



## Master Thesis

# **STUDY ON THE IMPACT OF MOBILE GAMES ON CHILDREN WITH COMMUNICATION DIFFICULTIES AND AUTISM.**

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keywords:

autism, Asperger's, communication disorders, mobile application, iOS, iPad, research, emotions, therapeutic, Swift

### short summary:

The goal of the thesis was to design, develop, and investigate the impact of mobile games on children with autism and communication difficulties. The analysis of literature and solutions available on the market were performed. The game was designed, implemented, and described. The research on the obtained product and its influence on children with communication disorders was performed in the facility for children with autism. Results were analyzed and described.

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## **ABSTRACT**

The main goal of this thesis was to design, develop, and investigate the impact of mobile games on children with autism and communication difficulties. The research on the literature and currently available on the market solutions was performed. The requirements and business rules were listed. The technologies and tools were investigated, and the most appropriate were chosen. The target platform was Apple iPad, and were written in Swift 5. The game containing two mini-games - recognizing items and emotions (in various modes) - was designed and implemented. The game offers to present images as illustrations or photos and to play in supervised mode (additional actions like pointing the object, in reality, or acting the chosen emotions are needed). The researches were conducted in the *Krajowe Towarzystwo Autyzmu z Odziałem w Szczecinie* - the facility for children with autism. The results were noted by supervisors in the prepared questionnaire and later analyzed. The game was evaluated, and possible improvements were suggested.

## **STRESZCZENIE**

Celem pracy było zaprojektowanie, implementacja oraz zbadanie wpływu gier mobilnych na dzieci z autyzmem i problemami z komunikacją. Został wykonany przegląd literatury i zbadane aktualnie dostępne na rynku rozwiązania. Została przygotowana lista wymagań i zasad biznesowych. Następnie przeprowadzona została analiza dostępnych technologii jak i narzędzi, i na jej podstawie adekwatne zostały wybrane. Platformą docelową był Apple iPad, natomiast całość została napisana w języku Swift w wersji piątej. Gra zawierająca dwie mini gry – rozpoznawanie przedmiotów i emocji (w różnych trybach) – została zaprojektowana i zaimplementowana. Oferuje ona możliwość wyświetlania obrazków zarówno na ilustracjach jak i zdjęciach, i grę w trybie z opiekunem (wymagane są dodatkowe czynności jak wskazywanie wybranych przedmiotów w rzeczywistości, bądź odtwarzanie zadanych emocji). Badania zostały przeprowadzone w *Krajowym Towarzystwie Autyzmu z Odziałem w Szczecinie* – ośrodku dla dzieci chorych na autyzm. Wyniki zostały zebrane przez opiekunów i umieszczone w przygotowanej wcześniej ankiecie, a następnie przeanalizowane. Gra została oceniona i zostały zaproponowane możliwe usprawnienia.



## CONTENTS

<b>Abstract . . . . .</b>	2
<b>Introduction . . . . .</b>	6
Aim and scope of the work . . . . .	6
Motivation . . . . .	6
Research problems . . . . .	6
Structure of the thesis . . . . .	7
<b>1. State of art . . . . .</b>	8
1.1. What exactly autism is . . . . .	8
1.2. Asperger's syndrome, how does it differ from autism? . . . . .	9
1.3. How does it start? Few words about history. . . . .	9
1.4. Therapies, curing . . . . .	10
1.4.1. Behavioral therapy . . . . .	10
1.4.2. TEACCH Approach . . . . .	11
1.4.3. ESDM . . . . .	11
1.4.4. Other therapy methods [20] . . . . .	11
1.4.5. Methods supporting therapies [20] . . . . .	12
<b>2. Therapeutic mobile applications, existing solutions . . . . .</b>	13
2.1. Autimo . . . . .	13
2.2. TapSpeak Sequence . . . . .	14
2.3. Calm Counter Social Story & Anger Management Tool . . . . .	14
2.4. Social Detective . . . . .	15
2.5. The evaluation of investigated therapeutic applications . . . . .	16
<b>3. Project requirements and rules . . . . .</b>	18
3.1. Business rules . . . . .	18
3.2. Functional requirements . . . . .	18
3.3. Non-functional requirements . . . . .	19
<b>4. Choice of technology . . . . .</b>	20
4.1. Operating systems . . . . .	20
4.2. Mobile applications implementation approaches . . . . .	22
4.2.1. Native application . . . . .	22
4.2.2. Web applications . . . . .	22
4.2.3. Hybrid applications . . . . .	22
4.3. Choice of programming language . . . . .	23
4.3.1. Swift . . . . .	23
4.3.2. Objective-C . . . . .	23

4.3.3. Comparison . . . . .	23
<b>5. Tools . . . . .</b>	<b>25</b>
5.1. Sketch . . . . .	25
5.2. XCode . . . . .	26
5.3. Swift . . . . .	26
5.4. Git . . . . .	27
<b>6. System design . . . . .</b>	<b>28</b>
6.1. Users of the system . . . . .	28
6.2. Designs . . . . .	29
<b>7. Implementation . . . . .</b>	<b>31</b>
7.1. Structure . . . . .	31
7.2. User defaults . . . . .	32
7.3. Items game . . . . .	32
7.4. Emotions game . . . . .	34
7.5. Final game views . . . . .	35
7.6. Game flow map . . . . .	39
<b>8. Research . . . . .</b>	<b>41</b>
8.1. Questionnaire . . . . .	41
8.2. Results of testing the game . . . . .	42
8.3. Reactions to the game . . . . .	45
8.4. Evaluation of the game . . . . .	48
<b>Conclusions . . . . .</b>	<b>50</b>
<b>Bibliography . . . . .</b>	<b>51</b>
<b>List of Figures . . . . .</b>	<b>53</b>
<b>List of listings . . . . .</b>	<b>55</b>
<b>List of Tables . . . . .</b>	<b>56</b>

## INTRODUCTION

### AIM AND SCOPE OF THE WORK

This thesis aims to design and implement a mobile game for children with communication difficulties and autism and study its impact. The main goal of the application will be to try to mitigate symptoms of autism and improve communication with children with investigated disorders.

The idea of this work is to perform observations if designed games make communication with children easier or if they have in any way better social skills. It will also allow parents to check their children's results and statistics – if they are getting better or worse.

### MOTIVATION

One of the most significant contemporary problems is the growth of the number of disorders and diseases among people. Air pollution, consumption of highly processed and preserved food or electromagnetic radiation are just a few factors that affect people's health among the most severe diseases United Nations except cancer, AIDS, and diabetes listed autism. Shocking is the fact that according to CDC studies, the ratio of children with ASD (autism spectral disorder) in the United States is equal to 1 in 59 (*Figure 1*).

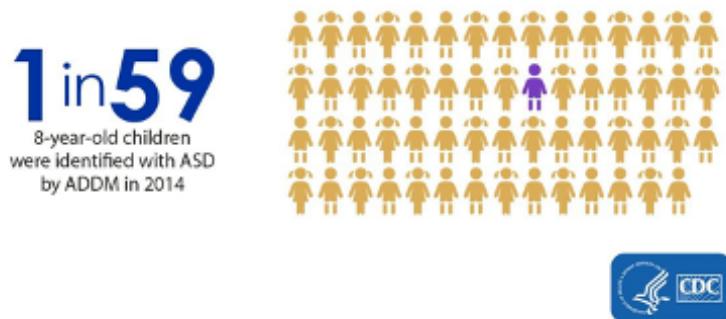


Figure 1. Statistic of children with ASD in United States [5]

### RESEARCH PROBLEMS

To perform a proper investigation, it is essential to research existing solutions that raise similar issues, how they work, what the goals are, and list their strong and weak sides. Besides checking existing applications, an excellent literature review is another essential point. Proper medical research should be enriched by consultations with specialists having

contact with children with autism or with communication problems – for example, by working in centers dealing with such kids.

After conducting theoretical research, designing, and implementing the game, it has to be tested – if it affects children with communication disorders, in which way and how. Tests should be performed in a particular facility under the guidance of experts. The detailed report should be done, including a survey of kid's parents or caregivers. The research will be performed by giving them the tablet and asking to play the game in each mode under the caregiver's eye. The results will be noted and then analyzed.

The critical part of designing a game is to plan features and functionalities carefully. Experts should deeply analyze them. The application target platform will be an iOS mobile system, and implementation will be done in Swift using XCode.

### **STRUCTURE OF THE THESIS**

The thesis script contains nine chapters. In the beginning, the introduction to the problem, presentation of the aim, scope, and motivation of the work were performed. Further, the overview of the market and existing therapeutic solutions, and their evaluations were provided. Later, the script of the thesis contains a listing of the system's rules and requirements, review, and choice of appropriate technology and design. In the last part, the description of implementation and researches was performed. The following thesis is closed by conclusions, bibliography, and lists of tables and figures.

## **1. STATE OF ART**

### **1.1. WHAT EXACTLY AUTISM IS**

First and important about autism is the fact that it is not diseased. Autism is a developmental disorder. Moreover, although it is visible from the early years, it is not a childhood disorder. The good approach to autism is to look at it through time view. Some symptoms develop during adolescence, and some of them disappear. There is no strict description of what exactly autism is. In contrast to diagnosing tonsillitis or pneumonia criteria of diagnosing patients having ASD changed plenty of times, and they still change basically by adding new observations and criteria. However, the main symptoms which can be listed are [6]:

- communication problems
- social disorders
- disorders of behavior, interests, and activities

Communication problems are not always connected with language. When a child reaches 3rd year and still does not speak or understand other people, of course, it concerns. However, children with ASD, apart from speech problems, also do not give other signs of communication attempts like gestures, sounds, or even mimics. That is the main difference between children with hearing difficulties and children with autism. Even if such a child learns the language, communication is still difficult. People with ASD often repeat sounds or sentences, but they do not build them on their own.

Social disorders are easier to identify when a child is about a second or third-year-old. In the beginning, lack of reaction to parents can be concerning - autism children often do not like hugging or another physical contact. They also do not like to play with other people. Social disorders can be more natural to observe when the child goes to kindergarten or during other contacts with peers or siblings. Autistic people usually do not care about people's existence, but they are close to their surroundings. They have good relations with objects, but with other people, it is different. For example, a child can play with toy dinosaurs, but when other people want to play with them, they are ignored.

The third symptom is about the specific behavior of autism people. Often behaviors like swaying or waving occur. They often need a particular routine, and it can be so strong that in case of disturbance whole routine has to be repeated from the beginning. ASD children can overreact or even be aggressive because they do not understand what is happening. Such behaviors are normal for infants, but when they do not disappear for older children, it can be connected with autism. Also, ASD children have very narrow interests or hobbies. They can be interested in for example planes, dinosaurs, or Lego blocks - and that would

be the only that they are interested in. They also want to know everything about their hobby. Another problem that often occurs is overreacting for sounds, light, or motion. It can happen when the child will cry, shout, and be aggressive hearing the mobile phone ringtone and be neutral for intercom or car horn.

The other symptoms of autism can be feeling comfortable in isolation, the need for stability (autism people do not like changes), and some savant skills [27]. There are special "genius" abilities that occur among about 10% people with autism. They appear in light or medium cases and on the average level of intelligence. These rare abilities can be divided into five groups [4]:

- Memory - they refer to mechanical memory, allows people to remember books, timetables, dictionaries, actors or addresses -
- Language - allows people to learn a few languages without trying to do it, or showing it to the surroundings
- Arithmetic - ability to perform rapid calculations by heart, also involving highly complicated problems
- Plastics - astonishing painting, drawing talents
- Music - referring to musical memory, remarkable musical hearing, and composing skills

## **1.2. ASPERGER'S SYNDROME, HOW DOES IT DIFFER FROM AUTISM?**

The most visible difference between Asperger's and autism is that patients with Asperger syndrome do not have problems with developing speech and mind processes [2]. Asperger's are much more often than autism, but it is more difficult to diagnose it. People with Asperger syndrome do not have visible physical symptoms that can be recognized at different ages but mostly at age 8-11 [12]. Asperger diagnosed during early school years can have the following symptoms:

- The child realizes that it is difficult to communicate with their peers. They do not have such problems with relations with family. Also, people suffering from Asperger's can have different interests, hobbies than others and do not want to take part in their activities
- A child can have difficulties withholding on their emotions
- Teachers can observe some problems with their ability to find in certain social situations
- Very strict and narrow interests can also be observed

## **1.3. HOW DOES IT START? FEW WORDS ABOUT HISTORY.**

The whole autism story started in 1943 when American-Austrian psychiatrist - Leo Kanner - published research on the behavior of eleven children aged from 2 to 8 years

[21]. He observed among his pupil's problems with contacts and living in society, good memory, repeating sounds and gestures, routine behavior, and overreacting. Kanner wrote: "*Since 1938, there have come to our attention several children whose condition differs so markedly and uniquely from anything reported so far, that each case merits - and, I hope will eventually receive a detailed consideration of its fascinating peculiarities*"[11]. A year later, in 1944, Hans Asperger - also an Austrian psychiatrist - also published work describing children with similar symptoms as Kanner. Asperger described children with strange speech, perfect memory, strange hobbies, and problems with coexisting with other people. What is interesting, both of them used the same word to describe their pupils - *autistic*. Even many years after publishing Kanner's and Asperger's work, there were many difficulties with diagnosing people suffering from considered disorders. A lot of new studies were conducted on a massive increase in the occurrence of children with such symptoms.

