ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

THEORY OF MIND AND CONCEPT LEARNING BASED MOBILE GAMES FOR CHILDREN WITH COMMUNICATION IMPAIRMENT

M.Sc. THESIS

Baransel Can GÜLKANAT

Department of Game and Interaction Technologies

Program of Game and Interaction Technologies

JULY 2020

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Baransel Can GÜLKANAT
(529171004)

Department of Game and Interaction Technologies

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Thesis Advisor: Assoc. Prof. Dr. Hatice KÖSE

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İLETİŞİM BOZUKLUĞU OLAN ÇOCUKLAR İÇİN ZİHİN KURAMI VE KAVRAM ÖĞRENME TEMELLİ MOBİL OYUNLAR

YÜKSEK LİSANS TEZİ

Baransel Can GÜLKANAT
(529171004)

Oyun ve Etkileşim Teknolojileri Anabilim Dalı

Oyun ve Etkileşim Teknolojileri Programı

Tez Danışmanı: Doç. Dr. Hatice KÖSE

TEMMUZ 2020

Baransel Can Gülkanat, a M.Sc. student of ITU Graduate School of Science Engineering and Technology student ID 529171004, successfully defended the thesis/dissertation entitled "THEORY OF MIND AND CONCEPT LEARNING BASED MOBILE GAMES FOR CHILDREN WITH COMMUNICATION IMPAIRMENT" which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor :	**Assoc. Prof. Dr. Hatice KÖSE** İstanbul Technical University	.....
Jury Members :	**Asst. Prof. Dr. Güven ÇATAK** Bahcesehir University	.....
	Res. Asst. Dr. Hüseyin Kutay TİNÇ Istanbul Technical University	.....

Date of Submission : 15 June 2020
Date of Defense : 24 July 2020

To anyone who needs motivation,

FOREWORD

This thesis “Theory of Mind and Concept Learning Based Mobile Games for Children With Communication Impairment”, is an applied study and its purpose is to determine the differences of children groups that have different development levels.

After a decision process, I decided to create a game for children who exhibit deficits in communication. Then, I chose to study on the area of children with autism and deaf children.

I would like to thank my advisor Assoc. Prof. Dr. Hatice Köse who encouraged me to do this study. I was able to walk on this difficult path with her support. Additionally, I wish all best for parents and teachers of the children that we have worked together; without their participation, this thesis would not achieve its purpose.

July 2020 Baransel Can GÜLKANAT

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ABBREVIATIONS

ASD	**:** Autism Spectrum Disorder
2D	**:** Two Dimensional
3D	**:** Three Dimensional
AR	**:** Artificial Intelligence
OS	**:** Operating System
Secs	**:** Seconds
UX/UI	**:** User Experience / User Interface
SLP	**:** Single Layer Perceptron

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THEORY OF MIND AND CONCEPT LEARNING BASED MOBILE GAMES FOR CHILDREN WITH COMMUNICATION IMPAIRMENT

SUMMARY

In the recent decade, both researchers and game creators have special interest to work with mobile devices, since everyone has their mobile phones in their pockets. With the combination of the two, gamification and the serious games, which have different purposes such as teaching and research rather than entertaining as the first priority, have been developed.

Within this study, theory of mind and concept learning based mobile game has been developed. These two methods were chosen because these are the natural part of a childhood development. On the other hand, concept learning and theory of mind methods commonly used to teach to children with autism by teachers.

Recent studies demonstrates a plenty of popular and efficient methods about education and therapy of children with autism. By evaluating these methods and fulfilling the requirements of mobile game development and preserving the schematic attraction, a game is developed which is fun and exciting to play according to the survey results of the game.

The developed game has four mini games in it. Three of them are related with the concept learning, these ones are shape matching game, color matching game and voice/object matching game. The fourth one is a facial expression recognition game related with the theory of mind.

All mini games are created carefully and then shared with experts to receive their opinions and feedback. After the feedback, some functions and images are re-designed to serve better for children. The purpose of the game is collecting player data and interpreting it while entertaining children. The obtained data will be used for the next stage of the project which will aim to diagnose autism in children.

This game is developed with Unity game engine, and some auxiliary services such as AR Emoji by Samsung and Wavenet by Google are utilized to better serve to children during the game play. The game is released to both Android and iOS application stores to be accessible easily by parents and teachers. Then, through acquaintances and teachers we know from the school of special education, we reached out to parents. Data has been obtained during the game play in the background. Also, there is a section that parents and/or teachers can complete a survey after the game to share their experiences with the game.

İLETİŞİM BOZUKLUĞU OLAN ÇOCUKLAR İÇİN ZİHİN KURAMI VE KAVRAM ÖĞRENME TEMELLİ MOBİL OYUNLAR

ÖZET

Özellikle son yıllarda, mobil cihazların da iyice hayatımızda yer edinmesiyle, gerek akademik çalışma yürüten araştırmacılar, gerek ise oyun yaratıcıları, mobil cihazlara yönelmiş durumdadır. İkisinin bir araya gelmesiyle oyunlaştırma alanı ve ciddi oyunlar denen, ilk önceliği eğlendirmekten ziyade öğretme, araştırma gibi farklı amaçlar taşıyan alanlar oluşmuştur.

Bu tez kapsamında çocukluk gelişiminin doğal bir parçası olan kavram öğrenme ve zihin kuramı yöntemleri ile çocuklara uygun mobil oyun tasarlanmıştır. Bu yöntemlerin seçilmesinin bir nedeni de, özellikle kendini ifade etmekte zorluk çeken, iletişim gücü düşük ve öğrenmekte güçlük çeken otizm spectrum bozukluğu olan çocuklara da eğitim aşamasında yine bu yöntemlerin kullanılmasıdır.

Literatür araştırması yapılırken en popüler, en etkili yöntemler ile, eğitim ve terapi gibi çok çeşitli konularda çalışma yapan makaleler incelenmiş, güvenilir web siteslerinden faydalanılmıştır. Tüm bu bilgiler değerlendirilerek, mobil oyun sektörünün popüler gereklilikleri ve tasarımsal cazibe de korunarak çocuklar için, anket sonuçlarının da gösterdiği üzere, oynaması heyecanlı ve eğlenceli oyun modları geliştirilmiştir.

Tez araştırmasının bir parçası olarak geliştirilen ve "Mini Oyunlar" adı verilen bu mobil oyunda dört tane mini oyun modu bulunmaktadır. Bunlar, kavram öğrenmesini destekleyen şekil eşleştirme, renk eşleştirme ile ses ve obje tanımanın yanında; zihin kuramıyla alakalı yüz ifadelerinden duygu tanıma oyunudur. Tüm oyunlar önceden tasarlanıp oluşturulmuş olup sonrasında özel eğitim öğretmenlerine gösterilerek fikirleri alınmış ve önerileri doğrultusunda yeniden yapılandırılmıştır. Bu tam koordineli çalışma hali, oyunu çocuklara ve özellikle de iletişim güçlüğü olan çocuklara biraz daha uygun hale getirmiştir. Tabi ki oyun bu ilk aşamasında direkt olarak eğitme amacı gütmemekle birlikte, bunu da başarmış ancak araştırma ve çocukların arasında verilere dayanan bir farklılık tespit edebilme gayesiyle hazırlanmıştır. Uzun soluklu düşünülen ve ilk kısmı bu tezi oluşturan bu projenin amacı ileride, elde edilmiş verilerle oyunu geliştirilerek, çocuklarda otizmin tespitine yardımcı olmaktır.

Oyun Unity oyun motoru kullanılarak geliştirildi. Samsung AR Emoji ve Google'ın gerçekçi ses sentezi oluşturmaya yarayan Wavenet gibi yardımcı unsurlar çocuklara oyun içinde asistanlık yapması amacıyla bir araya getirildi. Bu yardımcı asistan oyun içinde, ilk sahnede bir erkek ve bir kız olarak ekranda belirir. Oyuncu kişisel tercihine göre bu karakterlerden birini seçer. Daha sonra hem bilgi girme ekranında hem de tüm mini oyunların başında, bu karakterlerin animasyonu belirerek oyuncuya ne yapmasını gerektiğini anlatır. Bu sesli desteğin yanı sıra ek olarak her ihtimale karşı yazılı bilgilendirmeler de bulunmaktadır.

Oyunda her çocuk için, özellikle de otizm spektrum bozukluğuna sahip çocuklar için hem sesli hem de görsel uyaranlar bulunmaktadır. Bunlar oyunun nasıl oynanacağına dair ip uçları içerdiği gibi aynı zamanda da doğru ve yalnış hamlelerde bunun başarılı ya da hatalı olduğunu işaret eden sesler oyuna eklenmiştir. Kart/ses eşleştirme modu ve yüz ifadesi tanıma modunda aynı pozitif ve negatif uyaranlar kullanılmıştır. Her doğru seçenekte konfetiler patlar, ve alkış ile pozitif bağırışma sesleri duyulur. Her negatif seçenekte ise cansız ve negatifliği anımsatan bir ses çalar. Renk eşleştirme modunda görsel uyaran olarak nesnelerin patladığını gösteren çok hoş bir patlama efekti yaratılmıştır. Bu animasyona bir de ses eşlik etmektedir. Son olarak da şekil eşleştirme modu bulunmaktadır. Bu modda her doğru eşleştirme için yine bir başarım sesi çalmaktadır, ek olarak birleştirilen şekil yarım saniyeliğine yeşil renkte yanıp doğru eşleştirmeyi pekiştirmektedir. Bu sesli ve görsel uyaranlar içinde özellikle konfeti patlaması ile gelen alkış seslerine, bazı çocukların gülerek ve alkış yaparak her defasında eşlik etmesi paha biçilemez bir güzellikti.

