COMPARING MOBILE GAME INTERACTION METHODS IN TERMS OF PLAYER ENGAGEMENT: GAZE AND VOICE COMMANDED CONTROL METHOD VS. TOUCHSCREEN CONTROLS

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ABSTRACT

COMPARING MOBILE GAME INTERACTION METHODS IN TERMS OF PLAYER ENGAGEMENT: GAZE AND VOICE COMMANDED CONTROL METHOD VS. TOUCHSCREEN CONTROLS

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The purpose of this thesis is to compare two human computer interaction methods in a mobile game interface; the touchscreen controls and a novel multimodal method which is a combination of gaze and voice commands. A user experiment was conducted to collect gameplay data from participants playing a 2D runner-platformer game called "Neon Glider". After the participants play the game by using two interfaces separately, a user questionnaire was applied to analyze players' engagement level for both interfaces that provided two methods of game control. Gameplay data show that the participants were more successful when they controlled the game by touchscreen controls. However, they spent more effort for controlling the game with this technique. The questionnaire results revealed that the participants were more involved into the game in that they felt scared, different and spaced out when they controlled the game by gaze and voice commands. The results have also shown that they felt psychologically absorbed with the gaze-voice interaction method. These outcomes do not give a definitive result but surely participants felt a little higher level of engagement with this new method.

Keywords: Eye Tracking, Voice Command, Mobile Games, Touchscreen Controls, Multimodal Interaction

ÖZ

MOBİL OYUN ETKİLEŞİM YÖNTEMLERİNİN OYUNCU BAĞLILIĞI YÖNÜNDEN KARŞILAŞTIRILMASI: GÖZ VE SES KOMUTLU KONTROL YÖNTEMİ VE DOKUNMATİK KONTROLLER

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Bu tezin amacı, bir mobil oyun arabiriminde iki insan bilgisayar etkileşim yöntemini karşılaştırmaktır; bunlar dokunmatik kontrol yöntemi ile yeni çok biçimli bakış ve ses komutlu yöntemdir. Kullanıcılardan oyun içi veri alabilmek için, kullanıcılara "Neon Glider" adlı iki boyutlu bir koşu-platform oyunu oynatılıp bir kullanıcı deneyi yapılmıştır. Oyun bu iki farklı kontrol yöntemiyle oynandıktan sonra, katılımcıların bu kontrol yöntemleri için oyuna bağlılık seviyelerini ölçen bir kullanıcı anketi uygulanmıştır. Oyun içi veriler, katılımcıların oyunu dokunmatik kontrollerle kontrol ettiklerinde daha başarılı olduklarını göstermektedir. Ancak oyunu bu teknikle kontrol ederken daha fazla çaba harcamışlardır. Anket sonuçları katılımcıların bakış ve ses komutlu yöntem ile oyunu kontrol ederken oyuna daha fazla dâhil olduklarını ortaya koymuştur; çünkü oyunu bu teknikle kontrol ederken korkmuş, normalden farklı ve ortamdan atılmış hissetmişlerdir. Sonuçlar aynı zamanda katılımcıların bakış-ses etkileşim yöntemiyle psikolojik olarak soğurulmuş hissettiklerini göstermiştir. Bu sonuçlar kesin olmamakla birlikte kuşkusuz katılımcılar bu yeni yöntem ile oyuna biraz daha yüksek seviye bir bağlılık hissetmişlerdir.

Anahtar Kelimeler: Göz İzleme, Sesli Komut, Mobil Oyunlar, Dokunmatik Kontroller, Çokbiçimli Etkileşim

dedicated to the guide of my life,
my grandpa, Yılmaz Küçükyeşil;
and to the light of my life,
my grandma, Kudret Küçükyeşil...

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I would like to thank my parents, my mother Sevgi and my father Eşref; who were always supportive to me all the time, with every adventure that I've entered in my life. I am and I always will be proud to be their son. I also thank my brother Çağrı and my sister-in-law Nesrin, who were always there for me when I need and loved me no matter what. There are not enough words to describe the importance of my family's support and love, for that I will be eternally grateful.

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I dedicated this thesis to my grandpa Yılmaz and to my grandma Kudret; who are the inspirations for my imagination, the sources of my passion, the purposes of my commitment to my work and the hopes that I replenish every day. There has been not a single day that I do not miss them; they are lost but never forgotten.