#### **1.4. THERAPIES, CURING**

The first important thing about helping children with autism spectrum disorders is that they are not diseases but disorders, so we cannot speak about curing but about therapy.

There are no strict rules on how to conduct treatment. Each person with ASD is different, suffer from different symptoms, so therapy has to be planned and performed individually, and tailored to an individual patient's needs.

##### **1.4.1. Behavioral therapy**

One of the most important therapies in treating autism is behavioral therapy. This term is used to name some different actions aimed at educating that some behaviors or actions are not accepted in society and teach some new proper's one. Behavioral trainers have an approach that most of the abilities are the result of learning. Among people with developmental disorders, the process of learning works differently than for other people. Behavioral therapy is all about behaviors. However, the behavior is not only interacting with people, manipulating objects, or producing sounds. It is also how to communicate, use gestures, mimics, or words. Also, thoughts and emotions are considered as behaviors [17].

Behavioral therapy can be used in curing different phobias, which makes healthy existence problematic. An example of behavioral therapy can be changing the place of food that should not be eaten by the child.

When autism and other developmental disorders are concerned with applied behavior analysis of patient can be used. It is the field of study based on a philosophy that claims that the human body learns regularities occurring in the surroundings. ABA treats humans

as capable of changes and interacting with the environment. This conviction is essential to behavioral therapy for development disordered people.

#### **1.4.2. TEACCH Approach**

TEACCH (Treatment and Education of Autistic and Communication related disabled Children) is a program of education and therapy for autistic and communication disordered children [26]. The program was started in 1966 in the United States in North Carolina by doctor Eric Schopler and doctor Robert Reicher. In 1980 TEACCH was announced as the most successful state program for ASD children in the USA.

According to the following approach, the first step is to evaluate a child's level of development, psycho-educational profile, and its weak and strong sides [16]. Based on observations, the teaching strategy is prepared, which is supposed to short and long distanced aims of study by performing various exercises during individual therapies [34]. They have to be monitored by specialists who analyze progress and adjust therapy to many factors like unwanted behaviors, motor coordination, or communication. These therapies are conducted by parents.

Apart from therapy for children, there is also a psycho-educational profile for teenagers, which determines the essential life-needed skills necessary to exist in society in adult life autonomously.

#### **1.4.3. ESDM**

The ESDM (Early Start Denver Model) is one best prospecting method of therapy for autism children. [22] It is a method of first use created for children from 12 months to 5 years. It was created by two psychologists dr. Sally Rogers and dr Geraldine Dawson. It was created as a result of research on the growth of children with autism, properly developing children, and learning mechanisms. Therapy is prepared by the certified trainer and is individual for each child. It consists of 25 hours of training a week - conducted by specialists in the clinic or specially instructed parents at home. During therapy, there are used techniques that affect all disordered by autism fields - particularly the ones affecting social behaviors and communication. The progress of therapy is tracked, and modifications are made when needed. Parents are essential in the whole process. They are informed about every change, and their input is essential to help children use abilities learned in clinics, in real life. In 2009 it was proved that children after ESDM get higher results on language and intelligence tests, and autism symptoms become lighter.

#### **1.4.4. Other therapy methods [20]**

- RDI
- Son-Rise Method
- DIR/Floortime Model

— 3i Method

**1.4.5. Methods supporting therapies [20]**

- Veronica Sherborn Method
- Thomatis Method
- Dogotherapy
- Hippotherapy
- Biofeedback
- Knills Method
- Musicteraphy
- Sensory Integration
- P. Denninson Brain Gymnastic
- Alternative Communication AAC
- Affolter Method
- Simultaneous-Sequential Method

## 2. THERAPEUTIC MOBILE APPLICATIONS, EXISTING SOLUTIONS

In the medical area, mobile applications create various possibilities of creating and using innovative modern tools and ways of treatment. They can also be used to help with learning, communicating, and socializing among people with autism spectrum disorders [10]. There are several huge advantages for this approach:

- The touch interface is easy to use, fast, intuitive and interesting
- Graphical interface and sounds can be used as more attractive than the traditional way of learning
- Swipe and Tap gestures are easy and do not need a lot of thinking and efforts as drawing with a pen or using a computer mouse; they are also highly intuitive
- Data used in applications can be easily modified, enhanced or changed (for example adding new levels to the game)
- Faster and easier than creating and physical propagation solutions like memory games

### 2.1. AUTIMO

*Autimo* (Figure 2.1) [3] is a game that helps children with autism with understanding mimics and emotions. The game is divided into three mini-games - find the difference game, matching pairs and guessing game.

The application aims to help people with ASD recognize mimics, facial expressions, and reading body language. It is adapted for people of all ages with development disorders, with the help of special-need experts.

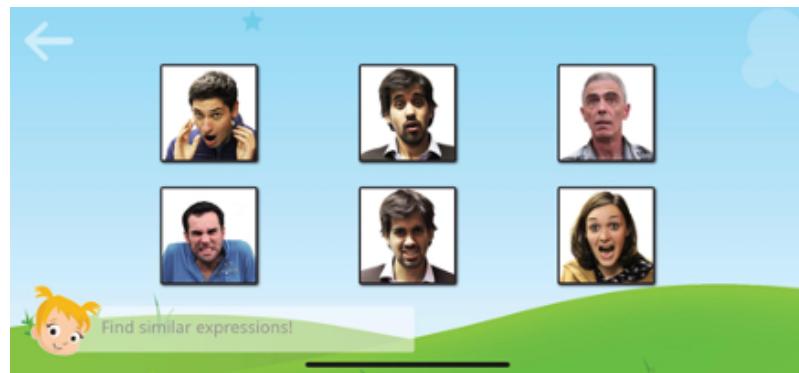


Figure 2.1. Example screenshot of Autimo [3]

The application consists of the free content - facial expressions matching-pairs game - and the rest of the content requires buying a subscription. It is available in English and French.

## 2.2. TAPSPEAK SEQUENCE

*TapSpeak Sequence* (Figure 2.2) [25] is a mobile application designed to help disabled children to learn to communicate. Application is designed for children with autism, cerebral palsy, CVI, or other problems that affect communication impairments. The game allows the user to touch or tap a series of images to play a sequence of messages. An example of usage is creating the sentence of a few images arranged in such a way that they make a sentence - exemplary image of the hand can mean I want. Taps in the application can be configured to require users to move fingers in a specific place in a specific time or take them off the screen. When the sequence is finished, then application returns to the first message in it.

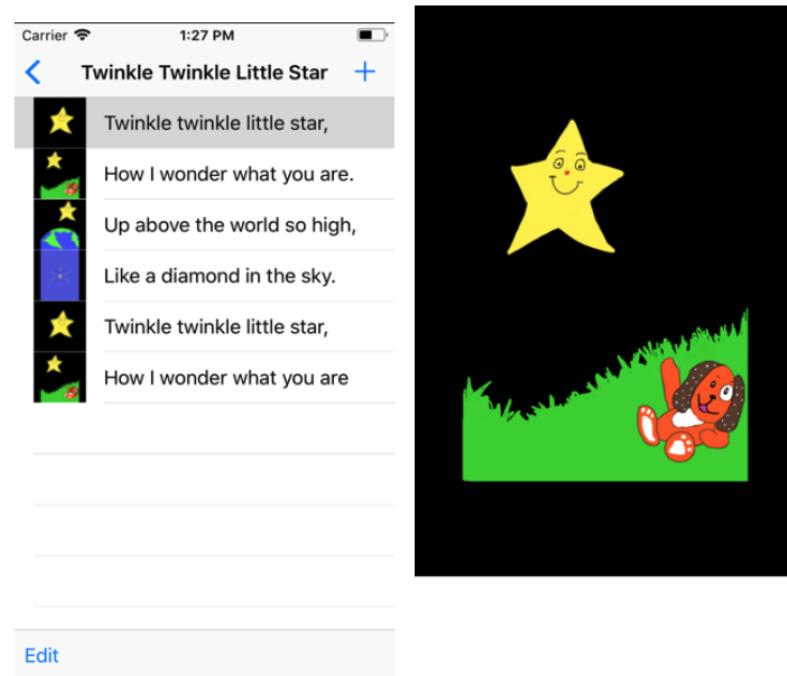


Figure 2.2. Example screenshot of TapSpeak Sequence [25]

*TapSpeak Sequence* allows creating an unlimited number of sequences with infinite length. It also contains a library with multiple colors, geometric shapes, and also different drawings and images that can be used as icons.

## 2.3. CALM COUNTER SOCIAL STORY & ANGER MANAGEMENT TOOL

*Calm Counter* [28] is a bit different game from previous ones. It can be used to help with calming people down when they are angry. It includes audio-visual tools for calming down and also social stories about anger.

When the application is launched, the screen turns red, and an angry face with number ten appears. When the screen is tapped, then the number decreases, the face becomes

calmer, and color changes to more pleasant (*Figure 2.3*). The application also offers telling stories about feeling angry containing calming exercises like counting to ten or taking deep breaths.

The application allows the changing voice of the person who counts to ten or reads the story.

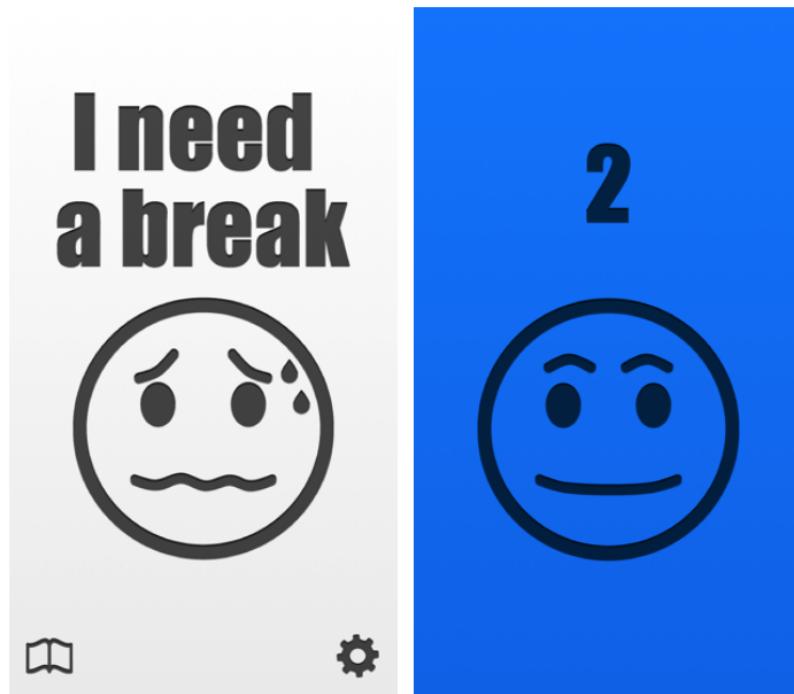


Figure 2.3. Example screenshot of Calm Counter Social Story & Anger Management Tool [28]

#### 2.4. SOCIAL DETECTIVE

*Social Detective* [23] is a game that teaches kids about expected and unexpected behaviors that can happen in everyday life. It helps children with using their eyes, brain, and ears to make investigations based on the found clues to solve the puzzles on how to behave in a particular situation, how others' emotions look like and how are they reacting to different situations (*Figure 2.4*). Game is based on You Are a Social Detective! The book was written by Michelle Winner and Pamela Crooke.



Figure 2.4. Example screenshot of Social Detective [23]

*Social Detective* lets children at the start to choose their avatar and then to collect some detective tools as the result of progressing in improving their social skills. Teachers or parents can track progress by sending emails with charts and percentage scores of completed levels. The game includes videos with real kids and practical tips, which can help apply learned skills and behaviors.

