identified with ASD, a tool that will help them develop reading skills. With that in mind, we developed an APP with the ambition of assist the progress of acquisition and assimilation of words and its meanings. Hopefully this work will simplify that process, for both children and caregiver, with a fun and substantiate approach.

To achieve a capable and suitable model we researched the impact of ASD in individuals, tools that are used everyday to help surpass obstacles created by this condition and studies that use technology to teach various skills. Also, in cooperation with a therapist that gave us professional feedback, we developed a plan of what our APP should consist, as well as what types of exercises and what features should it provide.

The implementation of the previous plan went through several iterations. When we thought we reached a stable and solid version we submitted it to tests, with the help of the therapist and a child with ASD, and concluded that this APP was effective and helped in the process of teaching a child to read.

1.2 Document Structure

This document is divided in seven chapters. In Chapter Two we present an overview of ASD, its impact on children and some available therapies that help children develop their skills. Chapter Three covers our research in related works, studies that have used technology to teach children with ASD, and what we could conclude from them. The result of the two previous research chapters is used in Chapter Four, where we define what our APP will consist of, what are its requirements and how we intend to implement it.

After all investigation was done and the initial development was set, in Chapter Five we describe the implementation of our APP, as well as the decisions and changes we made to our initial version. In

¹<http://www.assistiveware.com/product/proloquo2go>

²<http://www.ideotoylab.com/balloonimals/>

Chapter Six we discuss the evaluation and results of our APP and lastly, in Chapter Seven, we conclude all the work developed in this dissertation and what can be done as future work.

Chapter 2

Background

2.1 Autism

The term "autism", as it is known today, was first used in a paper[13] 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.[13]

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.[9]

According to DSM-V, a person diagnosed with ASD has to fit the following criteria :

- "A.** Persistent deficits in social communication and social interaction across multiple contexts (...) currently or by history (...).
- B.** Restricted, repetitive patterns of behaviour, interests, or activities (...) currently or by history (...).
- C.** Symptoms must be present in the early developmental period (but may not become fully manifest until social demands exceed limited capacities, or may be masked by learned strategies in later life).
- D.** Symptoms cause clinically significant impairment in social, occupational, or other important areas of current functioning.

- E.** These disturbances are not better explained by intellectual disability (intellectual developmental disorder) or global developmental delay. Intellectual disability and autism spectrum disorder frequently co-occur; to make co-morbid diagnoses of autism spectrum disorder and intellectual disability, social communication should be below that expected for general developmental level.”

2.1.1 Therapies

Although there is no known cure for this disorder there are several therapies that can help an individual to have a better quality of life and are scientifically proven to improve learning, communication and social skills.

Our APP is based on Applied Behaviour Analysis (ABA), a therapy that is widely recognised as the single most effective therapy for children with ASD, and that has been consistently validated through several scientific researches. [22]

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".[19]

2.1.2 ABA and Autism

Dr. O. Ivar Lovaas was a Norwegian born psychologist who dedicated his life to improve the life of children with autism. For forty years he researched and published studies that prove that children who receive ABA treatments were far ahead on cognitive tests and social skills than other children with the same age and condition.[11]

This treatments are based in behaviour modification, a field of psychology, and are applied by trained professionals who analyse what can be in the source of a behaviour, identifying the events in the surrounding environment, and develop and implement precisely described procedures in order to change the said behaviour.[17]

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.

Though this is considered the basis of a ABA therapy, every child suffering from ASD is different, and consequentially, the approach used on a child may not be the best approach to other.[25]

Chapter 3

Related Work

In this section we describe and analyse works that, as described before, study the use of technology to teach children with ASD. Afterwards, we will discuss the findings of such works and how they can be useful to us.

3.0.3 Using an iPad-based video modelling package to teach numeracy skills to a child with an autism spectrum disorder

The main objective of this study is to research the effectiveness of a video in teaching numeracy skills to a child with ASD. For this study, a video was made to explain to Jack (a pseudonym), a five year old boy diagnosed with ASD, what each number means, what is its value/quantity and how to write it. In order to make this task more personal and more enthusiastic to Jack, the video starts with Jack introducing himself 'Hi! My name is Jack! And I like counting my Angry Birds!'. Angry Birds, Jack's favourite cartoon, are used to demonstrate quantity.

There were several videos to perform the same task with the difference on the number of prompts. For example, the first video shown would have a still image of a number and the respective Angry Birds and it would be followed by a model's hand holding a pen and drawing the number, accompanied by voice-over instructions. The second video shown would not have the voice-over instructions and the third would only have the still image. At the end of each session Jack was allowed to play one game of Angry Birds on the iPad.

By the end of this study, Jack was able to identify, write and understand quantities from numbers one to seven and maintained a mastery-level performance, up to six weeks post-intervention, for all numbers except seven. This work shows that video modelling with fading prompts, reinforcement and in vivo prompts can be effective to teach children with ASD. It also shows that one way of making it more interesting and captivating for the child is to make it personal, using his name, his image and favourite cartoons.

This study is limited because it is only focused on one child and it is personalized for her. Although this worked on Jack, it does not mean it will work for other children. Also, being personalized makes it difficult to use with other children because almost all of the material would have to be remade. In our

situation we want to make an APP that can be customizable regarding prompts, reinforcement, etc., so that it can be adapted to more than one child.[5]

3.0.4 Teaching Functional Use of an iPod-based Speech-generating Device To Individuals with Developmental Disabilities

This study was based on the known efficiency of speech-generating devices (SGD), which come in various shapes and models, and focus on teaching individuals with ASD to use a new iPod-based SGD. The choice of device and SGD was based on reported advantages, hence iPad, iPod Touch and iPhone were chosen to be used as well as Proloquo2Go software. This study was made with the help of two adolescents and one adult (two boys and one girl, 13, 14 and 23 years old respectively) that were diagnosed with ASD or a related developmental disability. All three had an expressive language capability equivalent to a child of 2.5 years, or less. None of them had ever access to SGD training or had any type of impairment that would prevent them of operating the SGD.

This work uses the ABAB design (described in Section 6.1.1)(i.e., a design with a baseline phase, followed by an intervention phase, followed by another baseline phase, followed by another intervention phase).

The several phases were called baseline, acquisition-training, post-training and follow-up phases. Baseline identifies the starting point for this project. It analyses each individual current situation so that it can understand how much one evolved throughout the study. To do this there were trays in sight, with what was considered as a reward for each individual, but out of their reach and there was an iPod directly in front of each participant. The iPod had an interface with several symbols, and each symbol, when pressed, had a different voice-over output. The trainer would tell the participant, for example, "Let me know if you want a snack." and then it would move the tray in his direction and allowed the participant to take an item every thirty seconds. In this phase the iPod symbols were recorded but no consequences were programmed.

The next phase, acquisition-training, was conducted until participants made three successive independent requests for snacks. As in the previous phase the trainer would point to the tray of snacks and say "Here are some snacks. Let me know if you want something" and, in the first three trials, a second trainer would immediately hold the participants hand, isolate the index finger, and guide it to the "snack" symbol on the iPod so it would activate the corresponding speech output. After this the first trainer would move the tray towards the participant and let him take an item of his choice.

One of the participants (the older) failed to pass the criterion imposed by this phase and did not enter the post-training phase, which is very similar to baseline but with the exception that the access to the tray of snacks is only given after touching the snack symbol on iPod and no verbal or physical prompt is given. (Fig.3) Different control procedures were used during this phase to insure that the responding of the participants were not position based.

Follow-up sessions were conducted after a ten week interval in which none of the participants had access to an iPod or attended school.



Figure 3.1: Post-Training Phase

Though one of the participants showed no progress, the other two participants showed a rapid evolution of the use of iPod-based SGD.

Not only the results of the acquisition-training and post-training phases, where manipulation was introduced to test the liability of their answers, but also the results gathered from follow-up, suggest that the instructional strategy was effective and functional use of iPod-based SGD was achieved.

Although this study is successful with two of the three participants there is no proof of why an iPod-based SGD, or a similar device-based SGD, should be used over other SGD's. Also, due to the small number of participants, it is difficult to determine its effectiveness on other individuals with different ages.[15]

3.0.5 Effectiveness of Using iPads to Build Math Fluency

This research was made with the purpose of examining the effect of using an iPad APP to increase basic math fluency, which refers to the accuracy and speed of a student to solve simple problems like single-digit addition, subtraction, multiplication and division.