Her mod için belirli sayıda doğru cevap sayısı, oyunun uzun ve sıkıcı olmayacağı şekilde belirlenmiştir. Bu doğru cevap sayısına ulaşıldığında bölüm sona erip bir tebrik paneli ekranda gözükmektedir. Yine yeşil, pozitif bir renk kullanılmış olup bu sahneden ekranda balonlar yükselmekte ve alkış sesleri duyulmaktadır.

Bölümler sona erdiğinde oyuncu bir geçiş ekranına yönlendirilir. Burada tüm oyunların oynanmasını sağlamak amacıyla oynanan mini oyunlar listeden çıkarılır ve geriye kalan oyunlar gösterilir. Tabi ki her zaman ekranda bulunun geri tuşu ile yine tüm bölümlere erişmekl de mümkündür.

Oyun tasarlanırken çocukların ilgisini çekecek objeler, resimler ve sesler tercih edilmiştir. Direkt etkileşime geçilen nesneler haricindeki objelerin tasarımı ise yine hoş ama sade tutulmuştur. Özellikle otizm spektrum bozukluğuna sahip çocukların dikkat problemleri yaşadığı bilinmektedir. Ek olarak bazen, bazı şekillere de odaklanıp uzun süre geçirdikleri olabilmektedir. İşte bu sebeplerin önüne geçip, tüm çocukların dikkatini oyunun mekaniklerine çekmek için böyle bir yöntem izlenmiştir.

Oyun tasarlanırken, bu eğitim methodlarına yer verilmesinin yanı sıra, aratırma oyunu projesi olduğu için birinci önceliğimiz eğitmek değildi. Buna rağmen velilerden oyunu çocukları için çok bilgilendirici olduğu geri dönmüşlerini de aldık. Her çocuk grubundan çocukların oyunu hem eğlenerek, hem de bilgilenerek oynaması fazlaca ilham verici ve mutlu ediciydi.

Oyun ailelerle paylaşılırken ailelere ve öğretmenlere gerekli bilgilendirmeler hem direkt hem de yazı ile bildirilmiştir. Proje kapsamında hazırlanan bu oyun için, çocukların ilgilerini kaybedinceye kadar oyunu oynamaları istenmiştir. Çocuk artık oynamamaya başladığında, yeterli veri de elde edildiğinden aileden verileri göndermesi ve oluşturulan anketi doldurması istenmiştir. Salgın ve karantina dönemine denk geldiğimizden dolayı, çocuklara direkt olarak erişim sağlanılamadı, bu yüzden de ham oyun verileri tek başına yetersiz olduğundan, her çocuğun oyuna tepkisini de direkt göremediğimizden ankette bunu anlayacak sorulara yer verilmiştir.

Ailelerin kolayca erişebilmesini sağlamak amacıyla oyun, hem Android uygulama mağazasına hem de iOS uygulama mağazasına yüklendi. Daha sonra hem yakın çevredeki aileler hem de iletişimde olduğumuz özel eğitim okulunun eğitimcileri aracılığı ile çocukların ailelerine ulaşılıp oyun gönderildi. Oyun süresinde belirli veriler sürekli olarak kaydedildi ve bunlar tarafımıza iletildi.

İlk aşaması bu tezin konusunu belirleyen bu büyük çalışmada, değişik özellikteki çocuk gruplarının oyundaki karakteristiği ve performanslarının incelenmesi planlanmıştır. Öte yandan oyun modları, toplanan veriler ve daha geniş kapsamlı incelemeler sağlayacak oyunun ilk versiyonu bu tez kapsamında sunulmuştur.

Oyunlar sonunda toplanan veriler ile Weka3 programı aracılığı ile sınıflandırma analizleri yapılmıştır. Random forest ve single layer perceptron metotları kullanılması uygun görülmüş olup, bu proje kapsamında son derece başarılı kabul ettiğimiz yüzde 88.88'lik doğru sınıflandırma elde edilmiştir.

Proje devamı niteliğinde oyuna çoklu diller eklemek, ve diğer ülke pazarlarına da servisi sağlanıp daha çok veri elde etmek planlanmaktadır. Çeviri çalışmaları ve topluluk arayışları şimdiden başlayan bu projeye olan inanç şimdiden elde ettiğimiz verilerle daha da artmaktadır. Kapsam genişlediğinde ve elde edilen veriler arttığında, daha net sonuçlar elde edilip bir de makale yayınlama çalışmamız olacaktır.

Son olarak, bu beklenmedik koşulları yaşadığımız bir dönemde, kısıtlı kişi ve verilerle de olsa hazırlanan oyunla, hem normal gelişimini tamamlamış, hem de otizm spektrum bozukluğu bulunan çocukların oyunumuza verdiği güzel tepkileri ve oyunu oynarkenki heyecanlarını görmek, tanık olmak ve anket raporlarından okumak çok ilham verici ve destekleyici oldu. Projeyi ileri götürme konusunda büyük bir moral ve enerji oldu.

1. INTRODUCTION

1.1 Purpose of Thesis

This thesis, basically includes the study on different children groups on the theory of the mind and concept learning methods. The main purpose is detecting different play patterns between children with autism and normally developed children.

1.2 Literature Review

Wide variety of researches have been done in serious game for children with autism. Serious games' main purpose is could be education, training, examination rather than the fun [1]. Especially in research in autism, games aim to education, therapy for communication skills, improvement of social behaviours and so on [2].

Serious game for children with autism is designed actually for parents and teachers and aims to help them. There are many games developed for this reason. One of them is The Emotion Trainer [3]. This game has deleloped to teach emotions and help them to recognize facial expressions. Of course, these serious games are not made only for children. For instance, Mind Reading [4] is developed for adults with autism and it intend to teach complex emotions to them. Another example is What to choose game [5]. This game also was about the emotions and it demostrated that children with autism have failed to make inferences between situations and emotions. As anothers, the next instance is also used emotions to make a game. cMotion [6] was developed for computer. It was using virtual game character and it was aiming to teach emotions with different facial expression using drag and drop method in game. Let's Face It [7] is the another game for teaching the face recognition abilities. This game aimed the particular face disorders linked with autism spectrum disorder. Another serious game is Emotion Mirror [8] which is made for children who already have the ability of understanding facial expressions. This game was aimed to improve individuals recognitions skills. As a good example of serious game in this area, LifeIsGame also utilized a virtual character. This character had an ability to make diferent facial

expressions according to situation. As an intelligent instance, Echoes [9] designed as a serious game to train children's cummunicational abilities. In the game, virtual game character act like a friend and also teacher to children.

This kind of games can also be story based. Tobias in the Zoo [10] designed with five different scenarios which demonstrated different environment. Situational stories are given to the children and then Tobias' emotional statement asked to the children with facial expressins images.

As mentioned before, some serious game aims to investigate about in particular situation. The game data is investigated to assess autism level using speed [11], precision and attempts. They evaluate the outcomes with fuzzy logic. Table 1.1 demonstrates the features and missions of the games' above.

Table 1.1 : Computer interventions.

Intervention	Refers to	Age	Test / Evalua-tion	Mouse / Keyboard	2D / 3D	Virtual Characters	Images	Text Audio Video
VideoEmotion Trainer	Autism / Asperger Syndrome	School age	√	√	2D	-	√	T
Mind Reading	Asperger Syndrome / High Functioning Autism	From 8 years old	√	√	2D	-	√	T,A, V
What to choose	High Functioning Autism	teenagers	√	√	3D	√	√	T,A
cMotion	Autism	-	-	√	3D	-	-	-
Let's Face it!	Autistic Disorder / Asperger Syndrome / PDD-NOS	School age	√	√	2D	-	√	-
Emotion Mirror	ASD	-	-	√	-	-	√	V
LIFEisGAME	ASD	From 6 years old	√	√	3D	√	-	A
ECHOES	Autism Spectrum Conditions	Young children	√	other	2D/ 3D	√	-	T,A

For comparison the project name with the other above, this game includes text, video, audio, images and virtual character, other type of control which is touch control on mobile devices. On the other hand, it has test and evaluation for 4-6 years old normally developed children and children with ASD.

Some games that serve educational purposes are made to help teacher and or students during the learning phase. Another game is developed as a computer game which uses story telling concept [12]. They aimed two main features. The first one was teaching how to use money and the second one was how to behave during the shopping. Another good example for educational games is made for increasing fluency in the speech [13]. In this game objects shown in the screen in a given time and player had to tell their names in this short time. Another game is also made for increasing communication skills [14]. It mainly focused on children's personal needs and created the point system with percentage of every correct pronunciation. Another serious game, that aims to teach about healthcare and basic first aid knowledge, is developed for individuals with ASD [15].

Picture based game named TouchStory [16] is developed and aimed to improve the understanding of narrative. This game also made specifically for children with autism and had successful results.

Games for children with autism could have different purposes. Besides its educational side, they could be used as a therapy. For this goal, there is an instance of a game that aim to increase intelligibility in speech [17]. Researchers has made interactive therapy system design for children with autism [18]. With this project they aimed to examine potential of interactive design and assistive technologies. Another serious therapy game is EEG-based medical application [19]. The game uses EEG-based neurofeedback and possible futures are proposed in medical area.

Collaborative puzzle game designed as an interactive game which aims to create technologically supported activity for encouraging collaboration among children with autism [20].

Autism screening at the early childhood is crucial to return children with autism to normal life. Researchers have developed a game [21] which aims to train three important skills such as emotion recognition, emotion regulation and emergence of emotions.