## 2.5. THE EVALUATION OF INVESTIGATED THERAPEUTIC APPLICATIONS

After analyzing the number of therapeutic mobile games, the evaluation of them was performed. It could be highly valued for as developers as users - developers would know what such software should contain, and users is it worth using and helpful for the patients [14]. The experts prepared the various lists of criteria that should be satisfied to make the application valuable. Part of example one is presented below (*Figure 2.5*).

Mobile apps	Work offline	Accessibility	Communication	Social skills	Math Skills	Functional skills	Languages	Organizer	Entertainment	Educational	Medical care	Use media like video, audio, images
A BuZoo Story	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	No	Yes
AAC Autism Talk Now	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	Yes
Aacorn AAC	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AraBoard	No	No	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes
Aut2Speak	Yes	No	Yes	No	No	No	Yes	No	No	No	No	No
Autism iHelp – Play	Yes	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes	Yes
Autism Language and Cognitive Therapy with MITA	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	No	Yes
Avatalker AAC	Yes	No	Yes	Yes	No	No	Yes	No	No	No	No	Yes

Figure 2.5. Example evaluation table [14]

The evaluation of investigated games is presented in the *Table 2.1*

Table 2.1. Evaluation table of investigated mobile games

	Autimo	TapSpeak Seq	Calm Counter	Social Detective
Work offline	yes	yes	yes	yes
Accessibility	yes	yes	yes	yes
Communication	yes	yes	no	yes
Social skills	yes	no	no	yes
Math Skills	no	no	no	no
Functional skills	yes	yes	no	yes
Languages	yes	yes	no	no
Organizer	no	no	no	no
Entertainment	yes	yes	yes	yes
Educational	yes	yes	no	yes
Media care	no	no	no	no
Use media	yes	yes	yes	yes
Paid	no	yes	yes	yes

The scores obtained by evaluating applications are following:

- Autimo - 76%
- TapSpeak Sequence - 62%
- Calm Counter - 31%
- Social Detective - 62%

The most valuable game for the users is *Autimo*. It has many useful features, which could be used in the application that is being implemented while performing the following thesis. The game with recognizing emotions and facial expressions could be highly useful for children with autism and communication disorders. Other investigated applications also contain valuable content like presenting emotions on illustrations or tracking the player's progress.

### **3. PROJECT REQUIREMENTS AND RULES**

The first and essential part of creating software is preparing the list requirements, functionalities, and business rules that applications should contain. This part of the developing project should not be very technical but should allow preparing user stories, flow charts, and designs of all parts of the application.

The first step of designing the game for children with autism was listing business rules and both functional as non-functional requirements of the system.

#### **3.1. BUSINESS RULES**

- The game contains two modes defining the type of presented images - drawings or photos. In the first option, all items and emotions occurring in the game are presented on the drawings, and in the second they are presented on the photos.
- The game contains two modes determining if children are playing with the supervisor or without. The nonsupervised mode allows the player to choose between four images, and after the correct answer, the system rewards the player with the point. The supervised mode additionally requires from the player, after choosing the correct answer, to recognize and indicate the original item (from items located near the player) or to show selected emotion. If it is done correctly, then the supervisor should accept the answer and system rewards player with the point.
- Settings of the game contain the possibility to change the maximum number of points. It defines the total amount of points that players can earn - for example if 10 points are selected, the player can recognize ten different items or emotions.
- There is no possibility of losing in the game. Even if the final score of correct answers equals to 0, still the winning screen appears.
- Scoreboard of the game displays the last results with date, time, and score, sorted from the newest result.

#### **3.2. FUNCTIONAL REQUIREMENTS**

- The system shall allow the user to play one of two mini-games - emotions and items.
- The system shall allow the user to change the maximum number of points.
- The system shall allow the user to change game mode between images and photos.
- The system shall allow the user to change game mode between supervised and unsupervised.
- In supervised mode, the supervisor can accept or reject the answer of the player.

- The system shall allow the user to check the Scoreboard containing the latest scores.

### **3.3. NON-FUNCTIONAL REQUIREMENTS**

- The game should run only on iPads.
- The game should work on iOS or iPadOS with version 12 or higher.
- The game should be intuitive and easy for children with autism.
- The design of the game should be prepared for children with autism and communication disorders.
- The game should not contain dynamic animations or blink.
- The game should not accumulate vivid colors or annoying sounds.
- The main color of the game should be pleasant for children with autism - green.

## 4. CHOICE OF TECHNOLOGY

Nowadays, one of the most growing segments in the technology are mobile devices and mobile applications segments. In 2018 the mobile application market was priced to about 106 billion dollars. It was estimated to reach over 400 billions until year 2026 (*Figure 4.1*) [18].

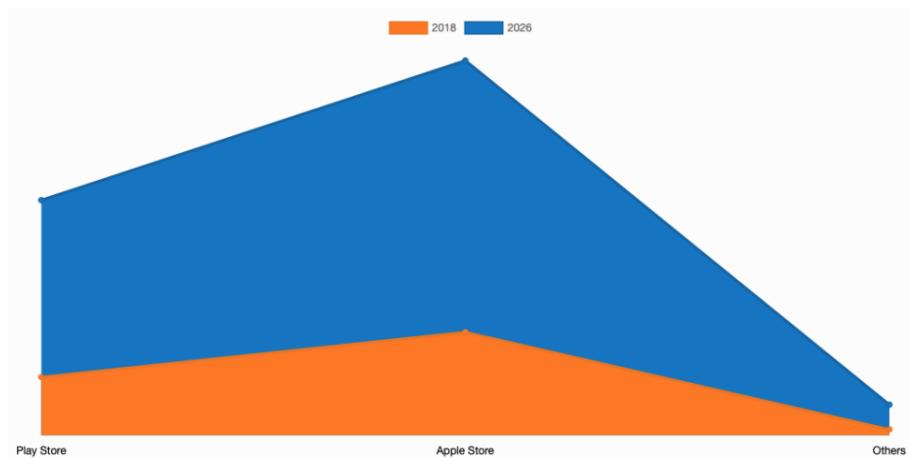


Figure 4.1. Increase of mobile applications market [18]

One of the main reasons for the constant growth of mobile devices' popularity is that they are small, handy, and comfortable to use and carry everywhere. Furthermore, people use them to perform various activities - starting from working, traveling, learning, playing games, and watching movies, ending on photographing and social networking. The following facts claiming that mobile devices are nowadays widely used in each field of life are the primary reason why solutions developing in the following thesis will be a mobile application.

Another reason for choosing a mobile game is that such solutions can be easier for parents than in physical games. They offer more than standard ones - animations, sounds, or videos. Mobile games also offer in a natural way extending content by adding more levels or more features.

### 4.1. OPERATING SYSTEMS

In the mobile devices industry, there exist two counting operating systems - *Android* and *iOS*. There are, of course, some other ones like *KaiOS* or *Windows*, but they are used by a low percentage of users (less than 1%), so providing an application for them will not be profitable enough (*Figure 4.2*).

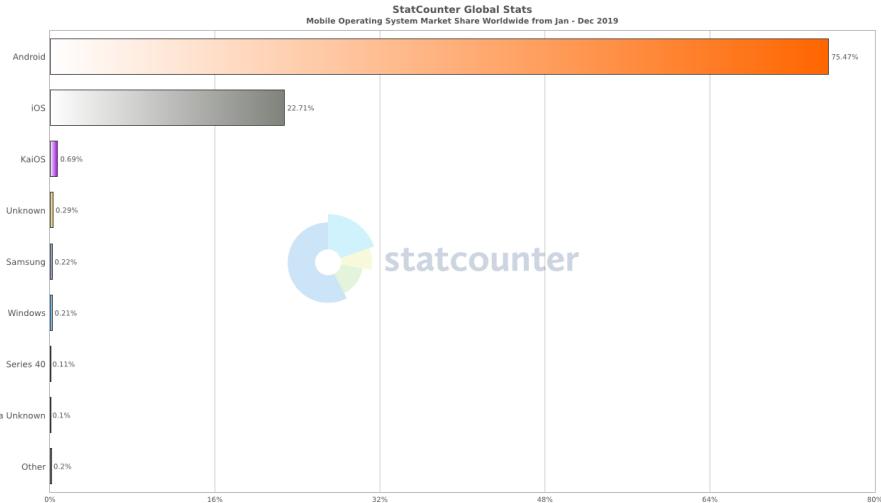


Figure 4.2. Mobile platform market share [7]

**Android** - the most popular open-source operating system (based on Linux kernel) developed by Google for mobile devices such as smartphones, tablets, smartwatches, or computers. *Android* was firstly released in 2008 with HTC Dream. Currently, the newest available version is *Android 10*. *Android* comes with Google applications such as a virtual market with applications - Google Play [29].

**iOS** - the second most popular mobile operating system, designed and developed by Apple Inc (initially known as iPhone IO). The operating system is based on the Darwin kernel and can be used only on Apple devices such as iPhones, iPads, and iPods Touch. It was released in 2007 along with the first iPhone [30]. On the contrary of *Android*, the whole *iOS* environment is closed for users what means that there is no possibility to install third-party applications - the only way is to purchase them from the Apple applications market - AppStore. At the moment of its release, there were no plans to allow users to use not native applications. However, after the rapid explosion of iPhone popularity, planes changed, and Apple offered the developers tools and resources to create applications, including their programming language - Swift [24].

This thesis aims to design a mobile game for children with communication difficulties and autism. The easiest way to provide it to children is by creating an application for tablets. Tablets have much bigger screens than smartphones, which will allow us to use bigger images and design bigger and easier to use by children with different disorders interface. Another advantage of making tablets the target platform is that many facilities for children with disorders already have tablets used for different therapies (also facility where research will be performed).

The tablet market tends differently than the smartphone market. Over 60% currently used devices are Apple iPads [8]. Besides popularity, another advantage for iPads is that

Apple places great emphasis on the healthcare sector and offers plenty of applications and support connected with it.

Following arguments advocate to design and implement mobile games for tablets, more specifically for iPads.

## **4.2. MOBILE APPLICATIONS IMPLEMENTATION APPROACHES**

There are plenty of different approaches to implementing mobile applications. The most popular way is implementing the application as a native, web, or hybrid. Each approach has certain advantages, and each one should be considered in the system designing part [19].

### **4.2.1. Native application**

A native application is a program that is launched directly on the mobile device. The implementation is provided for one particular platform. It allows reaching all functionalities of the devices - physical resources (various sensors, speakers, and microphones or device processing power) and software resources (gestures, notifications, various accounts, contacts). Native applications are also the fastest from the web or hybrid ones; however, they require developer knowledge about the target device. Often, if the application is designed for several platforms, there are needed a few teams that cause much higher costs. iOS native applications are implemented in Swift or Objective-C and *Android* ones in Java.

### **4.2.2. Web applications**

Web applications are applications that are not installed on the local device. They can be accessed through an internet browser and are mostly written by the usage of HTML, JavaScript, and CSS. Building such applications is much easier than native ones. It requires fewer efforts and costs and allows using the same code (after small changes) in desktop and mobile versions of the application. However, there are some limitations. They can use only resources granted by the internet browser and own server resources (but they have to be split among users). Web applications do not have access to devise sensors (only to basic ones), resources, or too advanced gestures. They also require an internet connection to load and work.

### **4.2.3. Hybrid applications**

Hybrid applications, as the name states, are hybrid between native and web applications. They are often also written in HTML (as web applications), but instead of working in a system browser, they are being presented in a browser built-in the application. They are faster than web applications and allow access to more device resources, but still, the amount is limited. This approach allows the developer to use the same code for multiple platforms

with small changes that decrease implementation costs.

Each approach offers several unique features which can be desirable in an implemented application. After performing analysis, the decision was made to use the native approach in the mobile game for children with communication disorders. Such a game needs to be highly responsive, contain animations, sounds, and other visual effects. Also, some device resources like a camera or motion sensor can be useful.

### **4.3. CHOICE OF PROGRAMMING LANGUAGE**

If native application implementation for the iOS system is concerned there are the Choice exists basically between two languages - *Swift* and *Objective-C*.

#### **4.3.1. Swift**

Swift is one of the modern compiled programming languages announced by Apple during WWDC conference in 2014 as a successor of Objective-C [32]. It allows implementing applications for iOS, macOS, watchOS, or Linux. It contains features like extensions, protocols, or optionals. It provides simple, clean, and easy to understand syntax without semi-colons. Swift is a very safe and quick language optimizing memory, keeping its usage minimal or preventing variables from being nulls. Swift supports Objective-C syntax, so using parts of already written applications in Objective-C would not be a challenge.