This study took place at a classroom of a special education school and had the participation of ten children diagnosed with ASD or multiple disabilities, between twelve and fifteen years old. It was conducted during four weeks. The research work used the ABAB design where on the first week (baseline phase) students completed paper and pencil timed math probes. On the second week (intervention phase) students completed timed math probes using an iPad APP. Week three was equal to week one and week four was equal to week two.

The conclusion of this study is that, overall, the iPad is an effective instructional tool to teach basic math fluency to students with moderate to severe disabilities. The majority of students improved math fluency but more data would be needed to assess its effectiveness at the student level. Also, teachers believe that the students were more engaged and interested in the iPad related activities and showed great interest in continuing to use it in classroom instruction.

Though the use of iPad seems effective in this conditions there is no evidence if in a long-term the

improvements would maintain. This study is limited in the perspective that it should be researched the impact of the use of iPad in different ages and subjects and, also, in different environments.[21]

3.0.6 Using Tablet Computers as Instructional Tools to Increase Task Completion by Students with Autism

The main objective of this work is to study the effect of using iPads in academic context to increase independent task completion and math skills in students with ASD.

This research was made at a special education school, in a classroom with seven students, from ten to thirteen years old, who were diagnosed with ASD. It was designed to supplement their regular math instruction and had the duration of four weeks. This work used a ABAB design, where in the first and third phase (baseline phases) instruction was given using traditional methods and in the second and fourth phase (intervention phases) instruction was given using an iPad app.

The results of this study were based on the independent completion of math tasks, presence of noncompliant behaviours and level of prompting, and show that the majority of students maintained or improved their performance but more data would be needed to conclude its effectiveness. This study should be made using longer baseline and intervention phases in order to collect more data. Other settings and age ranges could also contribute to assess the value of using iPad as an instructional tool.[20]

3.0.7 The Effect of Instructional Use of an iPad on Challenging Behaviour and Academic Engagement for Two Students with Autism

The purpose of this study was to examine the effect of iPad on student behaviours. This was made by comparing academic instruction delivered by traditional methods and with an iPad. The participants were two students with ASD who engaged in aggressive behaviours and screaming during academic demand.

One of the participants, Elton, was a seven-year-old boy diagnosed with Asperger's Syndrome who attended a general education third grade classroom. The sessions occurred twice a week, after school, for eight weeks. Each session took place in Elton's house, in his room, and only the participant and the researcher were present. The targeted academic demand for Elton was double-digit subtraction with regrouping. Elton knew the iPad and was using it for approximately a week.

The second participant was Dan, a three-year-old boy diagnosed with PDD-NOS. He attended a childhood center for children with autism, where the sessions occurred. In each session the researcher, the participant and data collectors were present. The sessions occurred twice a week, for eight weeks, and the targeted academic skill was matching colour cards. Dan had no previous contact with an iPad but a desktop computer was a preferred reinforcement.

This study was assessed using an A-B-A-B design. In the first phase (A) instruction was delivered using traditional materials, a pencil and paper for Elton and paper flashcards for Dan. In the second

phase (B) instruction was delivered using the iPad. The iPad APP used for Elton was the WritePad¹ (a handwriting recognition software whose background is similar to a traditional worksheet) and a stylus (similar to a pencil). Elton was instructed to answer to the math question using the stylus to write on the WritePad.

For Dan it was used the Little Matchups² APP, this application was personalized by the researchers so that the background would resemble a wooden surface and had color cards on each side. Dan would have to use his finger to select a card from the left side of the screen and drag it to the matching color card on the right side of the screen. Sound was disabled and reinforcement was applied the same way it was applied in the phase where no iPad was used, to ensure consistency between phases.

Elton's challenging behaviours occurred in 87% of the intervals (10 seconds interval) on the first phase (traditional materials phase), dropped for 6,2% in the second phase (iPad phase), raised for 100% on the third phase (traditional materials replication phase) and dropped for 0% in the fourth phase (iPad replication phase).

For Dan, the challenging behaviours occurred 62% of the intervals, in the first phase, dropped to 15,3% when the iPad was introduced (second phase), increased in the third phase to 39,8% and once again dropped to 13,4% on the last phase. These results allow us to conclude that both participants had an increase of academic engagement and academic responding when the iPad was used to deliver instruction. Although it is possible that these results are influenced by a possible aversion to traditional materials and/or participants could see the iPad as a reinforcement, what would mean that they had noncontingent access to a preferred item.

This study should be continued, to understand if this results are stable after a longer period of time. Also other academic demands should be used.[16]

3.0.8 Mobile Learning Technology Based on iOS Devices to Support Students with Special Education Needs

This study's main objective was to evaluate the use of a customized and adaptable APP in students with special needs. The APP designed for this purpose was named Picaa³ and included four kinds of educational activities (Fig.3.2):

- Exploration: where students learn concepts through the navigation of a hypermedia system.
- Association: where the student must indicate relationships between elements.
- Puzzle: where a fragmented image must be rebuilt.
- Sorting: where a list of elements must be ordered in a sequence.

These activities can be personalized (at content and user interface levels) to better fit the student needs.

¹<http://www.phatware.com/index.php?q=page/writepad/ipad>

²<https://itunes.apple.com/us/app/tell-time-little-matchups/id440944851?mt=8>

³<http://asistic.ugr.es/picaa/?lang=en>



Figure 3.2: Picaa Activities

The subjects of study were thirty nine students, with special education needs, from special and elementary schools. The age of the participants ranged from four to twenty, with 82% between six and fifteen years old. 46% of the participants were diagnosed with ASD. Students were divided in groups with a maximum of six individuals. There was a ratio of two students for device, which could be an iPad (higher proportion) or an iPod touch.

This study was conducted by the teachers of each class. Each teacher was instructed in the use of Picaa through classroom courses.

To assess the efficacy of this APP two questionnaires were designed. One with the purpose of evaluating the skills and knowledge of students (language, math environmental awareness, autonomy and social), before and after the use of Picaa. The other evaluated the use of activities by each student, like the frequency of use, the suitability of the activity, the acquisitions and the student motivation when working.

These questionnaires were completed for thirty four students and it was observed that there was an increase on skill levels/scores. On average, language skills increased 5,76%, math skills increased 5,56%, environmental awareness skills increased 7,59%, autonomy skills increased 7,26% and social skills increased 4,23%.

To assert the usefulness of the tool, comparative analysis was made separating the population by two factors, gender and diagnosis, where diagnosis were separated in two groups, students with ASD and students with other diagnosis. This enabled the conclusion that there was no significant differences between degree of improvement by gender or diagnosis. Also, this study was conducted in several schools, by different teachers, at different phases of educational process.

The heterogeneity of the sample leads to the conclusion that the increase of skills was related to the intervention with the Picaa APP and not to other independent variables.[1]

3.0.9 Multitouch Tablet Applications and Activities to Enhance the Social Skills of Children with Autism Spectrum Disorder

This study was conducted with the goal of developing a set of activities, based on APP's that run on multitouch tablets, that increase pro-social behaviours.

During three months, a total of thirteen two-hour sessions were conducted with sixteen elementary

school children and ten middle school children. These students were all diagnosed with ASD and ranged from highly functioning children to children who communicate mostly with picture cards. The authors developed four APPs:

- Drawing - an APP that enables children to draw with a stylus, zoom in and out and rotate the drawing with their fingers. This APP was used by children to express themselves and to conduct collaborative storytelling activities. This was made by sitting a group from two to six children around a table, one of them begins telling the story by drawing something on the touch screen and then passes the tablet to the next child so that she can continue the story by adding her own drawing.
- Music authoring - this APP allows children to select tiles set up in rows and columns. Each tile represents an individual note. Columns are played in sequence and displayed green when playing. Tempo is also adjustable. This APP was created with the aim of allowing children to create something to share with others. It was also used for collaborative music authoring which worked exactly as collaborative storytelling.
- Untangle - this APP consisted of a set of circles, each connected to two other circle through lines. The objective was to arrange the circles so that no lines would overlap. The number of circle could be chosen, ranged from ten to twenty five. This puzzle could be solved by one or more children at the same time, encouraging communication, collaboration, coordination and visuospatial thinking.
- Photogoo - this APP enables children to distort an image. Using their fingers, and drawing over an image using a stylus. There were developed activities two using this APP. The first was conducted with the objective of children exploring their emotion, where they modified the face of their favourite cartoon to express specific emotions (like dragging the end of the mouth up to express happiness). On the second activity, a scenario was shown to the child and it was asked for her to show how she thought the character or person in the picture felt.

Based on observations, the authors concluded that all of the APP's help and teach children to better express and enjoy social experiences and interactions and made them more willing to experience them.