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LIST OF ABBREVIATIONS

DLL	Dynamic-link Library
SR	Speech (Voice) recognition
SAPI	Speech Application Programming Interface
GEnQ	Game Engagement Questionnaire
EMG	Electromyography
FPS	First Person Shooter
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
ANOVA	Analysis of Variance

CHAPTER 1

INTRODUCTION

Computer games are electronic games that are played by manipulating an input device in response to the graphics on screen. Commonly used input devices are mouse-keyboard combination, gamepad and touchscreen. Touchscreen controls are on the rise in recent years because of the rising trend of mobile devices in the market. [1]

Mobile device is a small computer device, generally small to be handheld, having a screen with touch input and/or a mini keyboard. With the progression of hardware specifications of the mobile devices, they are widely used for playing games. Hence, the performance of mobile games is increasing day by day. The revenues of mobile gaming industry are increased 21% percent from 2015 to 2016. [2] Nearly all computer game genres can easily be adopted by the mobile platforms nowadays.

In the thesis, a multimodal control method was applied to a runner-platformer game which the author has coded in a collaborative researcher team. A combination of gaze and voice commands was employed for controlling the main character in the game, as a novel multimodal interaction method against the traditional mobile game interaction method, viz. touchscreen. Gaze data were collected by an eye tracker device and voice data were collected by a microphone, which are explained in detail in further sections.

Expected results of the thesis was that the participants would be successful in terms of their success rate in the game and they would feel a high level of engagement by using gaze and voice control method. With achieving this, the usage of this new gaze-voice control method for mobile devices may be encouraged and supported.

1.1 Research Question

The main objective of our thesis is offering a new, efficient and successful game control method to the mobile platforms, while the users of this control method having engagement into the game.

We wanted to find whether gaze and voice commands could be coupled effectively as a game control method in comparison to touchscreen controls in a mobile game environment. The gameplay data we obtained from the experiment will measure the success of this method in a fast-paced platform game and the questionnaire data about player engagement will evaluate the players' engagement level to the game.

1.2 Thesis Layout

Chapter 2 presents the background of the hardware and software used in the research setup and the earlier work has been done so far in this area. Chapter 3 describes the game design and the experiment layout of the thesis. In Chapter 4, experiment procedure is presented and after that; the results of the experiment are presented in Chapter 5. Chapter 6 discusses the findings of the thesis; and in Chapter 7, the thesis is concluded with the opinions about the future studies for this topic.

CHAPTER 2

RELATED WORK

As the mobile games spread, more people meet the computer game world. Gaze-based human-computer interaction in this world is a novel method, especially using gaze as one of the modalities in multimodal systems. Our goal in this thesis is to fill in this gap in the literature by means of a comparative analysis of two alternative human computer interaction methods. Result of this work may contribute to improvements of gaze-based game control methods for not only the people with normal motor capabilities but also the disabled population who lack some motor capability.

In particular, with our design in the thesis, it may be possible to offer alternative and novel human computer interaction methods to play a mobile video game.

This chapter consists of two parts: a review of previous work that aimed at measuring player engagement and the previous usage examples of eye tracking in applications and games.

2.1 Player Engagement in Computer Games

We reviewed previous work about player engagement in this section and discussed the usage of subjective measures.

Engagement in games is that a player reaching a level of near-obsessiveness. It is commonly described as deep play. [3] Engagement may be target-related or empathic, where target-status evaluations depended on target-related engagement though players build an empathic engagement. [4]

Jennett et al. [5] asks if immersion can be measured quantitatively. Their findings suggest that it can be done. They used task completion times and eye movements to measure this and found that immersion gives not only a positive experience but also some suboptimal emotions and anxiety to the players.

Weibel et al. [6] examined *presence, flow* and *enjoyment* concepts in an online game by comparing human-controlled opponents with computer-controlled ones. Their findings reveal that participants who are in the face of human-controlled opponents felt these feelings deeper. When they analyzed thoroughly, they saw that flow arises from the relation of presence and enjoyment.