#### **4.3.2. Objective-C**

Objective-C is an object-oriented language introduced in 1984 by Brad Cox and Tom Love. For many years it was the primary language used to implement applications for both iOS and macOS. It was created basing on C language extended by adding Smalltalk messages. The fact that is inherited from C allows compiling any of the C code using Objective-C [31].

#### **4.3.3. Comparison**

Both considered languages have many benefits. Objective-C has huge documentation and tones of frameworks because it exists for over 30 years. It is also highly compatible with C or C++. The downside is the fact that it is a bit complicated (because of being the merge of C and Smalltalk), and it is not easy to learn it or understand the code. Swift, on the contrary, is the new language. It supports many features of modern languages, is also easy to understand or learn. Additionally, Swift has automatically managed memory. Another advantage is the fact that it has Apple's support and recommendation and is continuously being developed. The downsides can be gaps in documentation (*Figure 4.3*).

## Swift VS Objective-C

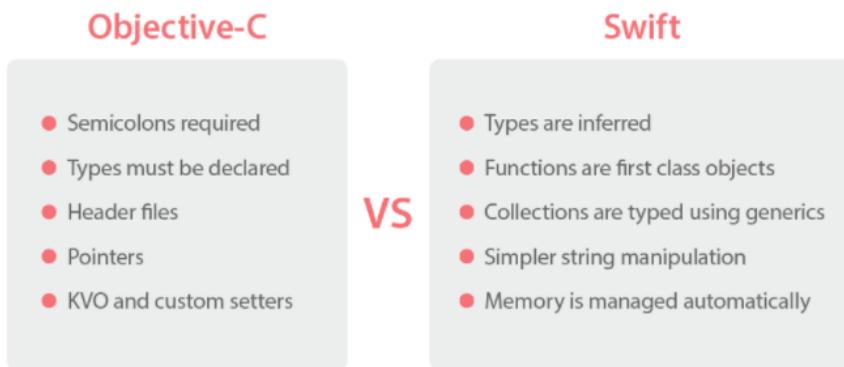


Figure 4.3. Objective C vs. Swift [9]

After conducting the pros and cons of each language, Swift was chosen as the primary implementation language. However, Objective-C code is fully compatible with it and, if the needed application can use some frameworks developed in Objective-C.

## 5. TOOLS

A mobile game developed to help children with autism and communication disorders was built in few stages using various tools and technologies. Designs were prepared in Sketch, and implementation was performed in Swift using XCode. Moreover, Git with Github servers was used as a version control system.

### 5.1. SKETCH

The first impression is one of the predominant aspects when considering if install the game or application. Therefore preparing encouraging, eye-catching designs is an essential part of developing the application.

The part of this thesis was developing a game for children with autism. It is highly important to prepare an interesting, colorful design for such an audience because it is straightforward to lose its focus. Also, it is important to keep everything simple and easy to understand. Perfect tool to prepare such designs and prototypes is Sketch (*Figure 5.1*).

Sketch is a tool designed to prepare vector graphics and interfaces of web pages, desktop, and mobile applications or icons. It was published in 2010 by Bohemian Coding. Target platform of Sketch are computers produced by Apple with macOS on board.



Figure 5.1. Example mock up created using Sketch

## 5.2. XCODE

The core part of preparing mobile game was implementation. It was performed in XCode - IDE (integrated development environment) provided by Apple Inc [33]. It is a free tool designed to create applications and other software for Apple operating systems such as iOS, macOS, or watchOS. It allows editing, building, and debugging software written in various technologies.

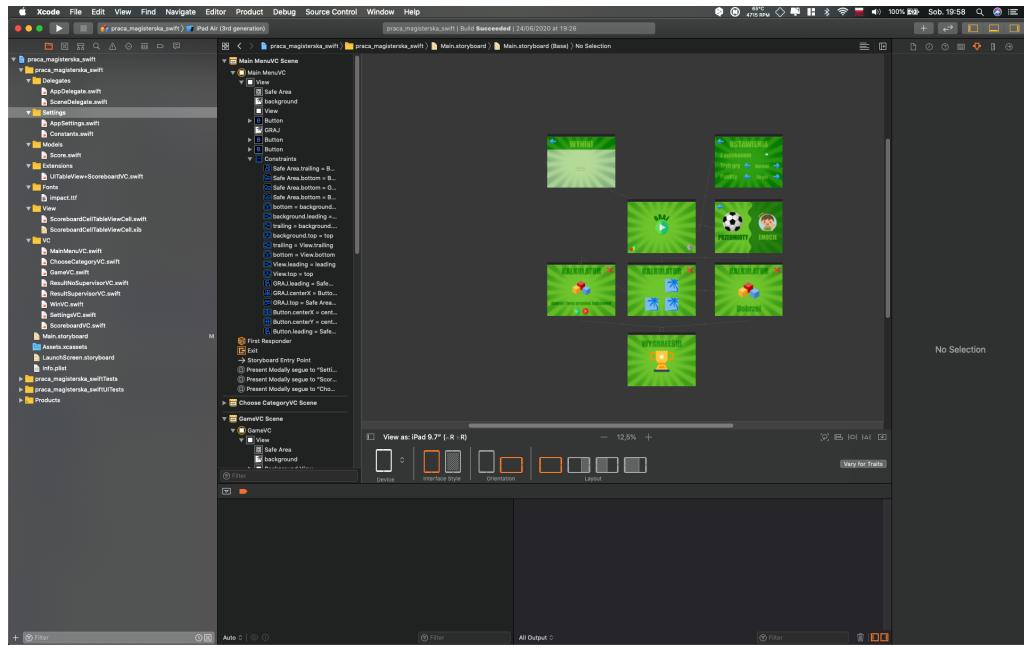


Figure 5.2. XCode interface builder

XCode allows implementing applications in many languages such as Swift, C, C++, Objective C, and Java. Its most crucial components are:

- Source editor - allows writing code, highlighting errors and suggesting solutions or fixes
- Interface builder - the editor, used to create the front-end part of applications by dragging, dropping and moving components (*Figure 5.2*)
- Simulator - tool emulates all supported devices produced by Apple, starting from iPhone, ending on Apple TV, allowing developers to test their solutions on all possible resources, not owning their physical versions.

## 5.3. SWIFT

Swift is a programming language created by Apple in 2014 as a successor of Objective-C. It is mainly used to develop software for iOS, macOS, watchOS, and tvOS. It is a powerful modern programming language with simple, easy to read, and understand syntax. It is

currently used by a lot of well-known companies like Mozilla or LinkedIn [15]. It supports inferred types, international languages, emojis support, options, generics, the possibility of returning different types and tuples, or functional programming [1]. Swift also provides such speed and performance that it is being used in machine learning - according to Apple, it is 8.4 times faster than Python [13].

#### **5.4. GIT**

Git is a version control system allowing to save and synchronize changes in projects across collaborating users. It also allows merging changes provided by several developers automatically. Additionally, Git provides the possibility to go back to older versions of the project (for example, in case of some bugs) and develop different code versions on various branches. Game for children with communication disorders uses GitHub servers to keep files.

## 6. SYSTEM DESIGN

The first step of designing the system was to list all requirements and functionalities of the game. Forthcoming everything should be visualized on the use case charts to help determine what and how should work and be implemented. An essential part of system designing is preparing mockups and prototypes of the system to tell developers how exactly everything should look like.

### 6.1. USERS OF THE SYSTEM

The game for children with autism and communication disorders will have two actors - first is the player, and the second one is the supervisor. The player's task is to play the game and supervisors to adjust the kid's setting, change game modes, or check results. Of course, the player also can do all tasks of the supervisor, and conversely - the roles are contractual. All tasks of actors are presented on the use case diagram below (*Figure 6.1*).

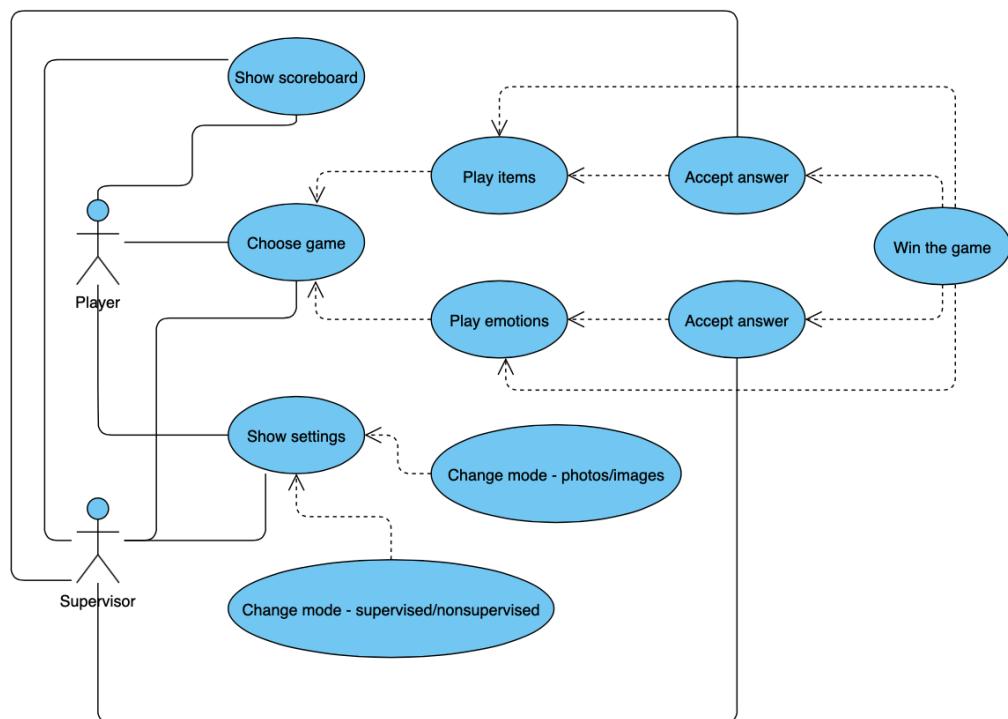


Figure 6.1. Player and Supervisor use case diagram

## 6.2. DESIGNS

Last but not least, part of designing the system was preparing mockups of the game. All designs were prepared in Sketch and modified number of times during the implementation process, to follow some issues that occurred while creating and testing the game. All mock-ups are presented in figures below (*Figure 6.2 - Figure 6.7*).