This study lacks of data to support the findings, given that no measurements were made to assess if there was in fact an evolution, or if this evolution was an outcome of the intervention with the tablet.[12]

3.0.10 Vocabulary Acquisition for Children with Autism Teacher or computer Instruction

This study was conducted with the intention of studying the impact of computers in vocabulary acquisition by children with ASD. To do so, two treatment conditions were applied, behavioural condition and computer condition. The participants were 14 children with ASD, ranged from three to six years old, who were randomly assigned to one of the two treatment conditions.

Behavioural condition consisted of teaching the name of simple objects through object labelling drills. In these drills, the participant was taught to respond to verbal commands such as "Give me (object)" or

“Touch (object)”. If the participant responded correctly, reinforcement would be applied (verbal praise or playing with a desired object). If the response was not the desired one, verbal prompts were given until the participant gave a correct response.

It was considered that the participant mastered an object name when three consecutive correct responses were given without prompting.

The computer condition was similar to the behavioural condition, with the difference that sensory reinforcement and attention-getting features, such as colours and music, were added. When a word was mastered, reinforcement was given through the use of such features.

During this study, three types of measurement were made: Learning measures, where teachers tested each child, relatively to learning defined nouns, previous and prior intervention; Attention measure, where, through videotaping of sessions, it was calculated the percentage of time each child paid visual attention to the teacher and learning materials (behavioural condition), or computer (computer condition). Motivation measure, to assess the motivation of each participant. After the final treatment session, each participant was asked if they wanted to continue working or if they wanted to go play.

These measurements showed that participants paid more attention to the computer rather than to the teacher, with an average of 97% vs. 62% respectively. Also, children that were exposed to the computer recalled more nouns than the ones exposed to teacher presentation, with an average of 74% vs. 41% respectively. And, respecting motivation, none of the children in behavioural condition chose to continue working whereas 57% of children in computer condition chose to continue working.

A regression analysis also allowed to conclude that, as expected, the children who paid more attention were the ones who learned more.

This study findings are of great value for our APP, as it proves that reinforcement through sound and images are effective to captivate the attention of children diagnosed with ASD.[18]

3.1 Discussion

	Number of Participants	Math Skills	Reading Skills	Other Skills	Reinforcement or Prompts using device	Personalization	Maintained or Improved Skills
3.1	1	x			x	x	x
3.2	3			x		x	x
3.3	10	x					x
3.4	7	x					x
3.5	2	x		x		x	x
3.6	39	x	x	x		x	x
3.7	26			x			x
3.8	14		x		x		x

Table 3.1: Articles Reviewed

After analysing the previous works (Table 1), we conclude 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 consequentially 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.

Chapter 4

Development

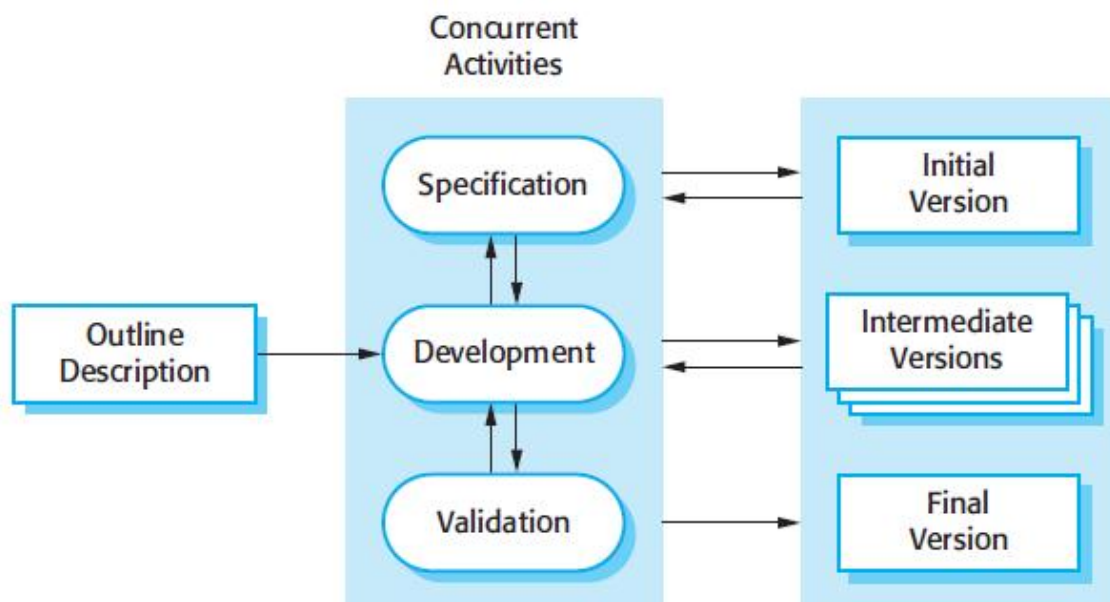


Figure 4.1: Incremental Development Model.[26]

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 (Fig.4.1). This method is based on the idea of implementing a base version, expose it to users and evolve it based on their comments.

Outline Description is the initial planning, where we determine what should be our first version, what it should consist of and what requirements should it meet, which we describe in this chapter. After we reach a valid solution we proceed to *Development*, which is interleaved with *Specification* and *Validation* through several versions, until we get to *Final Version*. All this phases are explained in the next chapter.

This APP is meant to have two users: children, who are supposed to develop their reading and writing skills from using it, and tutors, who have to customize it to better fit the child needs. With that in mind, the initial and intermediate versions were developed based on feedback given by a therapist,

graduated in Special Education and Rehabilitation and certified as an Applied Behaviour Therapist, and the final version and tests, were based on the outcome of her tutee. But before we reach that phase, we had to establish exactly what we expected from this APP so that we could develop the base version.

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. These requirements reflect the objectives of this project in a more formal perspective and oriented to development. There are two types of requirements, functional and non-functional. 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.[26] 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.[26] 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 (Fig.4.2) (Fig.4.3) that allowed us to test our concept and provide specifications for the next step, for example, of what should consist each exercise.

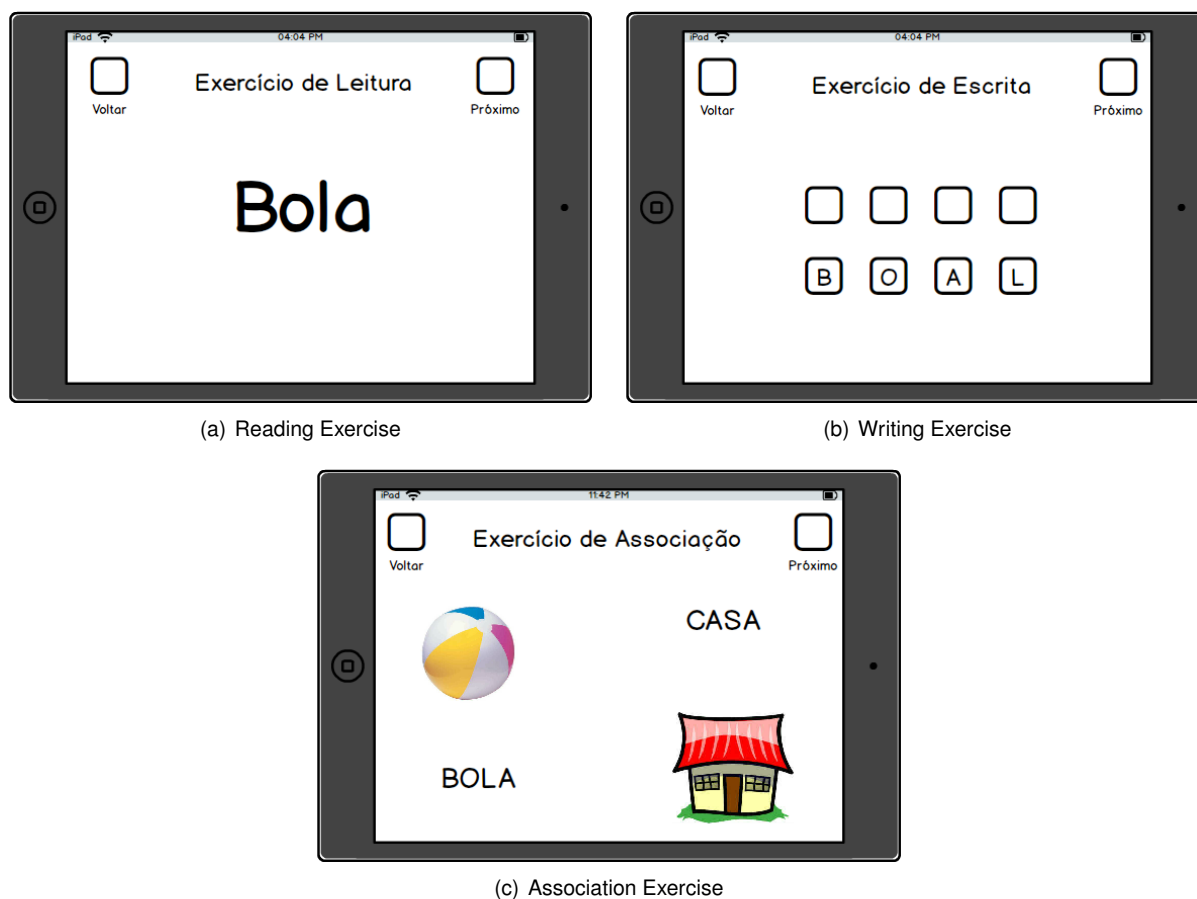


Figure 4.2: Available exercises.