Tobias in the zoo aims to improve social capabilities [22]. This game mode as AR based. There is a virtual character in the game. Story gives a real life situations to the player and asks that "Which emotion character felt on the state given before?".

General purpose game module is designed for children who have autism [23]. It has been made to help in the medicinal process of children. The module contains images and capability of touch with special sensors set by microprocessors. The displayed images includes facial expressions, various types of geometric shapes and so on.

Academics designed an application to measure influence of rehabilitating children using Leap-Motion [24]. Results are evaluated by AB testing method. Improvements such as color recognition and fine motor skills are improved after the intervention.

A curriculum for developing serious games is published in 2017 [25], includes some information about free-time activities of children with ASD. According to research, children with ASD spends their free-time using screen-based media than any other activities [26,27]. On the other hand, it also known that this kind of devices are time saver and useful for learning process [28].

2. GAME IN HEALTH AND AUTISM

2.1 Serious Games

Serious games provides more than fun [29]. Main purpose of serious games is not giving entertainment, they aim to educate, teach, do therapy and so on.

Serious games in health could serve to educate, do therapy, improve social behavior etc. On the other hand, problem solving is the main mission of this type of games and primary intention could be investigating [30]. With this project, the main purpose is investigating in-game data and behaviors of the children and then educating while fun.

2.2 What Is Autism Spectrum Disorder

Autism spectrum disorder (ASD) is an impairment accepted one of the most pervasive impairment belong to childhood. According to the statistics, it is more common than other disorders such as down syndrome, cancer and diabetes. International research demonstrates that prevalence rate increases [31,32], which is 1 in 59 at 2018 [33].

Detecting existence of autism can be difficult because there is no medical test such as a blood test or MRI to diagnose the disorder [34].

According to American Psychiatric Association, ASD is usually manifest itself in childhood, around 2-3 years old with many clear signs. Yet some children with autism grow up normally until being toddler and then they stop obtaining new abilities or lose previously obtained abilities. In addition, ASD is also three to four times more pervasive in boys than in girls. Also some girls with ASD shows less apparent signs than boys [35].

Autism is not an illness, it is a behavioral impairment related to neurobiological base. For this reason the diagnosis cannot be applied by DNA analysis or other clinical examinations. To diagnose ASD, behavior of the child must be examined by pediatric psychiatrist. Therefore, parent interest and attention is crucial to observe any abnormality in first hand.

2.1.1 Causes of autism

- Maternal and Paternal Age: There has been several research demonstrates risk increases with age [36-38], while some others has not find relationship [39,40].
- Vaccines: For instance thimerosal which contains mercury could cause autism [41].
- Genetic: There are conclusive evidences that genetic factors could cause autism [42].
- Pregnancy Condition: Consumption of alcohol, tobacco, drugs etc.
- Environment: Gene-environment interaction causing or contributing to autism [43].
- Medications: For instance, usage of thalidomide.

And so on.

2.1.2 Symptoms of autism

- Repetitive behaviors: Especially in particular activity, they do unintentional or continuous repetitive movements.
- Social Impairments: Inability of understanding others' emotions, discontinuous or lack of eye contact, not knowing how to act communicating with others.
- Restrictive behaviors: Interest to specific object, no command taking, hyperactivity or anxiety.

3. GAME DESIGN

This game consist eight scenes in total which includes four game scenes and one information/questionnaire scene.

When the player starts the game, the first screen they see is a user information panel (Figure 3.1) which contains the terms & conditions and privacy policy as a blue link so that the player can click and read more information about the game and then click the green accept and continue button to further proceed with the game. By doing this, all parents are volunteered and have accepted to participate to this study.

Every parent and teacher was informed about this project's purposes. Additionally, a game panel is added to the first scene so individuals are directed to the website which contains privacy policy, terms & conditions and more information about project by clicking blue text which is actually a button. So, all parents were volunteer and have accepted to participate to this study.

Figure 3.1 : User agreement.

As seen in Table 3.2, the game designed for both single user and multi users. Because of schools are closed during the quarantine and due to curfew, it was hard to reach children. So, the game is prepared for single users who stays in their homes. Additionally, the game was also played by many players on a single device. To meet this need, multi scenes designed.

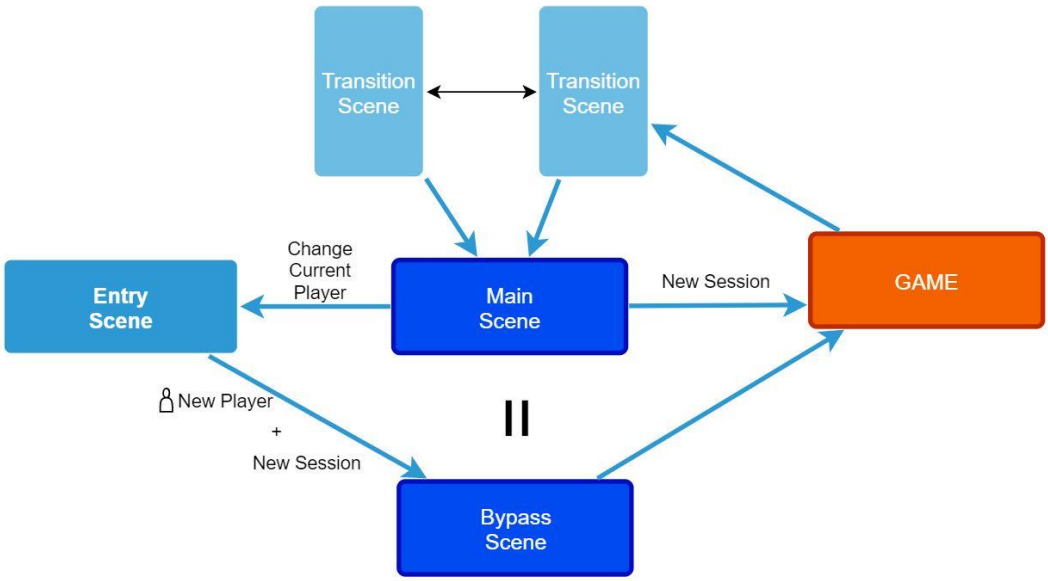

Figure 3.2 : Logic behind the game scenes

Game starts in entry scene. User login is provided here. When the player touch the play button, player redirects to bypass scene. This scene called by pass because it is shown just for ones. Like the main scene, the bypass scene is also contains mini games buttons which opens each mini games. When the player touches one of the buttons he/she redirects to the game play scene. In the game scene, there is two possible scenario to finish the game. One is completing the game and another is quitting the game. Both scenario opens one the transition scene according to which mini game played. Player only can see the remain mini games in this transition scene. This is designed to force the player to play every game modes. In addition, if the player does not want to play remain mini games, he/she always press to back button which opens the main scene.

In the main scene, new player button is located to de top left of the screen and it open entry scene to put new player information.

3.1 Design Principles For Children With Autism

Mobile devices with installed edutainment games can make children with autism more comfortable. There are some principles to do to provide better experience during the play. Although, there are many app out there, due to the bad design or content, they are not the good solutions.

Expected form of the game [44]:

- Color preferences: Black is the repulsive color so another color must be used instead.
- Icons: Especially the icons of the main page should be easily detectable.
- Number of images: Must be few
- User interface: Must be designed as simple. These children's attentions can easily be distracted. So, redundant contents or complex shaped wallpapers must be removed.

Expected contents from the game prepared for children with autism:

- Guide: Parents or teachers must accompany
- Audio: The audio used should comply with the objects.
- Language: The language utilized in the game must be understandable and clear.
- Admin section: Like in the project game, there must be a scene which is protected by the password.
- Pronunciation: Realistic pronunciations are better for this type the game.

Expected behavior:

- Navigation: Easy to use navigation buttons.
- Assessment Parameter: In game mechanics that holds user statistics.
- Images: Using images belong to real life objects can attract the children and teach in a better way.

3.2 Mini Games

There are 4 mini games in this project (Figure 3.3). Every one of them generated according to theory of mind and concept learning methods and re-designed after taking expert suggestions.

Every game mode consists of three parts. At the first part there is a speaking animated guide, a girl or a boy according to player's choice. Second part includes a visual tutorial for the player and the third part is the game playing. Four mini games are explained in details below.

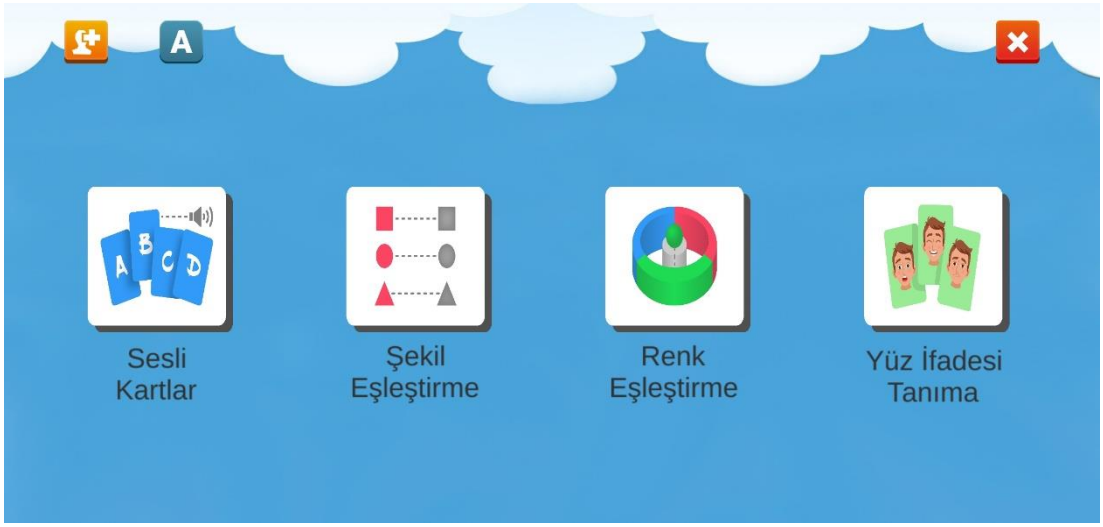

Figure 3.3 : Games screen.