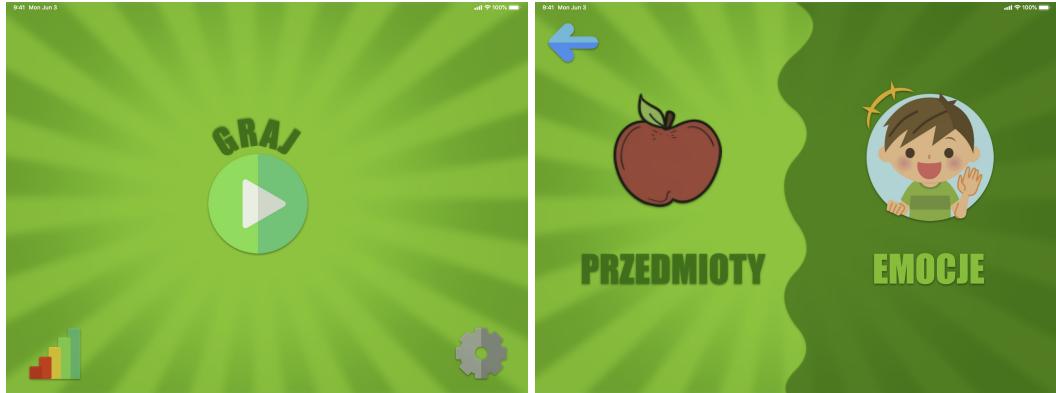


Figure 6.2. Main menu and choose game screens

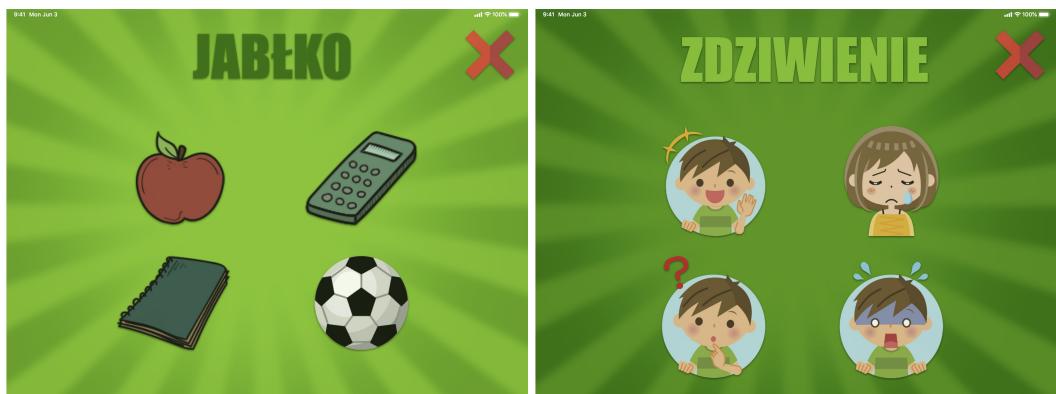


Figure 6.3. Items and emotions games screens

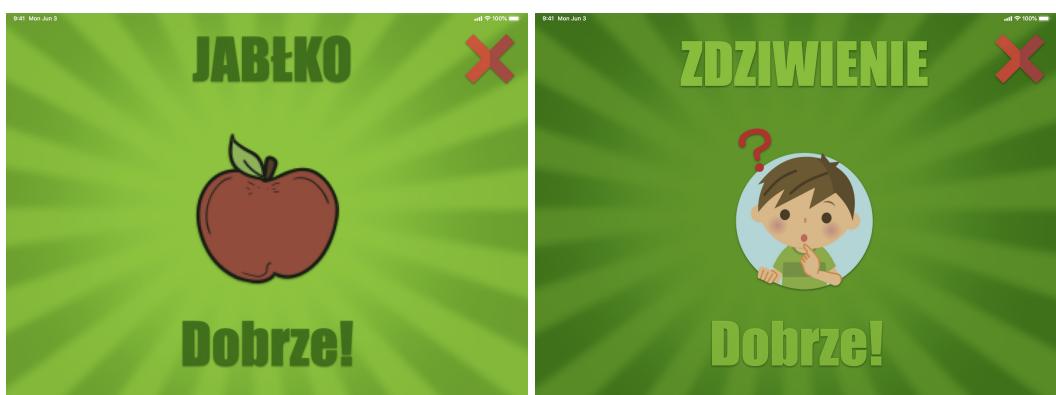


Figure 6.4. Items and emotions correct answer



Figure 6.5. Items and emotions correct answer in supervised mode



Figure 6.6. Items and emotions incorrect answer



Figure 6.7. Settings and scoreboard screens

## 7. IMPLEMENTATION

The nearly last but crucial part of the development process, after listing requirements, planning the functionalities, and preparing designs is the implementation process.

### 7.1. STRUCTURE

Game for children with autism and communication disorders contains seven ViewControllers (views of the game), the number of classes, delegates, and several assets like images and photos of items or emotions. The exact structure of the project is presented below (*Figure 7.1*).

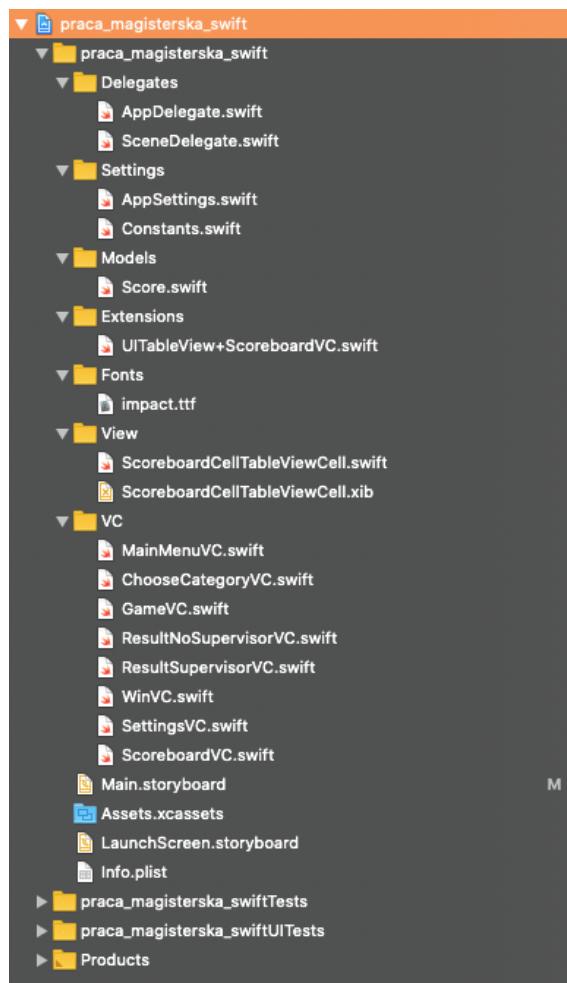


Figure 7.1. Structure of the project

The core front-end part of the application was done in the Storyboard using Interface Builder, but the more in-depth configuration of elements or some placements were set in the code.

## 7.2. USER DEFAULTS

The user scoreboard and settings of the game should be remembered by application in case of, for example, quitting the game. This problem was solved using *user defaults*. User defaults are a build-in application dictionary storing a small amount of data in different types, which is a great solution to use in saving user settings. The content is being deleted when the application is uninstalled. The structure of saved data is presented below (*Listing 7.1*):

```
[  
    "MaxPoints": Int,  
    "GameMode": GameMode.Images,  
    "GameSupervisedMode": GameSupervisedMode.Supervised,  
    "ScoreBoard": {  
        [  
            "Date": Date,  
            "Score": Int  
        ]  
    }  
]
```

Listing 7.1: User defaults structure

## 7.3. ITEMS GAME

The whole game is split into two smaller games with similar rules. The first game - items - shows four items to the player and the big label with the name of one item beyond (*Figure 7.2*). The child has to choose the correct item. In the unsupervised mode, the additional action is needed to get the point - the child has to point the item selected in-game in reality (which should be placed in the room).



Figure 7.2. Items game

The list of items available in game is presented below. The number of them were presented with images and photos (*Table 7.1*) and the rest in the list:

Item	Image	Photo
Ball		
Apple		
Calculator		
Book		
Car		
Pen		

Table 7.1. Items available in game

- Spoon
- Hanger
- Backpack
- Sock
- Shoe
- Eraser
- Ruler
- Rattle
- Block
- Teddy bear
- Pencil case
- Paper page

- Pencil
- Cymbals
- Broom
- Balloon
- Banana
- Cucumber
- Jumping rope
- Key
- Hat
- Paper plane
- Brush

#### 7.4. EMOTIONS GAME

The second game - emotions - displays a label with an emotion name and four pictures with a drawing or a photo of faces showing different emotions (Figure 7.3). The player has to choose the correct one. In supervised mode, it is additionally needed to activate the chosen emotion. If the child performs this correctly, obtains point.



Figure 7.3. Emotions game

The game contains seven different emotions. Each of them is presented in four different photos and four different pictures. The list of emotions with exemplary images is presented below (*Table 7.2*).

Emotion	Image	Photo
Surprise		
Joy		
Sadness		
Fear		
Disgust		
Anger		
Boredom		

Table 7.2. Emotions available in game

## 7.5. FINAL GAME VIEWS

After finishing the implementation process, the screenshots of all views in the application were captured and presented in the following section.

The first screen which is displayed after launching the game is the main menu (*Figure 7.4*). From the menu, users can go to application settings, view the scoreboard, and navigate to the screen with the choice of the game. The choice of the game (*Figure 7.5*) enables user

to choose between items and emotions games. From this screen, there is also the possibility to go back to the main menu by tapping the blue arrow in the top left corner.

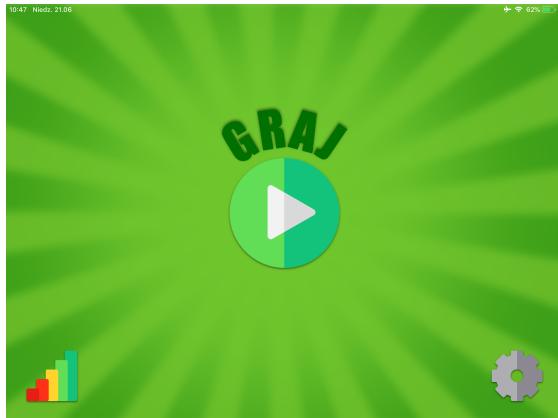


Figure 7.4. Main menu screen



Figure 7.5. Choose game screen

The item game (*Figure 7.6*) presents to the player the screen with the big label with name of the item and four images (pictures or photos - depends on the settings) containing four randomly chosen items (from the *table 7.1*). Additionally, the screen contains the red cross in the top right corner of the screen, which allows the player to go back to the main menu.

If the user chooses the correct answer (in the nonsupervised mode), he is redirected to the screen with information that he chose the right answer (*Figure 7.7*). Additionally, in such a case, the point is added to the total score.



Figure 7.6. Items game screen



Figure 7.7. Correct item screen

In the supervised mode, instead of the immediate information about the correct answer, if the user chooses the right one, he is being redirected to the screen with information that answer is correct, but he additionally has to perform one more task and two buttons - green

with a checkmark, and red with the cross sign (*Figure 7.8*). The player has to recognize items (placed in the room where the player currently is located) in the reality and point or bring it to the supervisor. The supervisor decided if the task was performed correctly, and if yes, he taps the green button; in other cases, he taps the red one. If the green button was clicked, the point is added to the player's score.

If player chooses the incorrect answer (in both modes) he obtains information about the wrong answer (*Figure 7.9*).



Figure 7.8. Correct item - supervised mode

Figure 7.9. Incorrect item screen

The second available game is emotions game. After launching the game screen is presented - the big label with the name of emotion and four images with four different randomly chosen emotions (*Figure 7.10*). The types of images - pictures or photos - depending on the chosen model. From this screen, the player can go back to the main menu by tapping the red cross in the top right corner of the screen. If the answer is correct, the user is redirected to the correct answer screen, and the point is added to his score.

The correct answer screen (*Figure 7.11*) tells user that he chose the right answer. It contains the name of the emotion, image, and information that emotion was recognized correctly.

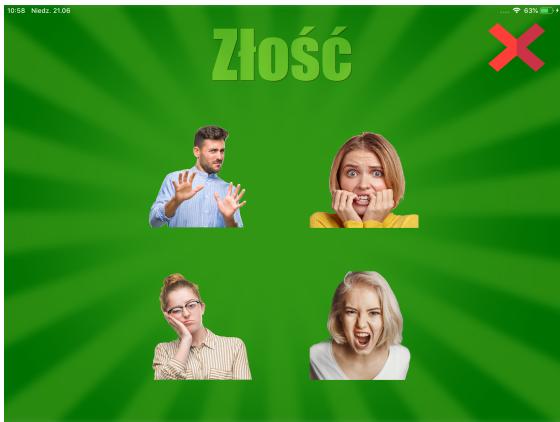


Figure 7.10. Emotions game screen



Figure 7.11. Correct emotion screen

In the supervised mode - alternatively to the items game - after choosing the correct emotion, the player has to perform the additional action. He is redirected to the screen (*Figure 7.12*) with information the next task is to act the emotion - for example, if the chosen emotion was anger, then the child has to show anger on its face. If it is done correctly, then the supervisor should tap the green button with a checkmark - otherwise, the red button.

If user choose the incorrect answer, application presents the screen with information that chosen answer is wrong (*Figure 7.13*).



Figure 7.12. Correct emotion - supervised mode



Figure 7.13. Incorrect emotion screen

If user plays the amount of levels specified in settings (default value is 10 points) then the winning screen is presented (*Figure 7.14*). Even if the player obtains 0 points in the whole game, still the winning screen is shown. This solution was applied to avoid annoying children with autism - information about losing could cause various negative reactions. This view also contains a label with the number of points collected during the game.

The important part of the application is scoreboard (*Figure 7.15*). It allows supervisors to check the progress or results of the last games. It could be highly useful during conducting the therapy.



Figure 7.14. Won game screen

Figure 7.15. Scoreboard screen

The last but not least screen of the application are settings (*Figure 7.16*). This view allows the user to set the configuration of the game. The first option determines if the game would run in supervised mode. The second one (game mode) allows to change between pictures and photos of items or emotions - the pictures are aimed into younger recipients, whereas photos into older ones. The last option determines the number of rounds which player has to play to obtain the winning screen - the default choice is 10.