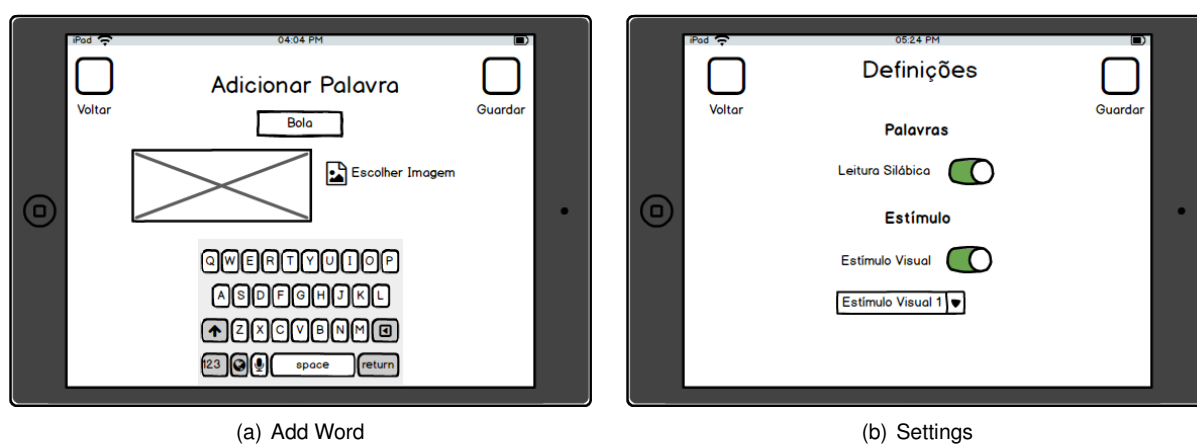


Figure 4.3: Settings.

4.3 Architecture

In this section, we describe the architecture that we used to develop our system, their components and in what form they connect.

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 ¹ 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.

4.3.1 Development Tools

To develop this project we will use Xcode software development tool. Xcode is an Integrated Development Environment (IDE) used to develop software for Apple products and can be used with several different programming languages.

Originally we were set to use Objective-C, an object-oriented programming language. But, by the time we started this project, Apple released a new multi-paradigm, compiled programming language, called Swift. This programming language is supposedly more resilient to erroneous code and more concise, which makes APPs faster. Based on that information, we thought it would be a good acquisition to our project and decided to use Swift instead of Objective-C.

4.3.2 Design Pattern

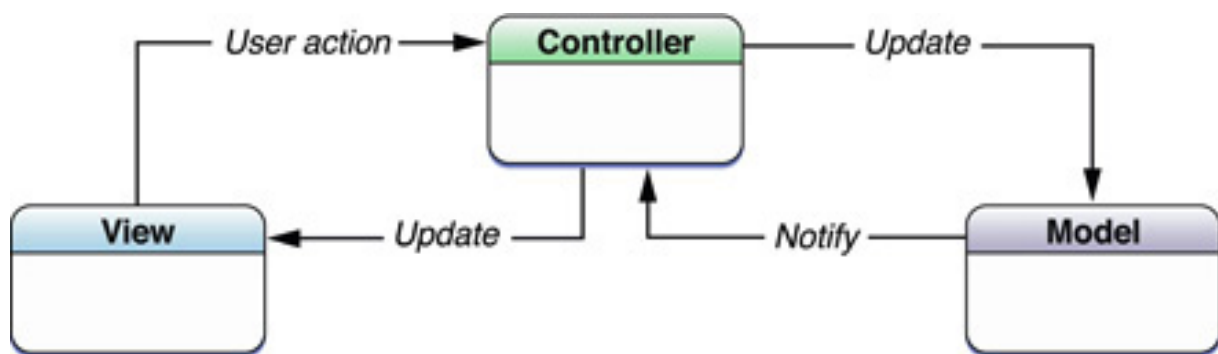


Figure 4.4: Model-View-Controller Design Pattern.[8]

iOS APPs development is based in Model-View-Controller (MVC) architectural design pattern (Fig.4.4). MVC pattern is used primarily in Graphic User Interfaces (GUI) and it is based on the premise of modularity, which allows to separate three different aspects: Model, where the data is encapsulated; View, the visual representation of the data to the user; Controller, the intermediary between models and views. In other words, this pattern will assign every object of the APP a role, which can be one of the three mentioned, and consequently define the way objects will communicate with each other.

¹In this APP we consider that data is words and images.

Model Component

As we mentioned before, the way our data will be stored is very important, given that all of the exercises will depend on the performance of this layer. The way our data is approached must be fast and responsive and it should easily allow removal and insertion of new data. After researching and testing several frameworks and types of files, that allowed to store serialized objects, we decided to use Core Data.

Core Data is an object graph and persistence framework, provided by Apple, that allows object graph and object life-cycle management. This high level data model has several features that met the criteria for our project. One of those features is the possibility of integration with the APP's controller layer, which will allow the user itself to add and manipulate the data through the view controller. Also, it allows to describe data in terms of entities and their relationships. In our specific case, we will use this feature to store a word and its respective image. Another very important feature of this framework, and one of the reasons we discarded other options of data storing, is the persistence of data, since the data is added by the user and it is not given by default. Also, the fact that it allows large amounts of structured data without compromising efficiency was also a key factor for our choice.

View Component

This component represents the objects of the APP that users can see. Here we represent a state and change it according to user actions. View component objects allow to show the data that we have in Model component and also to modify it. To do so, there are several objects we can use, for example, a text box will allow us to add words.

Xcode simplifies the process of constructing views using a storyboard editor (Fig.4.5). Storyboards allow to draw the visual representation of the user interface using scenes, that represent View controllers, and to define how they are connected. This editor allows to easily add and connect View objects, like buttons and text boxes, to Controller objects and to manage the transfer of data between different View controllers. Also, it allow us to visualize and modify the appearance and flow of the user interface.

Controller Component

The Controller component is responsible for passing information between the Model component and the View component. If a user edits the data in the View, the Controller will process the editing event (Fig.4.6) and send that information to the Model component, which will update the data and consequently communicate the changes to the Controller so that the View is updated to show the new data.