3.2.1 Voice match game

In this mini game mode (Figure 3.4), picture cards are used as a visual component and transferred to the digital environment by scanning.

Figure 3.4 : Voice match in-game screen.

3.2.1.1 Head-Up display (HUD)

In this game mode, there is a slider located on the upper-middle part of the screen. It demonstrates the current number of question phase, also provides information about when the game will end.

As in every game mode, there is a button in the top right corner which gives an option to player to exit the game whenever he/she wants. When clicked to this button, a

verification panel is shown asking if user really wants to exit the game. This panel helps to avoid exiting the game by clicking by mistake.

Cards enter to the question screen by sliding from right side of the screen and after choosing the correct card, they are leaving from the left side of the screen. This function allows buttons to be reached easily. Moreover, the question text remains on the screen constantly, because every phase has the same question. The question text in the game, which is shown at in-game screenshot of voice match game in English, “Which card is the source of the sound you hear?”.

3.2.1.2 Game play

At beginning of the scene, child’s guide character appears in the middle of the screen and tells the player what to do in this mode. Then phase of questions enters to the scene, repeatedly. Each phase has four cards related each other and an audio playback. Questions asks which card this voice belong to. There is only one correct answer and others are three wrong answers. If the player chooses one of the wrong answers, the card that touched, shakes gently. This is the incorrect answer feedback mechanism specific to this mini game mode. In addition, if the player selects wrong answer more than three times, a star appears on top of the correct option (Figure 3.5) which is encouraging the player to select the correct card. The reason behind this feedback is, as known, autism level could differ from mild to severe for each children [45] and from time to time, some of them could need indicators if they do not know the correct answers**.**

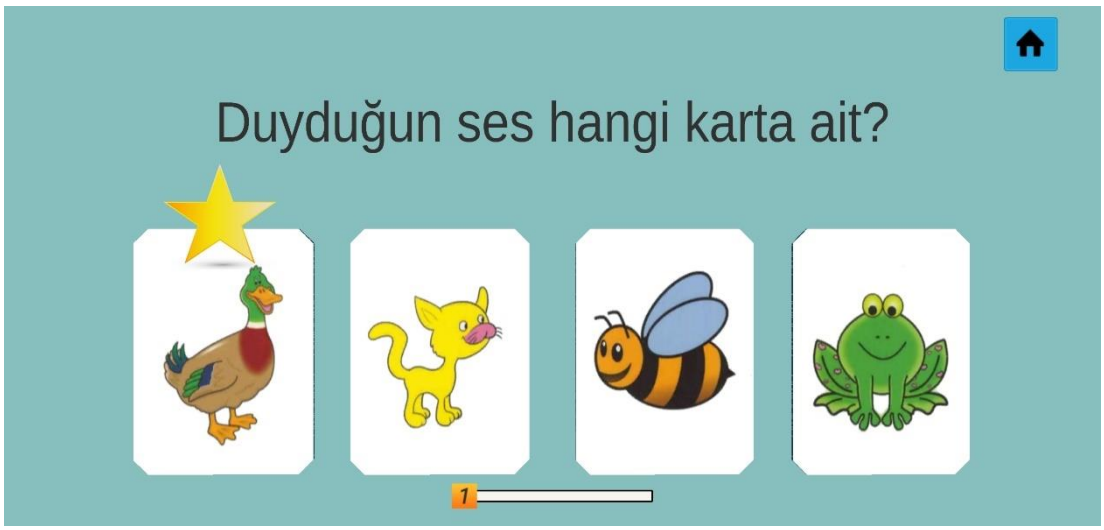

Figure 3.5 : The star demonstrating the correct answer.

On the other hand, if the player choose correct answer, the player hears the confirmation sound and at the same time variegated and animated paper confetti pours down on the screen (Figure 3.6). Two seconds later, new phase of cards enters to the scene.

Figure 3.6 : Confetti.

In order to obtain coherent outcome from all children, same thirteen questions are utilized in the first gameplay of the voice match mode. After the first session, new questions are added among the others.

3.2.2 Shape match game

Within this second mini game, one of the well-known game mode, called shape match, is prepared specially and then new game mechanics are added on it. Furthermore, this game type is pervasive learning method used to teach shapes to children.

First of all, the guide character greets the player (Figure 3.7) and communicates about the objective of the game. After that, visual stimuli appears on the screen as a tutorial and demonstrates how to play the game. At last, the game starts.

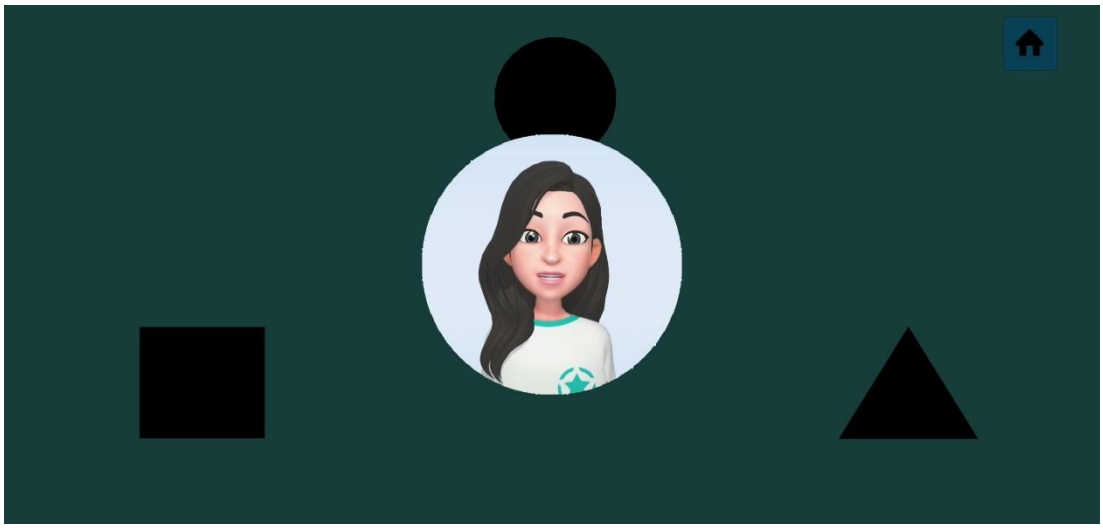

Figure 3.7 : Guide character speaks at the beginning of the game.

For this mini game, mobile devices' accelerometer sensor is utilized as a game mechanic which gives a unique mechanics for this type of game. We have decided to use this feature to detect player's two hands coordination skills and sensitivity of movements. Additionally, the mode generated in 2D (Figure 3.8), graphics are remained very simple to avoid confounding factors. Moreover, black shape targets and the moving object are fitted to the same size with a suggestion of a special education teacher who is specialized in the area of children with autism.

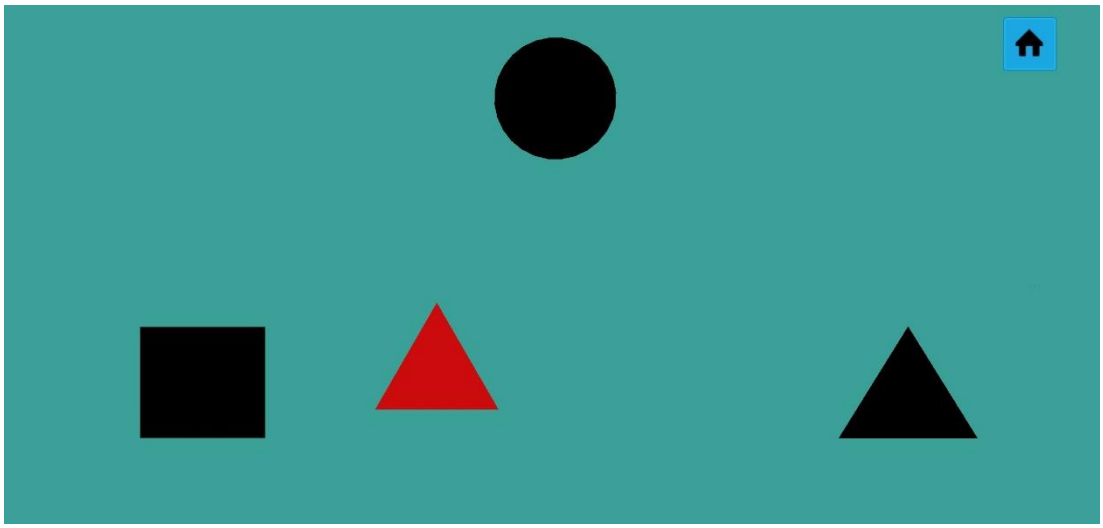

Figure 3.8 : Shape match in-game screen.

Other than that, when player makes correct match, black target's color turns to green, and a success sound plays. If the match is incorrect, nothing happens until the appropriate one. When the player reach the number of predetermined successful

movement, final celebration panel is shown and the player is redirected to the transition scene so that they can choose another game mode.