Figure 7.16. Game settings screen

## 7.6. GAME FLOW MAP

After presenting all screens of the game, the flow map (*Figure 7.17*) was prepared to show the exact flow of the application and what action can be performed from which place of the game. After launching the application, the main screen is presented. From the main

screen, the user can navigate the settings, scoreboard, or game choice. There are three possibilities from the game choice: going back to the main menu, starting items game, and starting emotions games. Item game screen redirects the user to the correct answer screen, the correct answer in supervised mode, or the correct answer screen. From each of them, after playing the specified number of rounds, the user is redirected to the winning game view. Alternative behavior is present in the emotions game.

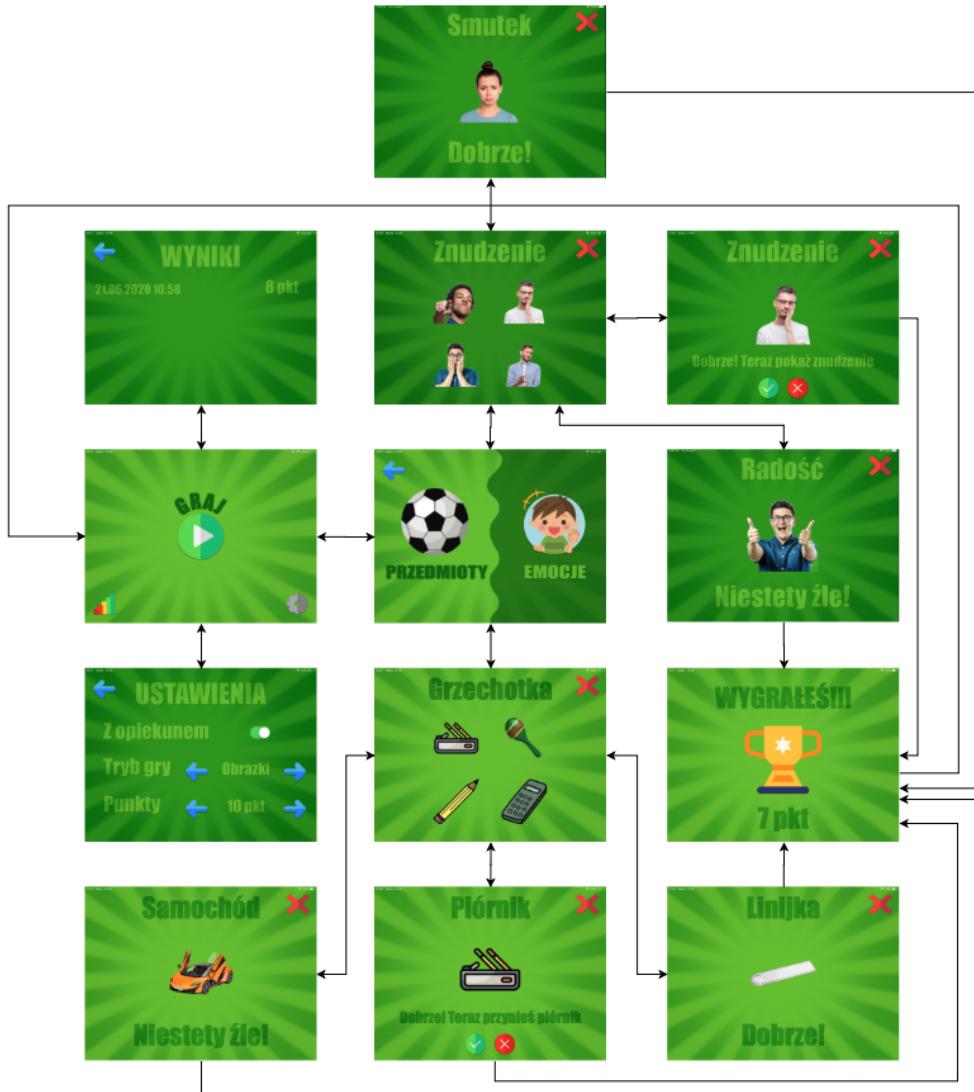


Figure 7.17. Game flow map

## **8. RESEARCH**

After implementing and testing the game, finally, it was ready to be played. All researches were conducted in "Krajowe Towarzystwo Autyzmu z Oddziałem w Szczecinie" - the facility for children with autism. The group of children (the trial group) consisted of ten kids with autism in the early school-age - from six to nine years old. The researches were conducted anonymously.

The first part was handing the tablet (iPad Air 1) to each kid and asking them to perform each of eight planned scenarios (under the eye of supervisor):

- Items game - pictures
- Items game in supervisor mode - pictures
- Items game - photos
- Items game in supervisor mode - photos
- Emotions game - pictures
- Emotions game in supervisor mode - pictures
- Emotions game - photos
- Emotions game in supervisor mode - photos

Scenarios concerning the items in supervised mode needed some additional preparations. The items (*Table 7.1*) were collected and placed on the table in front of the child. After preparations, the researches have begun. Each child was examined alone, with the caregiver. After performing each scenario by the player, the supervisor noted the results of the attempt. After fulfilling all scenarios, saved results were put in the questionnaire.

### **8.1. QUESTIONNAIRE**

The questionnaire was prepared in the cooperation with therapists from the facility. It contains questions about results of each scenario, about reactions to game and also the opinion and comment on the research results of the supervisor. The survey was prepared using Google Forms tool. All questions placed in the questionnaire are listed below:

- Effectiveness in recognizing objects in illustrations - *0 to 10 points*
- Effectiveness in recognizing objects in illustrations and indicating them in reality - *0 to 10 points*
- Effectiveness in recognizing objects in photos - *0 to 10 points*
- Effectiveness in recognizing objects in photos and indicating them in reality - *0 to 10 points*
- Effectiveness in recognizing emotions in illustrations - *0 to 10 points*

- Effectiveness in recognizing emotions in illustrations and acting them - *0 to 10 points*
- Effectiveness in recognizing emotions in photos - *0 to 10 points*
- Effectiveness in recognizing emotions in photos and and acting them - *0 to 10 points*
- Interest in the game - *0 to 5 points*
- Interaction autonomy - *0 to 5 points*
- Positive reaction to the successfully performed action - *0 to 3 points*
- Negative reaction to the incorrectly performed action - *0 to 3 points*
- Own observations, comments

## 8.2. RESULTS OF TESTING THE GAME

The first part of survey were results from the games. The results of this part was presented in tables below - Separately items game (*Table 8.1*) and emotions game (*Table 8.2*) - *S* is used as a shortcut of supervised.

Table 8.1. Results of items game in all modes

	Items	Items S*	Items (Photos)	Items (Photos) S*
Player 1	10	10	10	10
Player 2	10	10	10	10
Player 3	10	10	10	10
Player 4	6	6	7	6
Player 5	9	9	9	9
Player 6	8	8	8	8
Player 7	6	6	6	6
Player 8	6	7	9	8
Player 9	8	8	10	9
Player 10	5	6	6	6

Based on the table with results of item game two charts were prepared. The first one (*Figure 8.5*) presents scores of all players in each mode, and the second one (*Figure 8.2*) is about the average score in each mode.

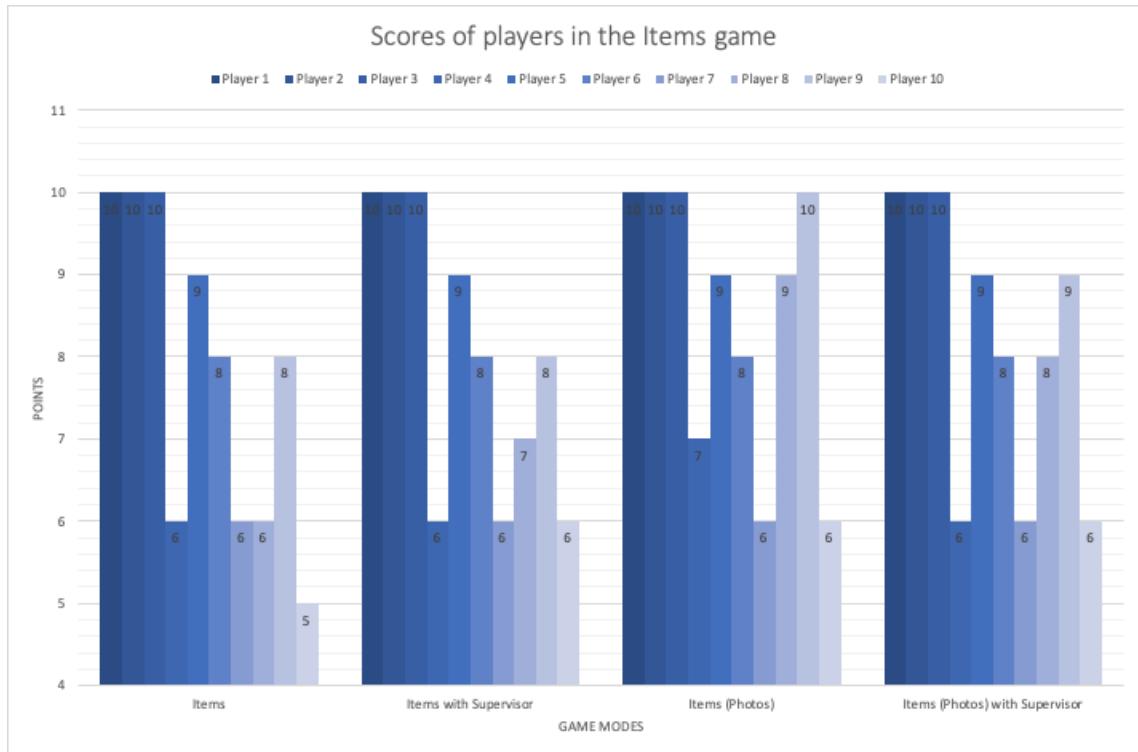


Figure 8.1. Scores of players in Items game

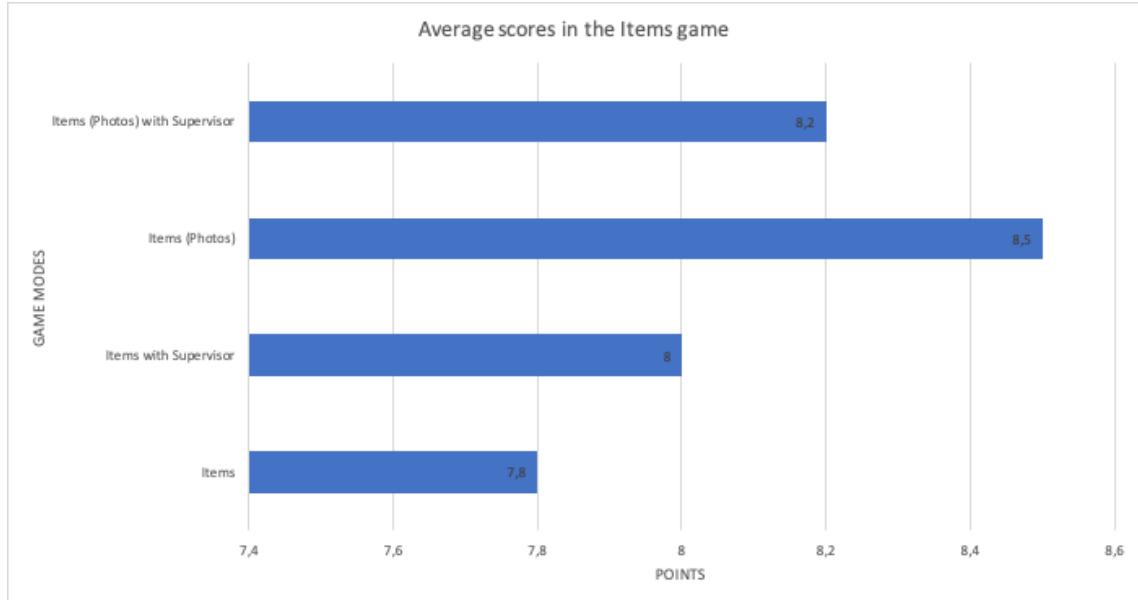


Figure 8.2. Average scores in the Items game

The following charts allow observing that scores of players were quite good. There was no score worse than five points, which means that each player answered correctly for more than half-answers. Results of each mode were similar among one player - there were some

differences, but the player with a lower score in one mode, also obtained lower scores in rest modes. The mode in which players scored the highest amount of points, was items with photos. The lowest scores were obtained in items with drawings mode.