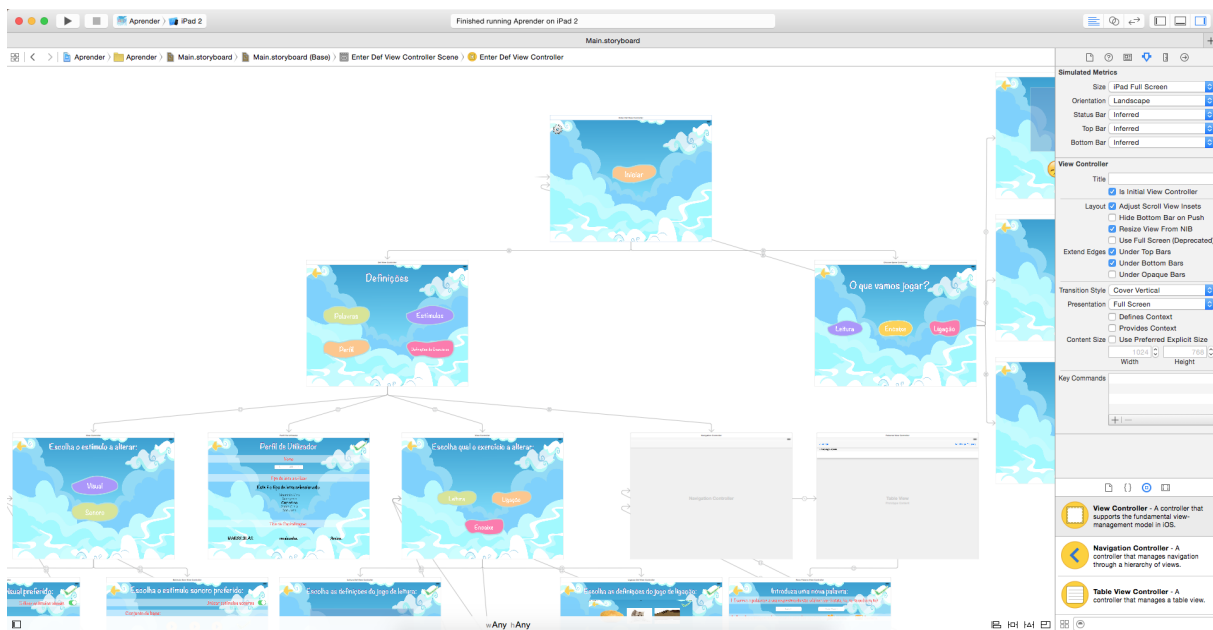


Figure 4.5: Storyboards

```
var appDelegate: AppDelegate = (UIApplication.sharedApplication().delegate as AppDelegate)
var context: NSManagedObjectContext = appDelegate.managedObjectContext!

let words = NSEntityDescription.entityForName("Palavras", inManagedObjectContext: context)!

//Instance of our custom class, reference to entity
var novaPalavra = Palavras(entity: words, insertIntoManagedObjectContext: context)

// Fill in the Core Data
//Palavra
var wordGotten = self.palavraField.text as NSString
let wordTrimmed = wordGotten.stringByReplacingOccurrencesOfString(" ", withString: "")
let wordToUse = wordTrimmed.lowercaseString

novaPalavra.palavra = wordToUse
```

Figure 4.6: Adding word to Core Data

Chapter 5

Implementation

In this chapter we document how the system was implemented. We describe how each exercise evolved, from the initial prototype to the present version, and explain the decisions that were made throughout this process, why we added new features and based on what groundings.

5.1 Data Store

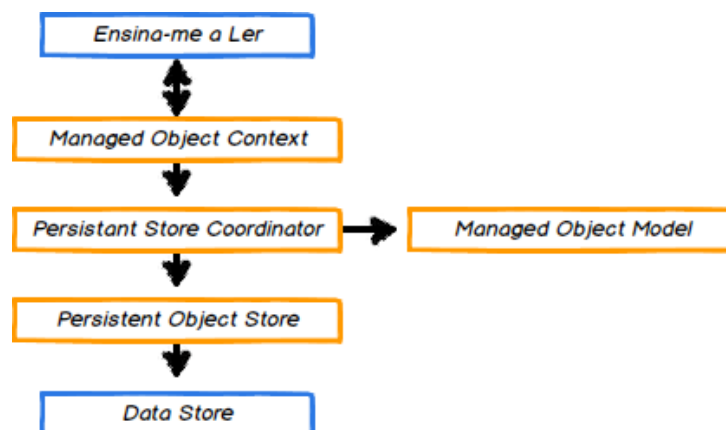


Figure 5.1: Core Data

As we mentioned before, we decided to use Core Data framework to deal with our data management. But this was not our first choice. The initial implementation was done using property lists (plist), a type of file that stores serialized objects. This type of file revealed not to be the best choice to our project when we decided, and needed, to add more than one attribute to the same object. Also, it did not allow to store persistently the data that was added by the user. Every time the APP was closed the data previously added was lost.

Figure 5.1 illustrates how Core Data works. Managed Object Context layer contains the objects that interact with the data in the persistent store. This is the most used layer of Core Data stack, as it is through it that we can fetch and save new objects. The Persistent Store Coordinator is responsible for managing different Persistent Object Stores and for saving the objects to the stores. Managed Object

Model refers to the description of the objects (also known as entities) and is defined in a file with the extension `.xcdatamodel`. Using the visual editor we can define entities, their attributes and relationships.

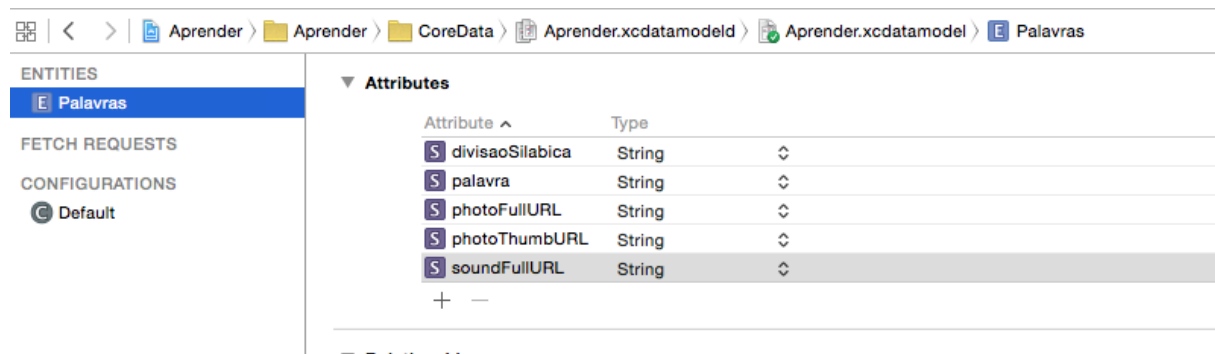


Figure 5.2: Managed Object Model.

For example, Figure 5.2 displays our managed object model, where our entity is *Palavras* and its attributes are *palavra*, *divisaoSilabica* (syllabic division), *photoFullURL*, *photoThumbURL* and *soundFullURL*. This kind of storage allows us to have several types of information associated to the same key.

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 (Fig.5.3) and to see the list of words already stored (Fig.5.4).



Figure 5.3: Add Word.

To add a word we have to fill a text field (Fig.5.3(1)), where the said word is written using a virtual keyboard, and an image, which can be chosen using the gallery (Fig.5.3(2)) of the iPad or taking a photograph (Fig.5.3(3)) with the iPad camera. We chose to implement the camera so that personal

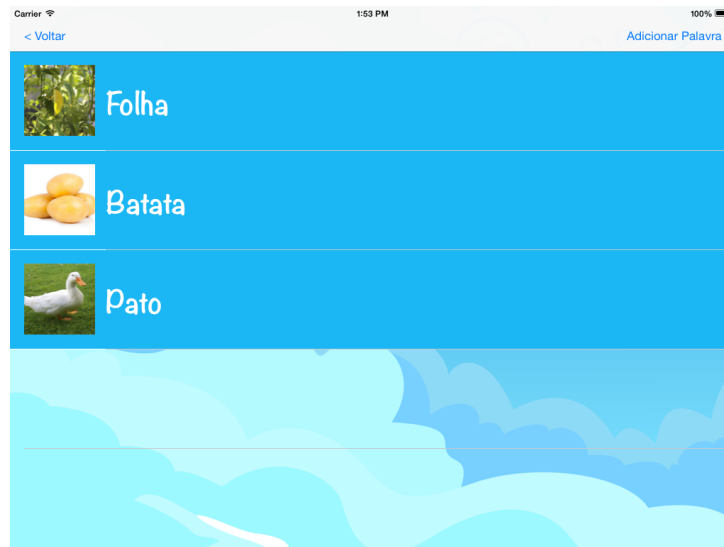


Figure 5.4: Words Added.

objects or representations can be added. For example, we can add the word "dad" and have the picture of the child's parent, instead of a generalization of the word.

5.2 *Leitura* Exercise

As we can see from prototyping, 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 (Fig.5.3(4)). This was implemented using the AVFoundation framework, which allows to create time-based visual media. In our specific case, it was used to record and play audio files, using AVAudioPlayer and AVAudioRecorder Application Program Interfaces (API's). The recording is made using the built-in iPad microphone and buttons on screen (Fig.5.3 record (4.1) and stop (4.2)). The user has also a play button (Fig.5.3(4.3)) that allows to hear the recording. If not satisfied, it is possible to record a new audio.