In a related study, Chanel et al. [7] offered an approach based on emotion recognition to preserve player engagement in a game by changing the game difficulty accordingly. They classified that there are three emotional classes which are boredom, anxiety and engagement. Analyses they had stated that playing a game on same difficulty level over and over again caused boredom. Furthermore, Liu et al. [8] investigated dynamic difficulty adjustment mechanism for computer games to achieve a high level of challenge and enjoyment, hence flow. They measured anxiety level of the participants with the help of his physiological signals. The study gives a promising result that measuring players' emotion levels quantitatively gives a good challenge for a better gameplay.

Carrigy et al. [9] designed a location based mobile game and evaluated the player experience in it. Their main focal point was engagement and immersion of the players in game. Their results suggest that their experiment setup created a high level of immersion at some stages and this could be influenced by some factors like usability, control, interaction methods, aesthetics and flow.

Table 2.1: Classifications of player engagement framework

Components	**Sub-components**
Objectives	Extrinsic, Intrinsic
Accomplishment	Completion, Progression, Achievement
Activity	Experiencing the Story, Socializing, Sensing, Exploration, Experiencing the Characters, Solving, Experimentation, Interfacing, Destruction, Creation
Affect	Positive, Absorption, Negative

In order to understand player engagement and experience, Schoenau-Fog [10] developed a process-oriented framework which consists four main components. These components are objectives, activities, accomplishments and affects. Classification of these components can be seen from Table 2.1.

Boyle et al. [11] did a comprehensive literature survey on player engagement and categorize these studies by some aspects which are subjective experience, physiological responses, motives for playing, game usage, loyalty to the game and impact of game on life satisfaction. This review of previous work considered engagement in games with positive feelings, but also referred the need to investigate in depth the fragile equilibrium between positive and negative emotions.

In these previous studies, researchers concentrated on investigating player engagement from the points of immersion, presence and flow which were explained in the following subsection. They defined some key concepts in player engagement and argued whether these concepts could be measured qualitatively and quantitatively. We benefit from their work and use these for measuring player engagement with a questionnaire in a gaze and voice controlled mobile game.

2.1.1 Game Engagement Questionnaire (GEnQ)

In the present study, GEnQ was employed for measuring the engagement level of the new multimodal game control method. Brockmyer et al. [12] stated in their previous work about the development of it that they wanted to fill the gap of having no reliable measurement for evaluating engagement in computer games and created the questionnaire which includes 19 questions. It is evaluated by means of a 1 to 7 scale which the ordered values are strongly disagree, disagree, slightly disagree, neutral, slightly agree, agree and strongly agree. GEnQ items can be found on Appendix A.

GEnQ includes concepts such as *immersion, presence, flow* and *psychological absorption*; which were introduced to the literature long before Brockmyer et al. Immersion is the experience of becoming engaged in gameplay experience while keeping some of the awareness of the surrounding environment. [13] Presence is having the experiences of being inside a virtual environment. [14] Flow is the feeling of enjoyment which happens when stability between skill and challenge is achieved while performing an intrinsically rewarding activity [15] and the psychological absorption is the total engagement in the present condition. [16]

The questions of GEnQ belong to the four modules accordingly. From the definitions, psychological absorption may be conceived as the concept which has the highest level of engagement. If one or preferably more of these modules were acquired by the participants in our novel game control method, we can say that their engagement level is better than the traditional mobile game control method.

In the following section, we review the use of eye tracking as an input modality in games.

2.2 Using Eye Tracking in Computer Games

The use of gaze as an input modality in games is a relative recent topic compared to the use of haptic or touch-based devices, such as keyboard, mouse and joystick. Spakov and Miniotas [17] created a chess game called "EyeChess" to evaluate the possibility of using gaze input in computer games. Their players gazed at the piece first and a specific grid after then to move a chess piece to the intended location. The players were able to select the piece with three methods: dwell time, blink and an eye gesture. Blinking and eye gesture gave them a little fatigue; preferred selection method among the players was dwell time. In our thesis, we also used dwell time, but our time period was very small; one look is enough to complete the appropriate action.

Jönsson [18] conducted one of the first studies in the literature to evaluate using gaze input in a computer game. Three different game prototypes were developed for evaluation; a shoot'em up game where the user aimed with his eyes, a first person shooter game where the user controlled the weapon, and another first person shooter game where the user controlled the view of sight this time. The participants reported that gaze input was easy to learn and more enjoyable than mouse control in the light of game experience they had.