The same actions were prepared for emotions game. Results are presented in the table (*Table 8.2*), and charts based on it (*Figure 8.3 and Figure 8.4*)

Table 8.2. Results of items game in all modes

	Emotions	Emotions S*	Emotions (Photos)	Emotions (Photos) S*
Player 1	8	4	8	4
Player 2	10	9	10	9
Player 3	8	8	8	8
Player 4	5	6	5	5
Player 5	8	8	8	8
Player 6	4	4	4	4
Player 7	3	2	2	2
Player 8	3	5	7	8
Player 9	7	8	9	9
Player 10	4	3	6	4

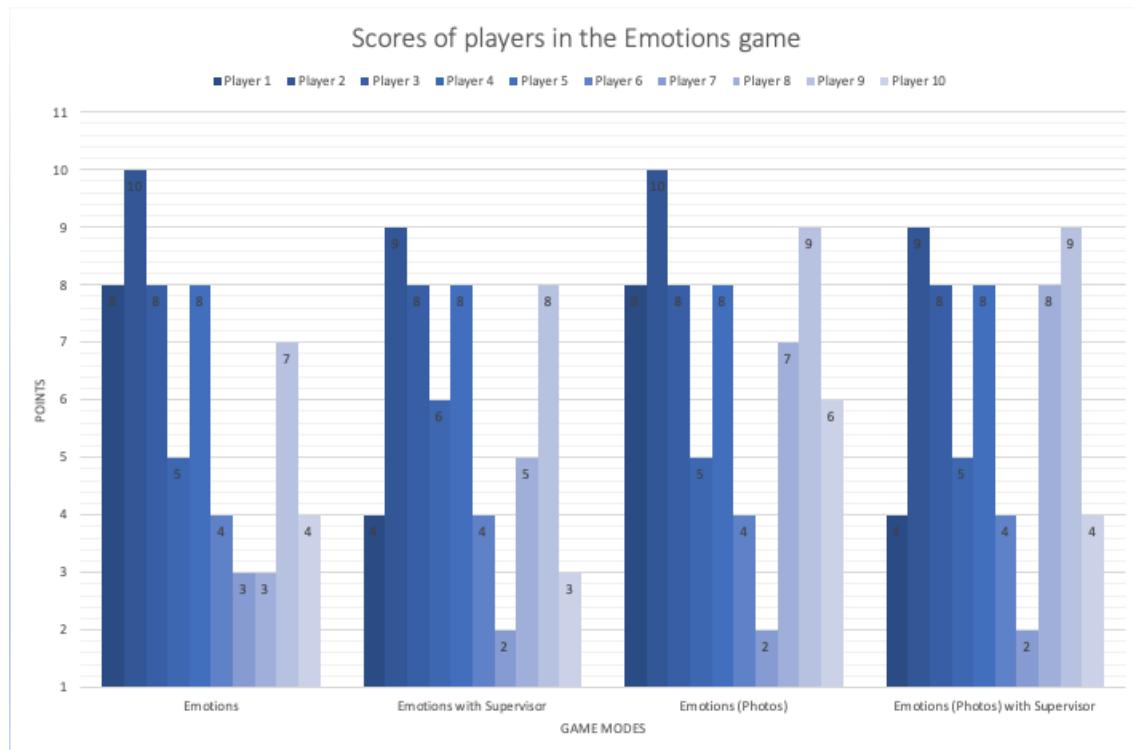


Figure 8.3. Scores of players in Emotions game

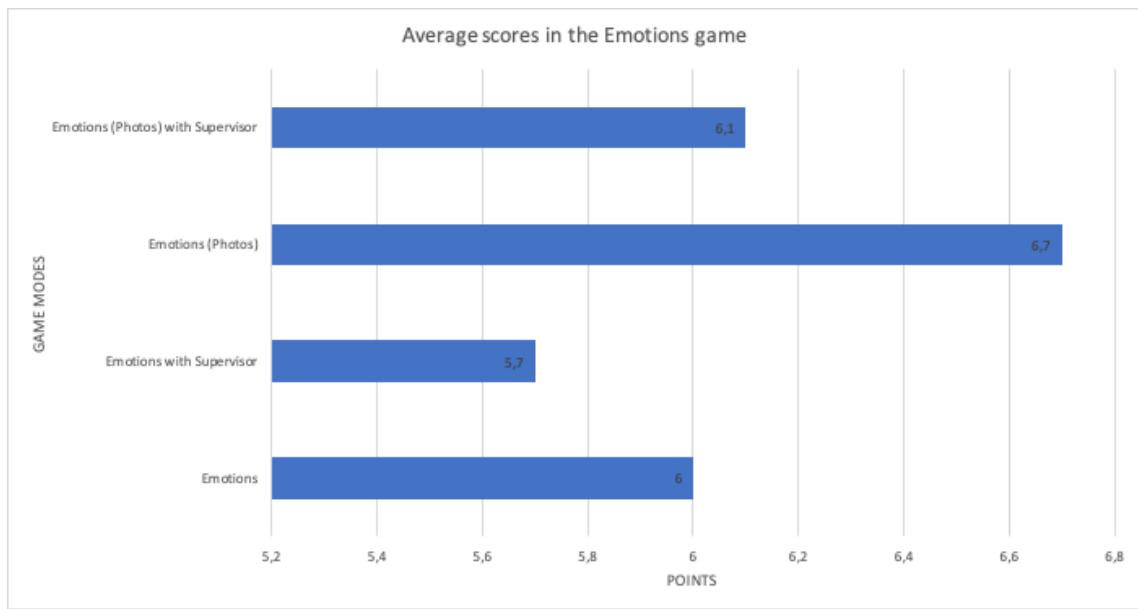


Figure 8.4. Average scores in the Emotions game

Results of the Emotions game were much worse than the Items game. There were even some scores with 2 or 3 points. Again the scores in different modes among one player were similar. Children were better at recognizing emotions on photos than on drawings, but still, it was challenging for them to act emotions by themselves even if they knew how they called and how they looked.

To sum up this part of the research, the scores in both games were quite good - the average amount of points for both games was over 50 percent. The more accessible part was the items game. Players were also more successful when emotions and items were presented on photos, not in drawings. Also, scores in each mode among one player and the game were similar, so if the player did not have problems recognizing items, he also did not have problems recognizing emotions.

### 8.3. REACTIONS TO THE GAME

The second part of the questionnaire were questions focusing on children's reactions to the game. The interest in the game, the autonomy of interactions, positive reactions to the success, and negative to the failure have been examined. The results of the survey were presented in the table below (*Figure 8.3*).

Based on the table, two charts were prepared (*Figure 8.5* and *Figure 8.6*). The data was presented separately because of differences in scale.

Table 8.3. Children reactions to the game

	Interest	Autonomy	Positive reactions	Negative reactions
Player 1	5	4	3	1
Player 2	5	5	3	2
Player 3	5	5	3	1
Player 4	2	2	2	2
Player 5	4	4	3	2
Player 6	4	3	2	1
Player 7	5	4	2	1
Player 8	5	5	3	1
Player 9	5	5	3	1
Player 10	5	3	2	2

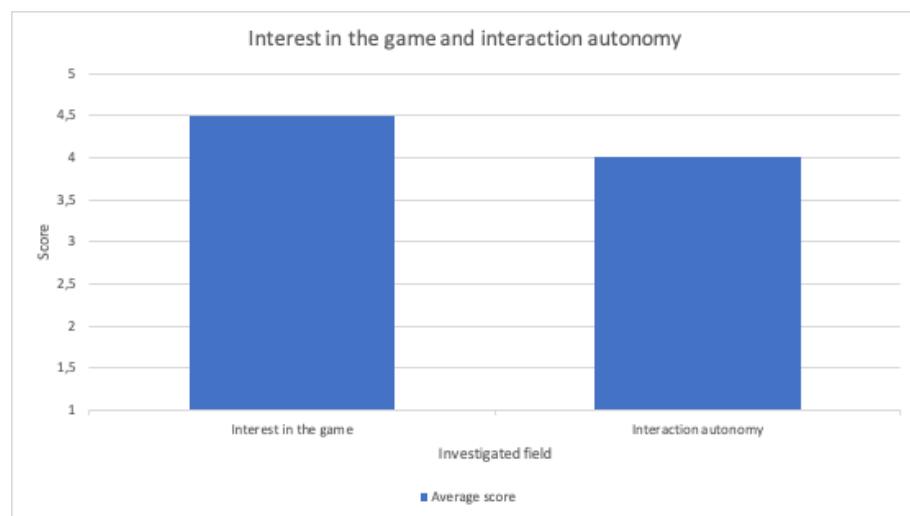


Figure 8.5. Interest in the game and interaction autonomy

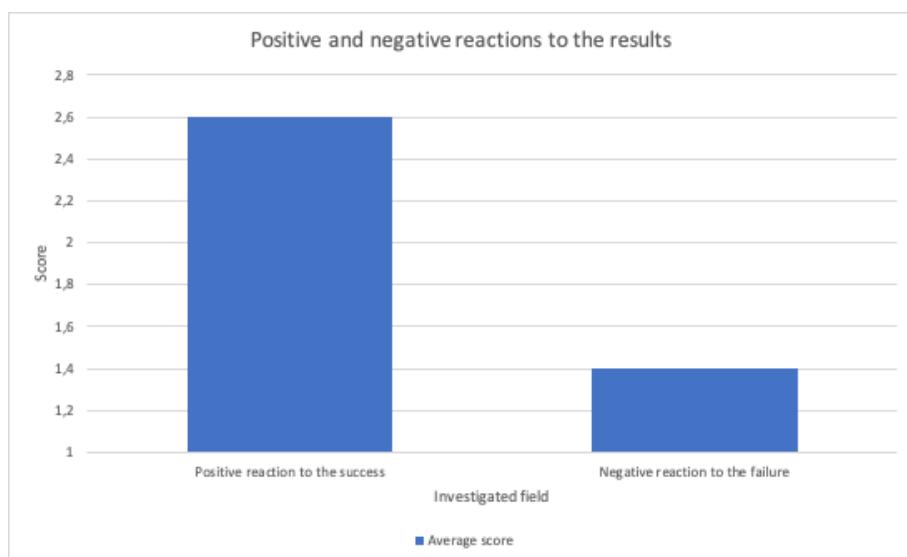


Figure 8.6. Reactions to the results

The reactions of the audience to the game were highly positive. The game was intuitive enough for children with autism - they did not have problems with understanding rules and playing. Supervisors did not need to explain the rules again - mostly, they knew what to do immediately. In both of these fields, the average investigated score was close to the maximum of 5 points.

The next investigated fields were children's reactions to correctly performed tasks and information about failures. At most, they were highly satisfied to see the information that they chose appropriate items or emotions (on average, 2.6/3 points). Also, adverse reactions to the wrong choices did not cause unwanted reactions - at most, there were no adverse reactions (on average, 1.2/3 points).

The last part of the questionnaire related to notes and insights of caregivers corresponding to the game and their pupils' reactions. The comments were translated and presented below.

### **Player 1**

*"The game was very popular among students. There was a smile and joy because there was another form (an attractive one) for practicing speech understanding and vocabulary development. I think that if such mobile games were created for the categories: kitchen, living room, hairdresser, etc. the chance to explore the world would be much greater =)"*

### **Player 2**

*"The Pupil was calm and continued to be interested in the game even when he received several times feedback, that he had failed to complete the task (usually that is the moment when difficult behaviors occur and great reluctance to continue the task). It was difficult to recognize the objects and emotions from the illustrations."*

### **Player 3**

*"The student was more interested in the object (placed on the table) than in the tasks he had to perform. The too big choice on the table made him unable to concentrate. He was given two objects to make him able to decide."*

### **Player 4**

*"The boy quickly grasped what was going on and showed the item afterward on the tablet. He had no problem finding the correct object, and sometimes he just had to discover the object."*

### **Player 5**

*"Pupil had great difficulty in recognizing and showing emotions. He was better at*

*pointing out the correct subjects.”*

**Player 6**

*“The game was positively perceived by a student. Feedback on the correct execution of the task was a great joy.”*

**Player 7**

*“He was doing very well, he was interested in the game, and the feedback was very satisfying.”*

**Player 8**

*“The student was interested in the game, he better handled the work on the pictures and real material.”*

**Player 9**

*“The student was happy to do the job. The form of the game was beautiful for him.”*

**Player 10**

*“A valuable game for learning and consolidating knowledge.”*

Most of the comments were highly positive. Children did not have problems with understanding the rules and performing the tasks (at most). There were better at recognizing items and emotions in the photos. The game was exciting and attractive to them what meant that even after the mistake, they were not discouraged and still wanted to play. Supervisors suggest that if there were additional categories, such a game would be hugely useful in the educational process. Some modifications could be introduced as a decreasing amount of objects available for a child not to distract children from the tasks they are performing at the moment.