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[7] as one common characteristic of children with ASD. Taking that into account we decided to implement two buttons. A sad smiley button (Fig.5.5(1)) and a happy smiley button (Fig.5.5(2)). When the therapist considers that the

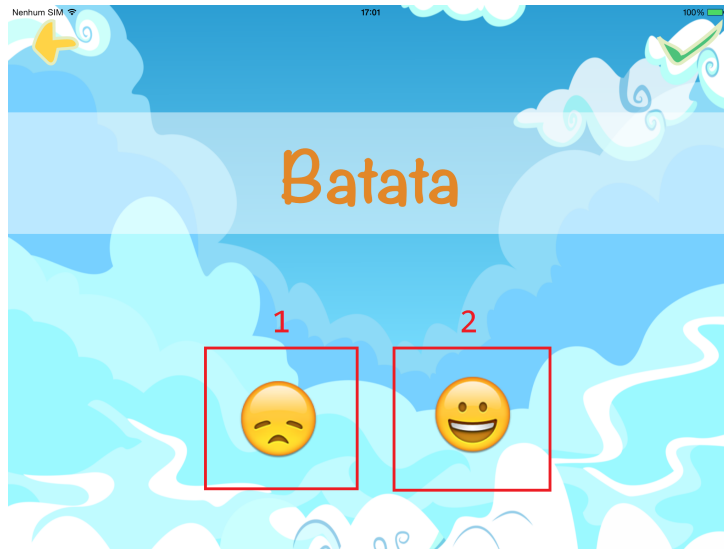


Figure 5.5: Reading Exercise.

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.

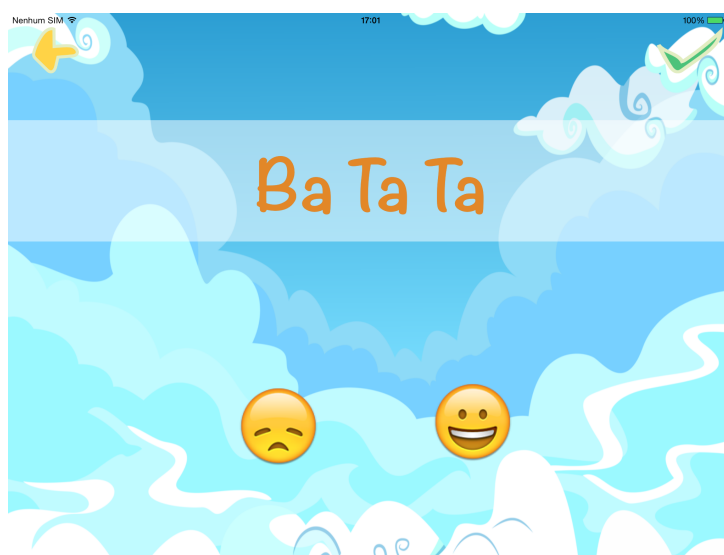


Figure 5.6: Syllabic Reading.

The next step was to implement the syllabic reading (Fig.5.6). To do so, we implemented a new

attribute to our entity *Palavras* and a new text field in word adding (Fig.5.3). Also, a new settings screen, where it is possible to turn on or off this feature, was added (Fig.5.3(1)).

As we reached a solution that, from our perspective, was fun and duly substantiated we decided to implement the reinforcement. We concluded from related works that the usage of images and colours as a reinforcement is very successful, so we wanted to make sure we could provide them in an attractive and captivating way. 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. This is accomplished using an image (particle) and an emitter. The emitter acts as the source of the particles and controls the initial behaviours of the particles. It is defined as a shape, with a certain size, in a defined position on the screen. The particle behaviours it controls include life-time, birth rate, acceleration in X and Y axes, velocity, scale, emission range amongst others.

In the first exercise, it was implemented to simulate stardust (Fig.5.7). 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 (Fig.5.8). This diversity will also allow to keep the child interested in the exercises.

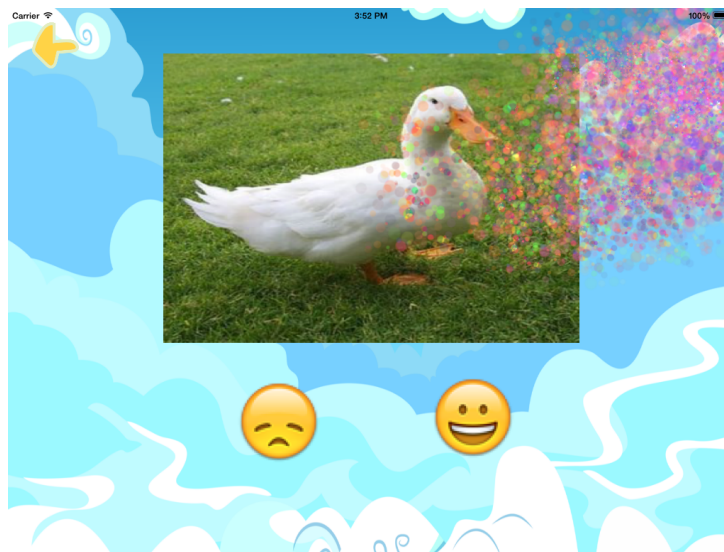


Figure 5.7: Stardust

5.3 *Encaixe* Exercise

Next, we started implementing the second exercise, *Encaixe* (Fig.5.9). 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.5.9(3)), and we display squares, called targets (Fig.5.9(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 straight forward what it is supposed to be written, so we decided to use the sound feature here too. When the word is displayed, the word



Figure 5.8: Visual Reinforcement Settings.



Figure 5.9: Writing Exercise.

recording is heard and at any time the speaker button (Fig.5.9(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 this 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 an explosion-like effect is displayed (Fig.5.10). 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.

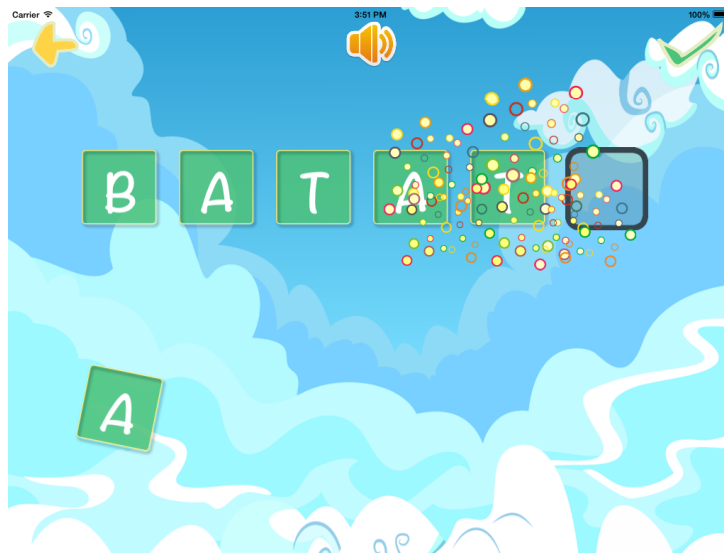


Figure 5.10: Single Reinforcement

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 (Fig.5.11).

Lastly, to solve the fourth problem, we implemented a new settings screen where we can choose between four different fonts and three different styles of capitalization (Fig.5.12).

5.4 *Ligação* Exercise

The third exercise (Fig.5.13) 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 pre-



Figure 5.11: Writing Prompt



Figure 5.12: Customization.

sented 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.

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 (Fig.5.14). 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 did 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.



Figure 5.13: Matching Exercise.



Figure 5.14: Matching Exercise Settings.

5.5 Improvements

When we reached this state of the APP, where the three exercises were implemented, we added the possibility of turning the reinforcements on and off (Fig.5.8(1)) enabling the reinforcement schedule (see section 2.1.1). Also, as we did with visual reinforcements, we added the possibility of recording three personalized sound reinforcements (Fig.5.15). 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 an image was big, it would still cut off some details. This was solved by readjusting the size to which the image is scaled.



Figure 5.15: Sound Reinforcements Settings.

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 (described in Chapter 2) 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.5.16). This prompt can be turned on and off on settings (Fig.5.14(1)).

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 (Fig.5.17).

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)%.



Figure 5.16: Model Prompt.

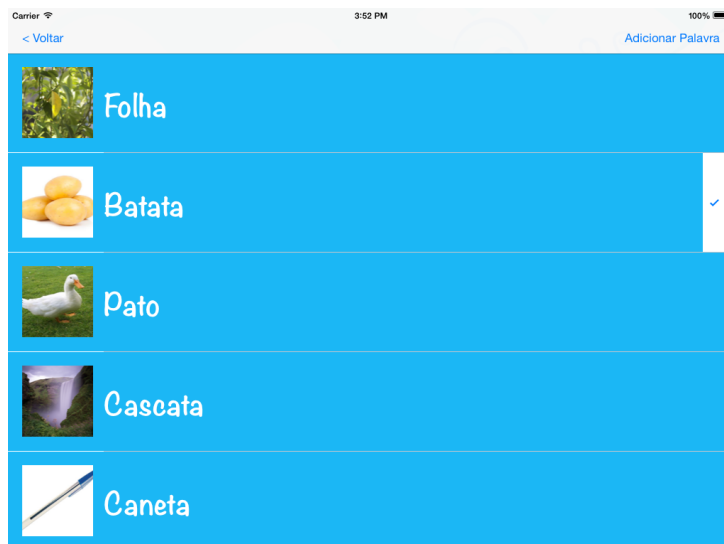


Figure 5.17: Word Selection

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.