3.2.3 Color match game

In the third mini game, there is a color match mode which is generated as a 3D game mode. In this mode, there is a turning arrow at the center of the screen surrounded by the cylindrical walls occurred by colors. Player throws an object to the walls from the center to the direction where the arrow points to.

3.2.3.1 Head-Up display (HUD)

There are 4 indicators and buttons on the screen in this mini game mode. One is, as usual, home button that returns to the game mode selection scene. It is located at the top right corner of the screen and has an approval panel to avoid touches by mistake. The other button is only an interaction button which effects directly the gameplay and mechanics. By using it, the player can throw an object located at the center to the direction of where the arrow points to. In addition, there are two indicators on the screen that are placed on the top left part on the screen (Figure 3.9). One of them demonstrate the points player has collected. The other indicator is a slider. It shows the number of correct move count. Also, gives an idea of when will the mini game end.

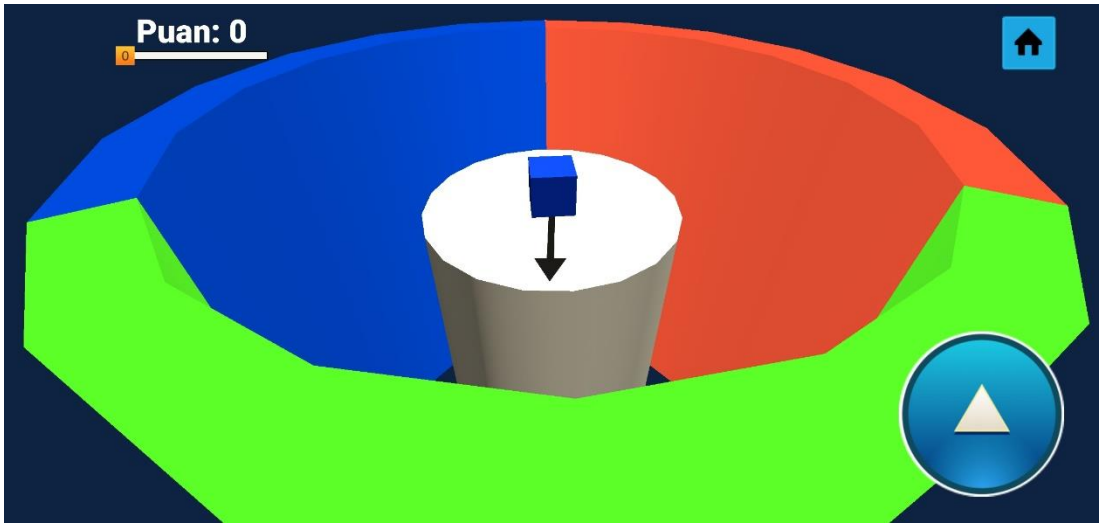

Figure 3.9 : Color match in-game screen.

3.2.3.2 Game play

As mentioned before, there is an interaction button that throws an object to the direction demonstrated by the arrow. Subjects make the move by pressing this button located at the bottom right corner of the screen.

Initially, there are three different colors. These are blue, red and green. In the beginning of the game, an object colored with one of these colors occurs on the screen, this color changes randomly each time after throwing the object. After throwing phase, object crashes to the wall and destroys with the cool splash effect which is created manually on Unity game engine. If crash happens at the wall with the same color, player earns 10 points for each crash and slider indicator proceeds. But if the object hits wrong colored wall, this time black pale splash animation plays with the disappearance of the object (Figure 3.10). Each move has also an auditory stimuli that motivates the player if it is the correct move, or has an ordinary sound if was the incorrect move. The reason not to play a fail sound is, disappointing player or demonstrating their mistakes obviously is not a convenient method for children with ASD.

Three difficulty levels are determined for this game mode. It starts with medium one. Arrow rotates at medium speed. If the game algorithm detects that the player plays better or worse than the starting conditions, difficulty increases or decreases according to the situation.

On the other hand, the camera in the scene rotates 120 degrees at certain times. With this mechanic, intensifying the three dimensional perception is intended. Another reason is preventing the player to get used to current positions of colors.

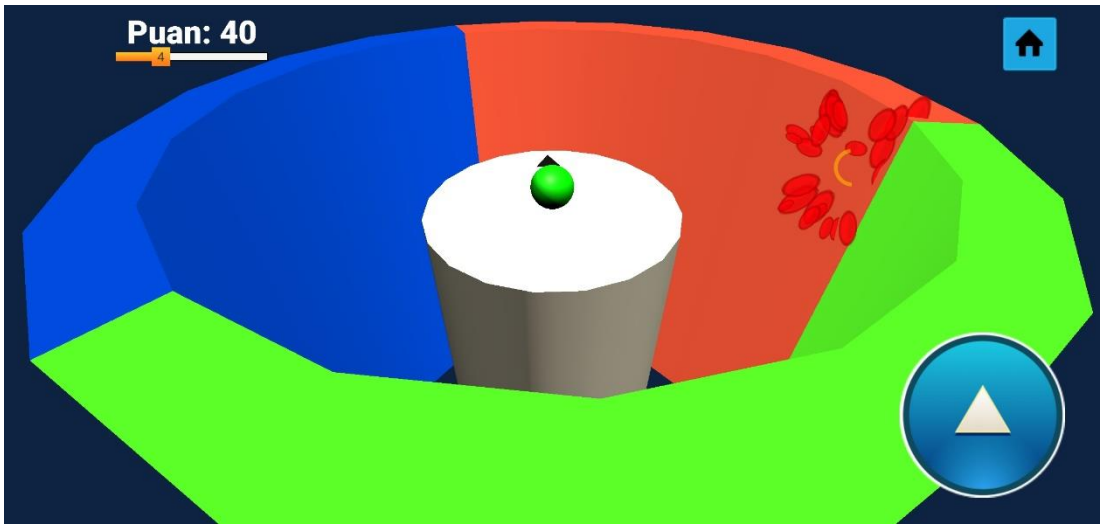

Figure 3.10 : Instance of splash effect.

Eventually, when the score reaches to one hundred and fifty, which means fifteen correct hits, game ends and a final panel appears, applause sound plays, balloons rise and then player is transferred back to the game selection scene

3.2.4 Facial expressions

Facial expressions are the key feature to understand and identify emotions [46]. Research shows that our brains extract information for face recognition, from eyes, eyebrows and the mouth [47].

Especially children with autism frequently fail to understand emotions and make relationship between facial expressions and emotions [48]. Generally, it is difficult to recognize emotions from the upper part of the face [49]. Because, children with autism looks in the faces and eyes less than other children [50,51]. Additionally, it is easy to look in the face on device screen than real life, so we decided to add this game mode on this project.

According to Ekman [52], there are six basic emotions. These are happiness, sadness, anger, fear, surprise and disgust. In this study, we used all the basic emotions except disgust.

In this mini mode, three options are demonstrated (Figure 3.11). Like in card game, correct choices pours confetti and plays applause sound. Wrong answers plays unpleasant sounds which gives a hint about it was wrong option. On the other hand, there are ten questions in this mode for each session.

Figure 3.11 : In-game screenshot of facial expressions mode.

3.3 Parental Screen

This section is specially created for parents and teachers who observe children statistics. Checking statistics and outcomes could be disappointing or can affect moral

or mental status negatively. Therefore, this scene is protected with a password. Thus, only parents and teachers can access to this scene.

Individuals can open password input field by pressing the “ANKET” button where located below the play button on the main scene (Figure 3.12).

Figure 3.11 : Entering to parental panel.

When the individual is authorized to enter the scene, player statistics table is available to her/him (Figure 3.13). In this scene, parents or teachers can see some information about the child and his/her performance. This information contains player’s name, sex, age, session number about how many times he/she played and additional information given by the parent. It also includes player performance such as wrong clicks/movements, correct clicks and total session time. This extra information panel is accessible with human shaped buttons standing at the right side of the screen. They are available for each session per player. In addition, the names in this panel do not represent real player names.

Figure 3.12 : Parental screen.

In addition, not all collected data is demonstrated in this table. It just shows adequate information like spending time and success in games.

4. AUXILIARY SERVICES

Two famous and well known, industry leader technologies are utilized within this project. These technologies are re-designed according to our purpose.

4.1 Samsung AR Emoji

AR Emoji is one of the highly advanced technologies that Samsung releases. There are several reasons to use this technology in this project. Firstly, in this project, the game is developed for Android OS. Samsung also uses android software so it is easy to work with same devices and operating systems. Secondly, as mentioned before, this software is very advanced and easy to prepare and use. And the last reason is customization options. AR emoji presents wide variety of customization choices. From face type to wearing, almost everything in the screen can be modified.

Besides, it is very easy to make animations with this software. Characters can mimic individual's facial expressions using camera view.

Two guide characters are created to meet the purpose of the game. One is a girl and the other is boy (Figure 4.1).

Figure 4.1 : Guide selection panel.

Both characters can speak like a real person with Google's Wavenet voice technology. Guides greets the player, tell them what to do in every scene and makes encouraging speeches during the game. Eventually, they celebrate the player at the end of the game.

Their cloths and views are similar to each other. It is because, we tried to avoid attracting players attention to something else than the game. Player's guide choice is collected as data.

4.2 Google Wavenet Text-to-Speech

Wavenet is Google's Text-to-Speech technology which is best among this type of voice synthesis services. It uses deep neural network to generate synthetic voices. This paid service provides sounds more natural compared to its opponents and speech systems. It can also synthesizes emphasis with words almost like a human (i.e. Figure 4.2).