#### **8.4. EVALUATION OF THE GAME**

The last step of investigating the application and performing the research was the evaluation of the game. It was done using the same table as earlier in evaluating mobile therapeutic applications. The results are presented below (*Table 8.4*).

The obtained score is equal to the 9 of 13 points - 69%. The evaluation process showed that the game is useful and could be evaluated for its target. It also exhibited some deficiencies. The application could be extended by adding more languages, implementing calendar, which would remind the player to practice every day or by connecting it with

Table 8.4. Evaluation table of implemented mobile game

	Occurrence
Work offline	yes
Accessibility	yes
Communication	yes
Social skills	yes
Math Skills	no
Functional skills	yes
Languages	no
Organizer	no
Entertainment	yes
Educational	yes
Media care	no
Use media	yes
Paid	no

some health services to synchronize the progress and give them access to all information to the therapist.

To summarize, the game for children with autism, allows them to recognize items and emotions both on drawings and the photos, and to recognize objects and act emotions in reality. The higher effectiveness was achieved in photo mode. Also, the items game was a bit easier for players. The reactions to the game were mostly positive, and it was attractive and exciting for children, did not cause unwanted behavior, however, gives much satisfaction if the answer was correct. Children also kept focus in case of failure, which is uncommon among other used educational materials. The game's evaluation showed that it satisfied most conditions of being evaluated the therapeutic application and showed that some functionalities could be added to increase its value.

## **CONCLUSIONS**

The thesis's main aim was to perform studies on autism and therapeutic applications, and to design, implement, and investigate the mobile game and its impact on children with autism and communication difficulties. The implemented application was supposed to relieve the symptoms of autism and improve children's communication skills.

The first steps were to perform the proper research and recess into studies on autism and other communications disorders. Additionally, there was made the research on the solutions currently available on the market; they were analyzed and evaluated using evaluation methods elaborated by experts - to extract the strong and weak sides of each of them.

Basing on the earned knowledge and consultations with the therapists from "*Krajowe Towarzystwo Autyzmu z Odziałem w Szczecinie*" - the facility for children with autism, there were prepared requirements and rules of the game. The next step was designing the application, including preparing use cases or graphical mock-ups. Before implementation, the analysis of technologies was also performed, to decide which tools would be better to implement such a game.

The next step was the implementation process. It also included gathering and preparing the assets - illustrations or photos of items and emotions. After implementing the application, it was ready to deliver it to the facility for children. The research was performed among ten kids with autism. The results were noted by their supervisors and then put in the questionnaire. It can be assumed after investigating the results that the game is intuitive and attractive for them. It can be noted that it was easier to recognize the emotions or items on the photos than on the drawings. The scores obtained during acquaintance and playing the game were right - most children did not have problems performing given tasks. From the feedback given by the caregivers of patients, it can be assumed that the game is exciting and valuable for the children. Contrary to the other educational materials that are being used, in the case of the failure, the problematic behaviors and discouragement do not occur.

All requirements of the application are satisfied; however, the evaluation of the game using one of the evaluation tables pointed out some possibilities for improvements. Other languages could be added to make it valuable for more people, or some reminders based on the calendar could be implemented to help keep the daily routine of practicing.

## BIBLIOGRAPHY

- [1] Apple, *Swift features*, <https://developer.apple.com/swift/>. Last available. 20 jun 2020.
- [2] Attwood, T., *The Complete Guide to Asperger's*, 1 edition. (Jessica Kingsley Publishers, 2008).
- [3] AUTICIEL, *Autimo — amikeo apps*, <https://apps.apple.com/pl/app/autimo-amikeo-apps/id495565736?l=pl/>. Last available. 8 may 2020.
- [4] Autyzmasd.pl, *Autysta geniusz - zdolnoŚci wysepkowe*, <http://www.autyzmasd.pl/zdolnosci-wysepkowe.php/>. Last available. 8 may 2020.
- [5] CDC, *Statistic of children with asd in united states*, [https://www.cdc.gov/mmwr/volumes/67/ss/ss6706a1.htm?s\\_cid=ss6706a1\\_w/](https://www.cdc.gov/mmwr/volumes/67/ss/ss6706a1.htm?s_cid=ss6706a1_w/). Last available. 8 may 2020.
- [6] Frith, U., *Autism: Explaining the Enigma*, 2 edition. (Wiley-Blackwell, 2003).
- [7] Gs.statcounter.com, *Mobile operating system market share worldwide*, <https://gs.statcounter.com/os-market-share/mobile/worldwide/#monthly-201901-201912-bar/>. Last available. 11 may 2020.
- [8] Gs.statcounter.com, *Tablet vendor market share worldwide*, <https://gs.statcounter.com/vendor-market-share/tablet/worldwide/>. Last available. 11 may 2020.
- [9] Ian Blair, *Objective c vs. swift: Which is better? (a definitive guide)*, <https://buildfire.com/objective-c-or-swift/>. Last available. 11 may 2020.
- [10] Jola Zielińska, *5 aplikacji mobilnych dla dzieci z autyzmem*, <https://symetria.pl/blog/artykuly/5-aplikacji-mobilnych-dla-dzieci-z-autyzmem/>. Last available. 8 may 2020.
- [11] Kanner, L., *Autistic disturbances of affective contact*, Nervous Child. 1943, p. 69.
- [12] Katarzyna Jaśkiewicz, *Zespół aspergera – czym różni się od autyzmu?*, <https://www.aptekagemini.pl/poradnik/zdrowie/zespol-aspergera-czym-rozni-sie-od-autyzmu/>. Last available. 8 may 2020.
- [13] knowledgehut.com, *Swift vs python*, <https://www.knowledgehut.com/blog/programming/swift-vs-python/>. Last available. 20 jun 2020.
- [14] Kraleva, R., Kralev, V., *An evaluation of the mobile apps for children with special education needs based on the utility function metrics*, International Journal on Advanced Science, Engineering and Information Technology. 2018, tom 8, 6, p. 2269–2277.
- [15] Ng, S., *Beginning iOS Programming with Swift* (AppCoda Limited).
- [16] Niegrzeczniedzieci.org.pl, *Metoda teacch*, <http://niegrzeczniedzieci.org.pl/asperger/swiat-nauki/terapia/teacch/>. Last available. 8 may 2020.
- [17] Paweł Bakalarz, *Terapia behawioralna w prostych słowach*, [http://www.poradnikautystyczny.pl/post/artykuly/terapia\\_behawioralna\\_w\\_prostych\\_slowach/](http://www.poradnikautystyczny.pl/post/artykuly/terapia_behawioralna_w_prostych_slowach/). Last available. 8 may 2020.
- [18] Pramod Borasi , Supradip Baul, *Mobile application market by marketplace (apple ios*

- store, google play store, and other marketplaces) and app category (gaming, entertainment music, health fitness, travel hospitality, retail e-commerce, education learning and others): Global opportunity analysis and industry forecast, 2019–2026, <https://www.alliedmarketresearch.com/mobile-application-market/>. Last available. 10 may 2020.*
- [19] Raluca Budiu, *Mobile: Native apps, web apps, and hybrid apps*, <https://www.nngroup.com/articles/mobile-native-apps/>. Last available. 11 may 2020.
- [20] Redakcja Polski Autyzm, *Leczenie autyzmu – metody terapii*, <https://polskiautyzm.pl/autyzm-leczenie/>. Last available. 8 may 2020.
- [21] Skawina, B., *Autyzm i zespół aspergera. objawy, przyczyny, diagnoza i współczesne metody terapeutyczne*, Medzinárodná interdisciplinárna vedecká konferencia. 2016.
- [22] Slysze.inz.waw.pl, *Esdm. nowa próba terapii autyzmu*, <http://slysze.inz.waw.pl/esdm-nowa-proba-terapii-autyzmu/>. Last available. 8 may 2020.
- [23] Social Skill Builder, Inc., *Social detective*, <https://apps.apple.com/pl/app/social-detective/id975189305?l=pl/>. Last available. 8 may 2020.
- [24] Szczęgielski, D., *Sommelier's mobile application*. 2019, p. 46.
- [25] Tapspeak, *Tapspeak sequence*, <https://abledata.acl.gov/product/tapspeak-sequence/>. Last available. 8 may 2020.
- [26] teacch, *Teacch official website*, <https://www.teacch.com>. Last available. 8 may 2020.
- [27] Temple Grandin, R.P., *The Autistic Brain: Thinking Across the Spectrum*, reprinted edition. (Mariner Books, 2013).
- [28] Touch Autism, *Calm counter social story anger management tool*, <https://apps.apple.com/pl/app/calm-counter-social-story-anger-management-tool/id470369893?l=pl/>. Last available. 8 may 2020.
- [29] Wikipedia, *Android (system operacyjny)*, [https://pl.wikipedia.org/wiki/Android\\_\(system\\_operacyjny\)](https://pl.wikipedia.org/wiki/Android_(system_operacyjny)). Last available. 11 may 2020.
- [30] Wikipedia, *ios*, <https://pl.wikipedia.org/wiki/IOS>. Last available. 11 may 2020.
- [31] Wikipedia, *Objective-c*, <https://en.wikipedia.org/wiki/Objective-C>. Last available. 11 may 2020.
- [32] Wikipedia, *Swift (programming language)*, [https://en.wikipedia.org/wiki/Swift\\_\(programming\\_language\)](https://en.wikipedia.org/wiki/Swift_(programming_language)). Last available. 11 may 2020.
- [33] Wikipedia, *Xcode*, <https://pl.wikipedia.org/wiki/Xcode>. Last available. 20 jun 2020.
- [34] Zawadzka, P., *Podejście teacch w terapii autyzmu*, <https://polskiautyzm.pl/podejscie-teacch-w-terapii-autyzmu/>. Last available. 8 may 2020.

## LIST OF FIGURES

1.	Statistic of children with ASD in United States [5] . . . . .	6
2.1.	Example screenshot of Autimo [3] . . . . .	13
2.2.	Example screenshot of TapSpeak Sequence [25] . . . . .	14
2.3.	Example screenshot of Calm Counter Social Story & Anger Management Tool [28] .	15
2.4.	Example screenshot of Social Detective [23] . . . . .	16
2.5.	Example evaluation table [14] . . . . .	16
4.1.	Increase of mobile applications market [18] . . . . .	20
4.2.	Mobile platform market share [7] . . . . .	21
4.3.	Objective C vs. Swift [9] . . . . .	24
5.1.	Example mock up created using Sketch . . . . .	25
5.2.	XCode interface builder . . . . .	26
6.1.	Player and Supervisor use case diagram . . . . .	28
6.2.	Main menu and choose game screens . . . . .	29
6.3.	Items and emotions games screens . . . . .	29
6.4.	Items and emotions correct answer . . . . .	29
6.5.	Items and emotions correct answer in supervised mode . . . . .	30
6.6.	Items and emotions incorrect answer . . . . .	30
6.7.	Settings and scoreboard screens . . . . .	30
7.1.	Structure of the project . . . . .	31
7.2.	Items game . . . . .	32
7.3.	Emotions game . . . . .	34
7.4.	Main menu screen . . . . .	36
7.5.	Choose game screen . . . . .	36
7.6.	Items game screen . . . . .	36
7.7.	Correct item screen . . . . .	36
7.8.	Correct item - supervised mode . . . . .	37
7.9.	Incorrect item screen . . . . .	37
7.10.	Emotions game screen . . . . .	38
7.11.	Correct emotion screen . . . . .	38
7.12.	Correct emotion - supervised mode . . . . .	38
7.13.	Incorrect emotion screen . . . . .	38
7.14.	Won game screen . . . . .	39
7.15.	Scoreboard screen . . . . .	39
7.16.	Game settings screen . . . . .	39

7.17. Game flow map . . . . .	40
8.1. Scores of players in Items game . . . . .	43
8.2. Average scores in the Items game . . . . .	43
8.3. Scores of players in Emotions game . . . . .	44
8.4. Average scores in the Emotions game . . . . .	45
8.5. Interest in the game and interaction autonomy . . . . .	46
8.6. Reactions to the results . . . . .	46

## **LIST OF LISTINGS**

7.1 User defaults structure . . . . .	32
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## **LIST OF TABLES**

2.1.	Evaluation table of investigated mobile games . . . . .	17
7.1.	Items available in game . . . . .	33
7.2.	Emotions available in game . . . . .	35
8.1.	Results of items game in all modes . . . . .	42
8.2.	Results of items game in all modes . . . . .	44
8.3.	Children reactions to the game . . . . .	46
8.4.	Evaluation table of implemented mobile game . . . . .	49