Chapter 6

Evaluation and Results

In this chapter we will describe how we evaluated *Ensina-me a Ler* and if our final solution achieved the goal of this thesis. We begin by describing the evaluation metrics used, followed by how it was implemented and, finally, we describe the results and what we can conclude from them.

6.1 Evaluation Metrics

In this section we explain the chosen type of evaluation as well as its methodology and application.

6.1.1 Single-Subject Designs

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 methodology is characterized by different features:

- **The subject is the unit of analysis** - The subject serves as his own control. His performance prior, during and after an intervention is compared to evaluate the effectiveness of the intervention.
- **Participant and setting description** - This type of research requires the description of the participants, the setting in which the research was performed and the process of selection of the participants. Other researchers should be able to reproduce the research.
- **Repeated measurement** – To assess a subject progress it is necessary to perform several measurements of the target problem. These measurements are acquired through direct observation and should be made prior to and during the intervention with regular periodicity (hours, days, weeks...).
- **Dependent variable** - The research employs one or more dependent variables to be defined and measured. These variables should be defined so that it is possible to make a valid assessment and to replicate the process. One example of a good dependent variable would be the number of words read in a minute.

- **Independent variable** - Typically refers to the intervention or to the mechanism under intervention. This variables should be defined so that it is possible to make a valid interpretation of the results and also to allow the replication of the process. A good independent variable should describe the materials used (e.g. a reading card of 5cm x 5cm) as well as the procedure (e.g. the tutor implemented the reading curriculum thirty minutes per day, every day).

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** – This design includes a baseline and an intervention phase. Although it is possible to see a relation between the intervention and the outcome this design is susceptible to uncontrolled influences. For example, consider an intervention with the purpose of increasing study time, during the baseline phase the subject had a study time range from ten to seventy minutes, at the end of the intervention this range increased to between eighty and one hundred and twenty minutes. Though the results of the intervention phase suggest that it was successful, there is the possibility that this could be the result of a third variable considering the fact that time range was already increasing during baseline. (Fig.1)

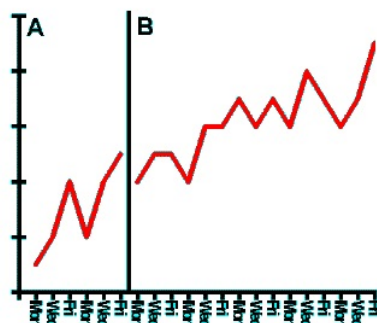


Figure 6.1: A-B Design

- **A-B-A Design** – This design implements A-B design and it is followed by a post intervention follow-up, that will also include repeated measures. Ideally this design will help determine if the

intervention was successful and if the results maintain after it is over. It is also possible, depending on the length of the follow-up phase, to determine for how long the effect of the intervention persists.

- **A-B-A-B Design** – A-B-A-B is specially useful for research, it implements A-B-A and applies a second intervention phase, identical to the first one. It helps establish if the results are a consequence of the intervention. For example, if during the follow-up phase the results started to reverse, and intervention is once again successful, this reduce the possibility of a third variable influence. (Fig.2)[23]

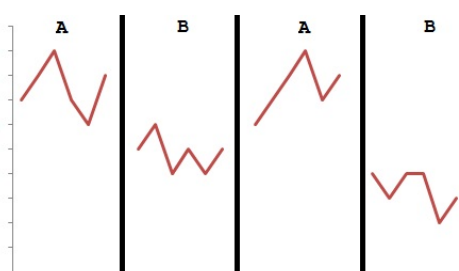


Figure 6.2: A-B-A-B Design

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.[24] In this case it was only tested in one child due to lack of available children who would fit the criteria¹.

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 *Ligação*.

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.

¹ A child diagnosed with ASD in the process of learning to read/write.

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.

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.5.16). If the tutee performed the exercise correctly² 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 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.

²An answer is consider correct when every letter is placed in the correct order at the first try.

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

In this section we present and discuss the data collected (Fig.6.3) and what were the results of each phase (Fig.6.4) and of the research as a whole.

	DAY	SESSION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
BASE LINE	1	1 st	-	-	-	-	-															
		2 nd	-	-	-	-	-															
	2	1 st	-	-	-	-	-															
		2 nd	-	-	-	-	-															
INTERVENTION	3	1 st	P	P	P	P	P	P	P	P	P	P	-	P	P	P	P	P	P	P	P	P
		2 nd	P	P	P	-	P	P	P	P	P	P	-	P	P	-	P	P	P	P	P	P
	4	1 st	P	P	P	-	P	+	+	+	-	P	P	+	-	P	+	+	+	+	+	+
		2 nd	+	+	+	+	+															
	5	1 st	-	P	+	+	-	P	+	+	-	P	P	+	+	+	+	-	P	+	+	+
		2 nd	+	+	+	+	+															
	6	1 st	+	+	+	+	+															
		2 nd	+	+	+	+	+															
FOLLOW-UP	7	1 st	+	-	+	+	+															
		2 nd	+	+	+	+	+															

-	Wrong Answer
P	Right Answer with Prompt
+	Right Answer

Figure 6.3: Data Collection

6.3.1 Baseline

The baseline phase in Figure 6.3 shows that 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.

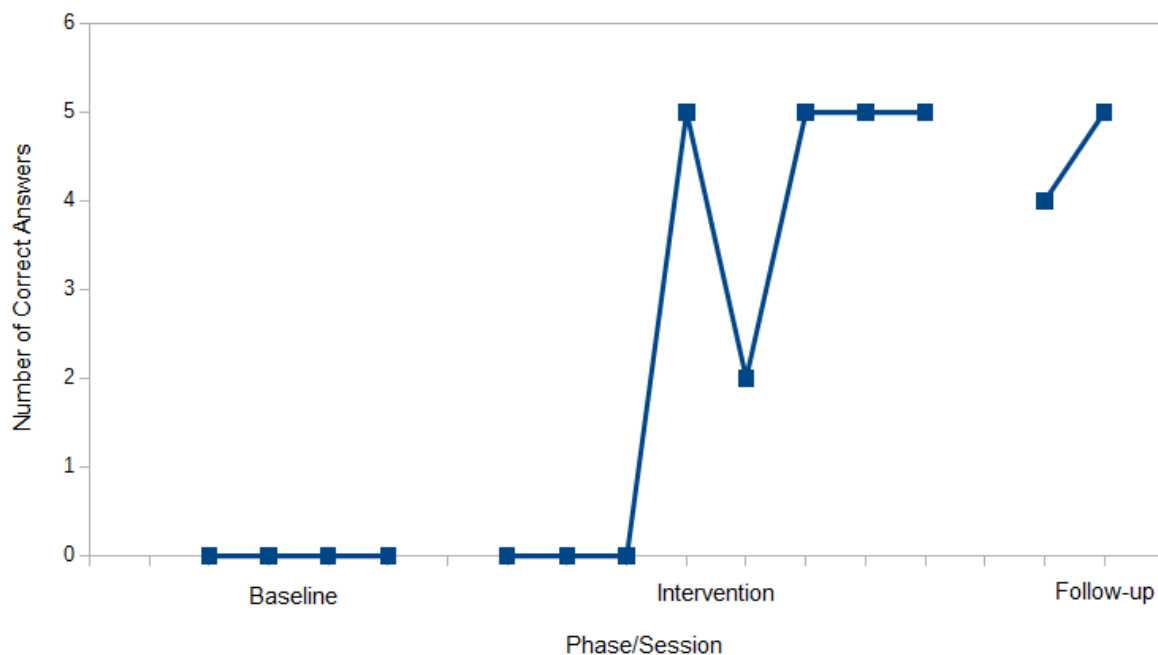


Figure 6.4: Results

6.3.2 Intervention

As we can see from Fig.6.4, 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 data collection (Fig.6.3), 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 to consider the word as acquired.

On the first session of the next day (day 5), and 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 Data Collection table (Fig.6.3) 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 (see Appendix A) 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 to 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.