Within this project, using boy and girl voices were necessary. For this purpose, one woman voice and one man voice were selected among many other voice types. Another reason why this software is chosen is, it is not just providing realistic sounds, but it also provides options such as speed and pitch.

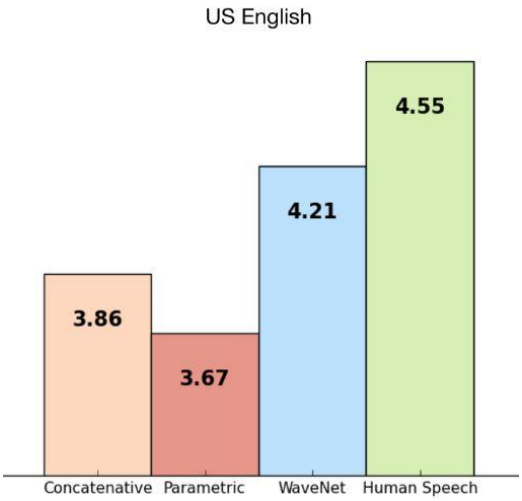

Figure 4.2 : Comparison of WaveNet and other voices.

5. UI / UX FOR SPECIAL CHILDREN

5.1 Feedbacks

Suggestions were received after the first build of the game. Gathering suggestions was useful to improve the game for children. Positive feedbacks was also taken from the children with these changes which are demonstrated in Table 5.1.

Table 5.1 : Educationalist suggestions.

Game Modes	Teacher's Suggestions
Voiced Cards	Number of cards doubled Visual stimuli for success touch Order of the cards randomized
Shape Match	Same size of shapes Auditory stimuli for success moves
Color Match (3D)	Colors set as single tone Dynamic difficulty adjustment
Facial Expressions	Both visual and auditory stimuli

5.2 UI Elements

The game in this project is developed not only for normally developed children but also for children with autism. The attention of children with autism can easily be distracted. Therefore, plain and simple wallpapers are used in the game menus.

The other point is button size. Since children play this game, buttons are designed big and wide. Hence, they could easily manage to click objects and buttons on the screen.

5.3 Win Screen

Rising balloons and applause voices are utilized as a stimuli for this panel (Figure 5.1).

Figure 5.1 : Celebration panel.

6. DATA AND CODES

In this section, the collected data and the way of the collection are included. Examples of the data collected as a demographic data (Table 6.1) and in-game data per session (Table 6.2) below:

Table 6.1 : Demographic data.

Game Session	Player Name	Player Gender	Player Age	Information
1	Player 1	Boy	5	ASD

Table 6.2 : In-game data.

Mini Game	Done/Quit	Time	True	False	TotalClicks
Cards	Done	125 secs.	13	23	40
Shapes	Quit	80 secs.	3	1	-
Colors	Done	136 secs.	15	25	44
Emotions	Quit	58 secs.	3	6	13

In addition to this, the date information, total session time, device information and the guide that is chosen by player is also collected as data.

6.1 Mail System

Mail system is the core feature which is an essential part created in this game. Outcomes are received with an e-mail report.

Initially, automatic mail system is generated and worked fine. The version of that time is tried on 5 different devices and worked on those devices.

Codes of automatic mail script:

```
using UnityEngine;
using System.IO;
using System.Net;
using System.Net.Mail;
using System.Net.Security;
using System.Security.Cryptography.X509Certificates;
public class mono_gmail : MonoBehaviour
{
    public string logFilePathD;
    public void ClickedMain()
```

```
   {
      MailMessage mail = new MailMessage();
     string deviceID = SystemInfo.deviceUniqueIdentifier;
      string deviceName = SystemInfo.deviceName;
      string time = System.DateTime.Now.ToString();
      string language = Application.systemLanguage.ToString();
      string logFilePathS = Application.persistentDataPath + "/Data.txt";
      string logFilePathD = Application.persistentDataPath + "/DataCopied.txt";
      File.Copy(logFilePathS, logFilePathD, true);
      mail.Attachments.Add(new Attachment(logFilePathD));
      mail.From = new MailAddress("MyMail ");
      mail.To.Add("MyMail ");
      mail.Subject = deviceName;
      mail.Body = "Player Data" + "\n" + "Device ID : " + deviceID + "\n" + "Time
: " + time + "\n" + "Language : " + language;
     SmtpClient smtpServer = new SmtpClient();
      smtpServer.Host = "smtp.gmail.com";
      smtpServer.Port = 587;
      smtpServer.DeliveryMethod = SmtpDeliveryMethod.Network;
      smtpServer.Credentials = new System.Net.NetworkCredential("MyMail",
"MyPassword") as ICredentialsByHost;
      smtpServer.EnableSsl = true;
      ServicePointManager.ServerCertificateValidationCallback =
         delegate (object s, X509Certificate certificate, X509Chain chain,
SslPolicyErrors sslPolicyErrors)
            { return true; };
      smtpServer.Send(mail);
      Debug.Log("success");
      Invoke("DelCopied", 1);
}
private void DelCopied()
{
      File.Delete("/DataCopied.txt");
}
}
```

After first release, an error was noticed that affects some devices and data could not obtained from these devices. After that situation, secondary and supportive manual mail system was placed into game. This method uses stock mail application, opens it and puts all data obtained in it. Manuel mail system is generated with the following script:

```
public void SendEmail()
   {
      string email = "autigame34@gmail.com";
      string subject = MyEscapeURL("Rapor");
      string myReport = AllAppended;
      string body = MyEscapeURL(myReport);
```

```
    Application.OpenURL("mailto:" + email + "?subject=" + subject + "&body="
+ body);
  }
  string MyEscapeURL(string URL)
  {
    return UnityWebRequest.EscapeURL(URL).Replace("+", "%20");
  }
```

6.2 Data To Text

With this project, some demographic information and other data which belongs to player's game performance was obtained. As mentioned before, game uses mail system to send data to our mail service. Actually, the mail system sends the text file created internally.

There are variety of save method in the Unity game engine. One of the famous one is PlayerPrefs. It is very simple and powerful method to save some variables. The data we collect is considered large. So, in order to not give redundant information, just a part of the code is provided below.

```
a = PlayerPrefs.GetInt("Session");
string path = Application.persistentDataPath + "/Data.txt";
File.WriteAllText(path, "");
for (int i = 1; i <= a; i++)
    {
      string session = PlayerPrefs.GetInt("SessionNumber" + i).ToString();
      string name = PlayerPrefs.GetString("PlayerName" + i);
      string sex = PlayerPrefs.GetString("PlayerSex" + i);
      string age = PlayerPrefs.GetString("PlayerAge" + i);
      string info = PlayerPrefs.GetString("PlayerInfo" + i);
      string time = PlayerPrefs.GetInt("Time" + i).ToString();
      string wrong = PlayerPrefs.GetInt("Wrong" + i).ToString();
      string True = PlayerPrefs.GetInt("True" + i).ToString();

      string All  = session + "," + name + "," + sex + "," + age + "," + info + ","
      + "\n" + "Kartlar" + "," + doneWrite + "," + notDoneWrite + "," + time +
      "," + True + "," + wrong;
      if (!File.Exists(path) || (File.Exists(path))) //create file if it does not exists
            {
              File.AppendAllText(path, All);
            }
      }
```

And then, text file is attached to mail.

6.3 Google Wavenet

According to synthesis voices that required, Wavenet's easy-to-use API is utilized and program.cs script generated given below:

```
using Google.Cloud.TextToSpeech.V1;
using System;
using System.IO;
namespace TextToSpeechApiDemo
{
   class Program
   {
      static void Main(string[]&nbspargs)
      {
         var client = TextToSpeechClient.Create();

         var input = new SynthesisInput
         {
            Text = "Example sentence."
         };

         var voiceSelection = new VoiceSelectionParams
         {
            LanguageCode = "tr-TR",
            Name = "tr-TR-Wavenet-B",
            SsmlGender = SsmlVoiceGender.Male
         };

         var audioConfig = new AudioConfig
         {
            SpeakingRate = 1.11,
            Pitch = 6,
            AudioEncoding = AudioEncoding.Linear16

         };

         var response = client.SynthesizeSpeech(input, voiceSelection, audioConfig);

         using (var output = File.Create("exampleSentence.mp3"))
         {
            response.AudioContent.WriteTo(output);
         }
         Console.WriteLine("Audio content written to file \"
exampleSentence.mp3\"");
      }
   }
}
```

7. RESULTS AND EVALUATION

Data evaluation with machine learning methods, and additionally, player states according to the questionnaire have been examined. According to the results and outcomes, we can say that both data analysis function and fun factor are successfully provided with the game.

In the game, the data was evaluated with Weka3 software as planned with my supervisor. Weka is an easy to use machine learning and data mining program. Data was loaded to the system and evaluated according to being whether it is ASD positive or not.

Totally 30 instances used in the dataset that each includes 20 attributes given in chapter 6. High accuracy classifications were obtained with chosen methods (Table 7.1). A single layer perceptron (SLP) and random forest methods are utilized for our goal. SLP method provided the best solution with 88.88% success rate by means of correctly classified instances. In addition, for this classification 70% of data used for training and 30% of data used for testing.

Table 7.1 : Classification.

Classification Method	Accuracy of Classification
RandomForest	76.66 %
Single Layer Perceptron	88.88 %

When the game delivered to children through families and educators, we stated that we were asking them to fill out a questionnaire. While the children were playing the game, they were under the supervision of the teachers and families, by this far their reactions and emotions were observed. Totally 31 parents and teachers are participated to questionnaire.

In this survey, there are questions assessing player's diagnosis state, emotional state, like or dislike status, understanding of the game, opinions about the virtual character and general review about game.

The participation rates of children are indicated in the Figure 7.1.

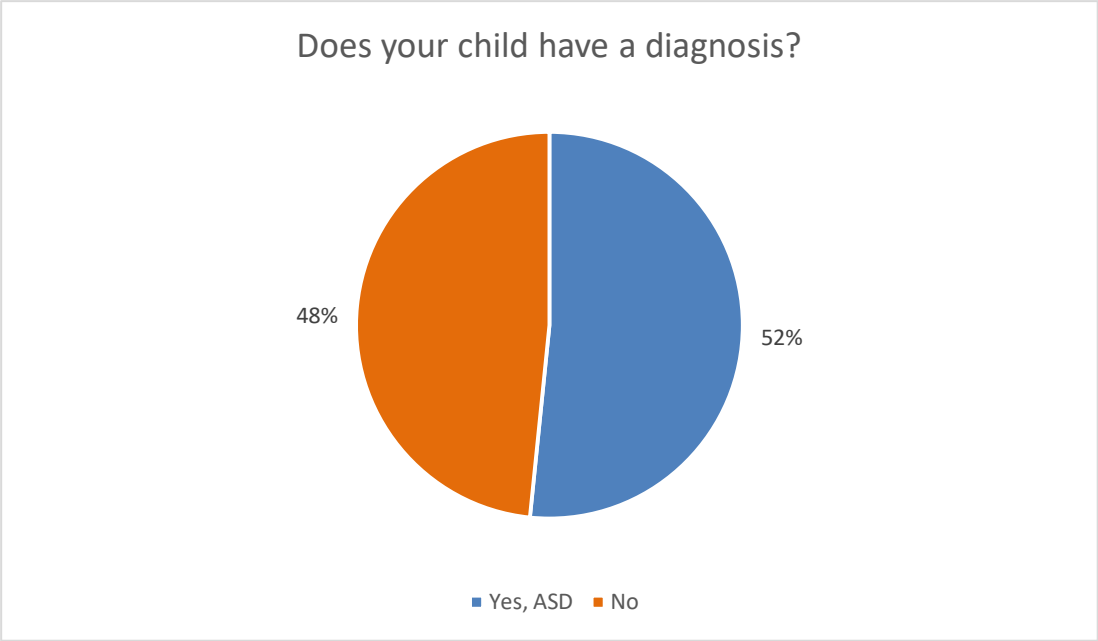

Figure 7.1 : Player rate.

Forty percent of those who were interested and liked the game (Figure 7.2) have ASD. This demonstrates that not only normally developed children but also children with autism were interested in the game within the group we reached.

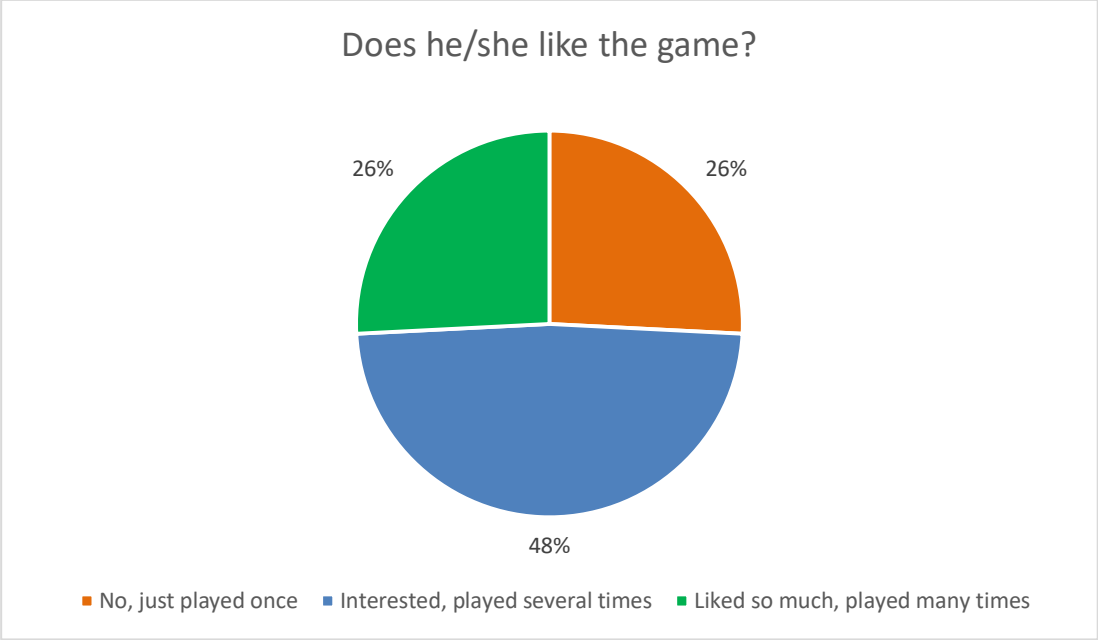

Figure 7.2 : Distribution of likes.

On the other hand, players' interest against mini-games was also observed. Voice match game was the most popular game mode during the tests and children liked to play this minigame much more than others (Figure 7.3).

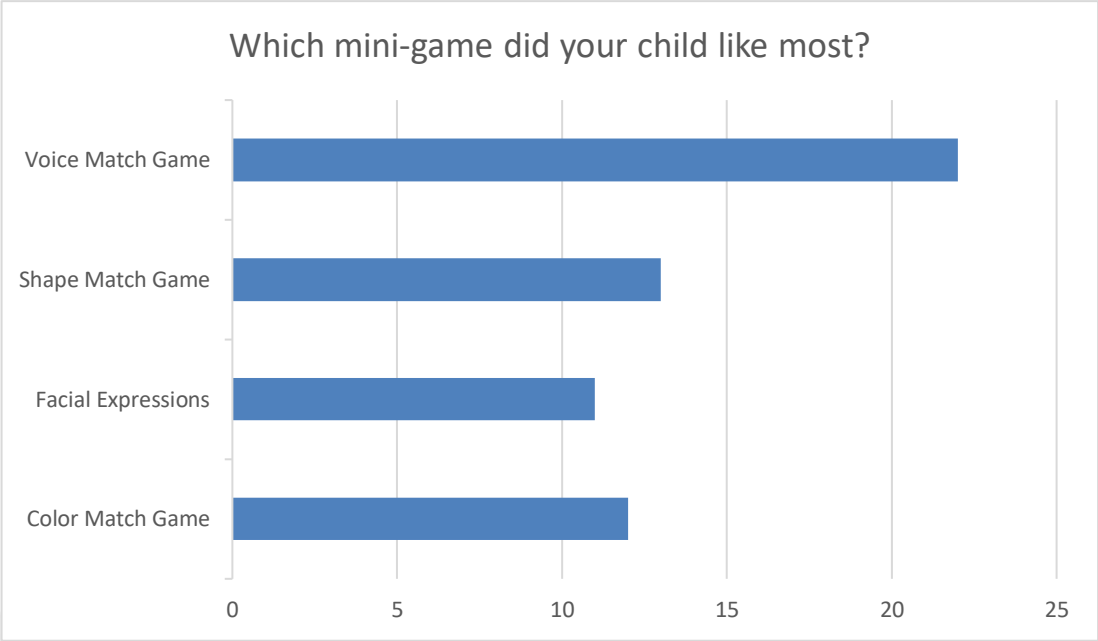

Figure 7.3 : Mini-games popularity.

Children found color match game more difficult than the others (Figure 7.4) but only 25 percent of these children were diagnosed with autism. The reason for this is that attraction with colors and 3D environment could attract the children with autism.

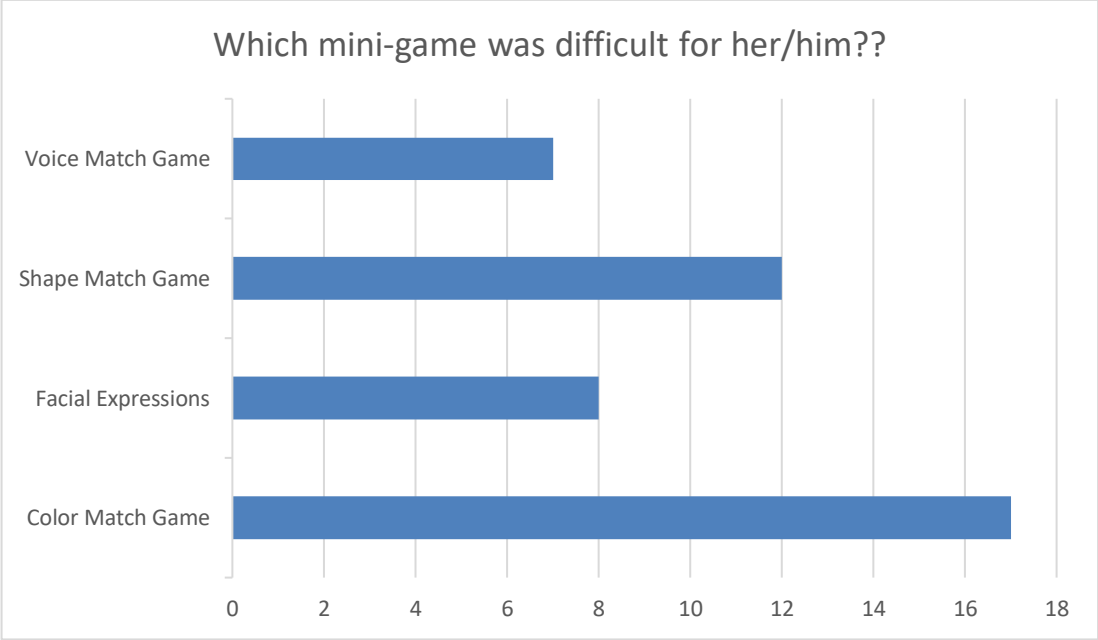

Figure 7.4 : Difficulty of game modes.