Chapter 7

Conclusions

As stated in Section 1.1, 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 in Section 3 helped us understand how some of these concepts had been applied in teaching through technology 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. A child diagnosed with Autism Spectrum Disorder, who is currently in the process of learning to read and write, and his therapist, who helped us to conduct a research that allowed us to conclude the effectiveness of our application.

Due to the availability of both therapist and child, we could only perform our research in one of the exercises. We chose the exercise that, from our perspective, better represents the capabilities of our application and extrapolated the obtained results to the whole application. Also, we conducted an interview and a questionnaire with the therapist that helped us evaluate her experience as a user and as a professional. 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 "chão" 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.

Bibliography

- [1] Maria Luisa Rodriguez-Almendros Maria Jose Martinez-Segura Alvaro Fernandez-Lopez, Maria Jose Rodriguez-Fortiz. Mobile learning technology based on ios devices to support students with special education needs. *Computers and Education*, 2012.
- [2] American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. American Psychiatric Association, 2000.
- [3] Jon Baio. Prevalence of autism spectrum disorders autism and developmental disabilities monitoring network. *Centers for Disease Control and Prevention*, 2008.
- [4] Sathiyaprakash Ramdoss Mark F. O Reilly Giulio E. Lancioni Tonya N. Davis Mandy Rispoli Russell Lang Peter B. Marschikg Dean Sutherland Vanessa A. Green Jeff Sigafoos Debora M. Kagohara, Larah van der Meer. Using ipods and ipads in teaching programs for individuals with developmental disabilities: A systematic review. 2012.
- [5] A. ANDERSON E. L. JOWETT, D. W. MOORE. Using an ipad-based video modelling package to teach numeracy. *Developmental Neurorehabilitation*, 2012.
- [6] Association for Behavior Analysis International. What is behavior analysis? <http://www.abainternational.org/abai/behavior-analysis.aspx>. Accessed: 2014.03.28.
- [7] Ofer Golan and Simon Baron-Cohen. Systemizing empathy: Teaching adults with asperger syndrome or high-functioning autism to recognize complex emotions using interactive multimedia. *Development and psychopathology*, 2006.
- [8] Apple Inc. *Model-View-Controller*.
- [9] Autism Speaks Inc. How is autism treated? <http://www.autismspeaks.org/family-services/tool-kits/100-day-kit/treatments-therapies>. Accessed: 2014.03.28.
- [10] PORDATA INE. Populacao residente segundo os censos: total e por grupo - portugal. <http://www.pordata.pt/Portugal/Populacao+residente+segundo+os+Censos+total+e+por+grupo+etario-2,11>. Accessed: 2014.03.28.
- [11] Lovaas Institute. <http://www.lovaas.com/lovaasnote.php>. Accessed: 2014.04.29.

- [12] Thomas E. Hansen Juan Pablo Hourcade, Natasha E. Bullock-Rest. Multitouch tablet applications and activities to enhance the social skills of children with autism spectrum disorder. *Ubiquit Comput*, 2011.
- [13] Leo Kanner. Autistic disturbances of affective contact. 1943.
- [14] Donna Achmadi Vanesa A. Green Christina Herrington Jeff Sigafoos Mark F. O Reilly Giulio E. Lancioni Russell Lang Mandy Rispoli Larah van der Meer, Debora Kagohara. Teaching functional use of an ipod-based speech-generating device to individuals with developmental disabilities. *Journal of Special Education Technology*, 2011.
- [15] Siglia Camargo Heather Davis Margot Boles Leslie Neely, Mandy Rispoli. The effect of instructional use of an ipad on challenging behavior and academic engagement for two students with autism. *Research in Autism Spectrum Disorders*, 2012.
- [16] Raymond G. Miltenberger. *Behavior Modification - Principles and Procedures*. Thomson Wadsworth, 2008.
- [17] Sandra Calvert Monique Moore. Vocabulary acquisition for children with autism teacher or computer instruction. *Journal of Autism and Developmental Disorders*, 2000.
- [18] 8th edition. (2009) Mosby's Medical Dictionary. Respondent conditioning. <http://medical-dictionary.thefreedictionary.com/respondent+conditioning>. Accessed: 2014.11.15.
- [19] M.E.B. Lewis Ed.D. Claire Donehower M.S.Ed BCBA Patricia OMalley, Ph.D. Using tablet computers as instructional tools to increase task completion by students with autism. *Kennedy Krieger Institute*, April 2013.
- [20] Sandi Jenkins M.Ed. Brooke Wesley M.Ed. Claire Donehower M.S.Ed BCBA Deidre Rabuck M.S. MEB Lewis Ed.D. Patricia OMalley, Ph.D. Effectiveness of using ipads to build math fluency. *Kennedy Krieger Institute, Baltimore Maryland*, April 2013.
- [21] Nienke Peters-Scheffer, Robert Didden, Hubert Korzilius, and Peter Sturmey. A meta-analytic study on the effectiveness of comprehensive aba-based early intervention programs for children with autism spectrum disorders. *Research in Autism Spectrum Disorders*, 2011.
- [22] Russell K. Schutt Rafael J. Engel. *Fundamentals of Social Work Research*. SAGE Publications, 2014.
- [23] James Halle Gail Mcgee Samuel Odom Mark Wolery Robert H. Horner, Edward G. Carr. *The Use of Single-Subject Research to Identify Evidence Based Practice in Special Education*. 2005.
- [24] John McEachin Ron Leaf. *A work in progress. Behavior Management Strategies and a Curriculum for Intensive Behavioral Treatment of Autism*. DRL Books, 1999.
- [25] Ian Sommerville. *Software Engineering*. Addison-Wesley, 9th edition, 2011.

Appendix A

Questionnaire

Avaliação da Aplicação Ensina-me a Ler

Achou que a interface estava adequada ao tema da aplicação?

1 2 3 4 5

Muito Adequada ☒ ☐ ☐ ☐ ☐ Nada Adequada

Achou a variedade de exercícios adequada?

1 2 3 4 5

Muito Adequada ☒ ☐ ☐ ☐ ☐ Nada Adequada

Achou os exercícios adequados ao intuito da aplicação?

1 2 3 4 5

Muito Adequados ☒ ☐ ☐ ☐ ☐ Nada Adequados

Achou os exercícios difíceis de executar pelo aluno?

1 2 3 4 5

Nada Difícil ☒ ☐ ☐ ☐ ☐ Muito Difícil

O aluno teve dificuldade em perceber o tipo de interação necessária em cada exercício?

1 2 3 4 5

Nenhuma Dificuldade ☐ ☒ ☐ ☐ ☐ Muita Dificuldade

Figure A.1: Questionnaire part one

Qual o nível de facilidade do aluno em aprender a escrever com esta aplicação face à utilização dos materiais tradicionais?

1 2 3 4 5

Mais Fácil ☐ ☒ ☐ ☐ ☐ Mais Difícil

Achou que o aluno prestava mais atenção ao que era ensinado com esta aplicação face à utilização dos materiais tradicionais?

1 2 3 4 5

Mais Atenção ☐ ☒ ☐ ☐ ☐ Menos Atenção

As prompts utilizadas eram suficientes?

1 2 3 4 5

Muito Suficientes ☐ ☒ ☐ ☐ ☐ Nada Suficientes

Os reforços utilizados eram suficientes?

1 2 3 4 5

Muito Suficientes ☐ ☐ ☐ ☒ ☐ Nada Suficientes

Quão relevante foi o uso de reforço visual?

1 2 3 4 5

Muito Relevante ☒ ☐ ☐ ☐ ☐ Nada Relevante

Quão relevante foi o uso de reforço sonoro?

1 2 3 4 5

Muito Relevante ☐ ☒ ☐ ☐ ☐ Nada Relevante

Figure A.2: Questionnaire part two

Quão relevante foi o uso de reforço sonoro?

1 2 3 4 5

Muito Relevante ☐ ☒ ☐ ☐ ☐ Nada Relevante

Acha que o nível de customização permite adaptar a aplicação às necessidades de diferentes crianças?

1 2 3 4 5

Muito Adaptável ☒ ☐ ☐ ☐ ☐ Nada Adaptável

Acha que esta aplicação poderia ser utilizada profissionalmente como veículo de ensino?

1 2 3 4 5

Certamente ☒ ☐ ☐ ☐ ☐ Nunca

Achou a aplicação de fácil utilização enquanto utilizadora?

1 2 3 4 5

Muito Fácil ☒ ☐ ☐ ☐ ☐ Muito Difícil

Achou que a aplicação era melhor do que as disponíveis no mercado?

1 2 3 4 5

Muito Melhor ☐ ☒ ☐ ☐ ☐ Muito Pior

Figure A.3: Questionnaire part three