Generally, we received very positive feedback from families. They stated that they think the game was very instructive for their children. According to both family feedback and the children we observed, almost all of the children were very happy and excited. This showed that the entertainment factor was also exist besides the primary

goal of the game which is testing. As we can see in the Figure 7.5, the vast majority of children had fun, have been happy and excited.

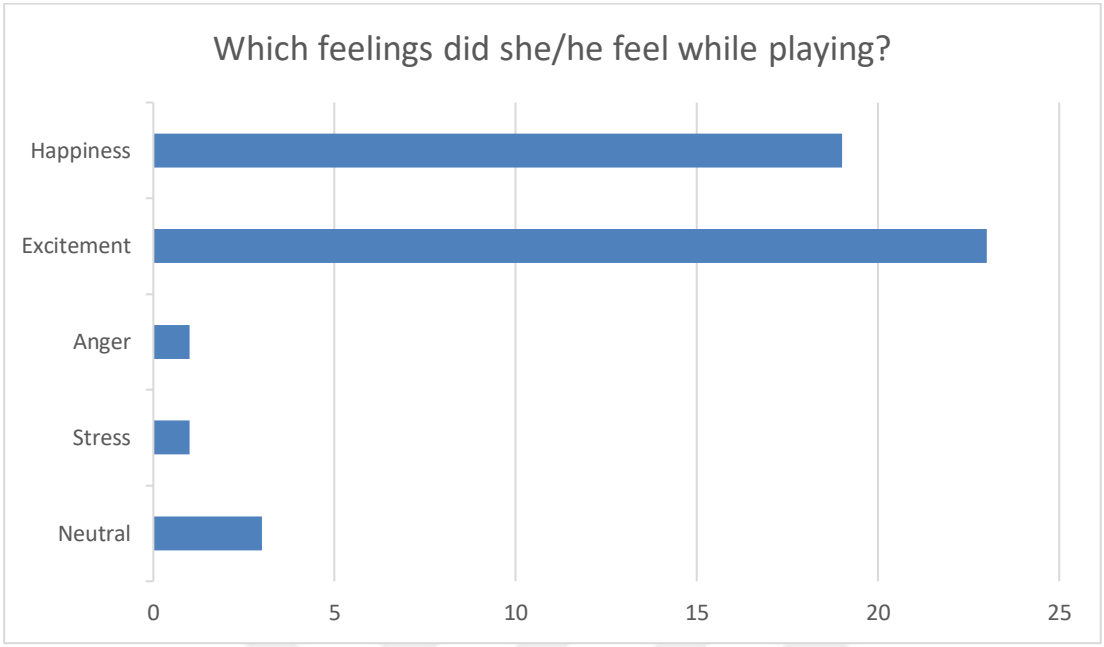

Figure 7.5 : Feelings while playing.

As the feedbacks are examined, it was clear that many of the children could play the game without help or with a little help (Figure 7.6). Thus, it has been determined that the audio and visual helpers in the game were sufficient. Only 13 percent of children could not understand and make progress and all of these children are children with autism.

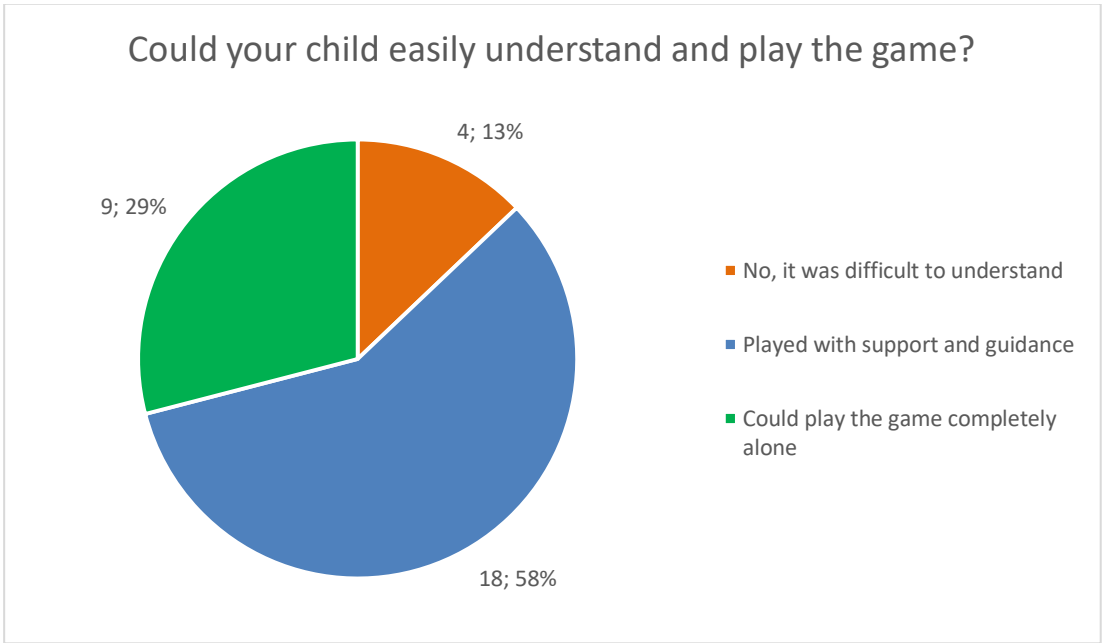

Figure 7.6 : Intelligibility of the game.

As mentioned before, cartoonish style guide characters are designed and used in the game to help players. It was also checked if the children liked this character or not (Figure 7.7).

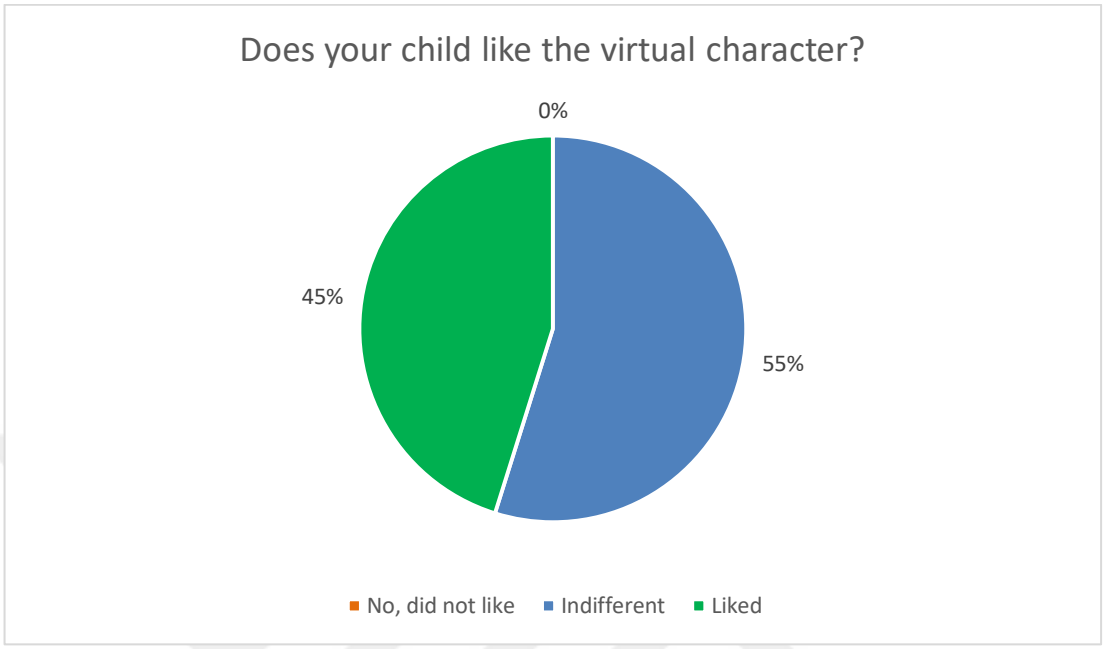

Figure 7.7 : Thoughts about virtual character.

8. CONCLUSION

In this thesis, a theory of mind and concept learning based mobile game has been designed and developed for the children with communication impairements, especially children with Autism. The games are tested with both children with autism and children with typical development, and the results and feedbacks are successful and motivating for the future studies. Even though children with autism have common symptoms, every child is unique and has different characteristics than others. Despite this difficulty, we were able to catch a similar patterns in the same group and classification difference between different children groups via game statistics.

Although it is serious game, it has fun factor. It is obvious that the game entertain children while playing according to observations and survey reports. It is important to make serious games more enjoyable despite their first goal is testing or educating. According to the outcomes, this criteria was provided by this project.

As a future work, the game will be developed according to outcomes and feedback taken from both parents and teachers. For expand the scope, multi-language system will be implemented which already have been started to improve. Besides theory of mind and concept learning, another methods will be studied and new game modes will be activated.

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CURRICULUM VITAE

Name Surname **: Baransel Can Gülkanat**

Place and Date of Birth **: İstanbul 04/03/1991**

E-Mail **: baranselgulkanat@gmail.com**

EDUCATION **:**

- **B.Sc.** **:** 2016, Pamukkale University, Faculty of Engineering, Mechanical Enginnering Department

PROFESSIONAL EXPERIENCE AND REWARDS:

- 2016 Yılmaz Machine
- 2014 Tuzcu Heat Group
- 2012 Unilever