Isokoski and Martin [19] followed Jönsson [18] and in their work, they evaluated the efficiency and effectiveness of gaze input in first person shooter (FPS) games rather than including only the user impressions. They found that adding eye-tracker support to an FPS game not generally improves player performance. However, they speculated that using gaze input as one of the multimodal inputs might improve this unless the other input modality is mouse or keyboard. The usage of voice commands as a complementary method for gaze commands in our thesis might support this idea.

Dorr et al. [20] developed a breakout game clone which could be controlled by either a mouse or by gaze direction. A small tournament was held and participants of the trial found gaze control method very enjoyable. Also a statistical analysis was done and it showed that the participants, who played the game with gaze control method, were more successful on the average. Castellina and Corno [21] on the other hand, presented six different control methods for interaction in computer games and conducted a usability study on these methods. The study was not limited only a specific method or a specific game, it uses the combination of these. The participants of the study interested in these new control methods heavily.

Gowases et al. [22] measured the effects of using gaze input as an input modality for computer games on user experience and immersion. They found that the participants felt more immersed with gaze control method; though mouse control method was the easiest and most conventional way to solve in-game problems. The feeling of being in the game is an important factor for us in our thesis too.

Agustin et al. [23] used two commonly used tasks in computer game control, target acquisition and target tracking in their study. In their first study, performance of gaze input was similar to mouse input and was better than the gamepad. In the second study, they compared target acquisition performance between using gaze or mouse for pointing and mouse or electromyography (EMG) for clicking mutually. Gaze and EMG combined control method was faster than only mouse used control method. This work also supports addition of a complementary modality to the gaze.

Nacke et al. [24] investigated gameplay experience in a gaze interacted game by using a questionnaire which is Game Experience Questionnaire (GExQ). Their findings indicate that using gaze as a control method in a game provides a positive game experience, feeling in the flow of game and feeling immersed. It was also found a relationship between autotelic experience and immersion.

Isokoski et al. [25] benefit from the previous studies and offered a classification for conventional computer games with the aim of using it in games which can be controlled by gaze input. This classification can be seen from Figure 2.1. Gaze controlled gaming seems promising according to the authors. According to their classification, our game in the thesis have a positive indicator (one player mode) and a negative indicator (dissociation of focus of attention and control).

Istance et al. [26] used gaze input in a massively multiplayer online game. This has been known as the first of its genre. They mimicked mouse and keyboard input and used this in navigating and interacting in the game with gaze input. The participants of the study successfully interacted with the game for basic events and they showed a similar performance to mouse and keyboard input.

Muñoz et al. [27] introduced the concept of using gaze as a single modality for controlling the game character in a fast-paced platform game. They analyzed where the participants looked most while they were playing the game and made an inference about the meaningful information a game designer may use to create a successful game control method. Position of the participants' eyes was used as inputs of an artificial neural network and its results showed a promise towards the development of gaze controlled platform games.

Game genre	Indicators for eye tracker use						
	Positive		Negative				
	One player mode	Turn-based gameplay	Online multiplayer	Online real-time multiplayer	Continuous position control	Dissociation of focus of attention and control	Large number of commands
Board games and puzzles	x	x	x				
Card games	x	x	x				
Shoot-em-up	x				x	x	
Beat-em-up	x				x	x	x
First person shooters	x			x	x		
Flight simulators	x			x	x	x	x
3rd person action and adventure	x						x
Level jumping (platform)	x				x	x	
Turn-based Strategy	x	x	x				x
Real-time strategy	x			x			x
Turn-based role playing games	x	x					x
Real-time role playing games	x			x			x
Racing	x			x	x		

Figure 2.1: Positive and negative indicators for eye tracker usage compatibility of a game genre, extracted from Isokoski et al. [25]

Nielsen et al. [28] compared performance and user experience of gaze and mouse interaction a simple 3D flying game. It has only one action which is steering the plane. Mouse interaction provided better performance, however the participants played the game with gaze interaction reported that they were more entertained and engaged.

Prada [29] stated in a thesis study that implementing a gaze based interaction method to give players in-game assistance might improve players' performance. Time needed to finish the game was significantly decreased with developed setup and many of participants found gaze controlled game more fun than traditionally controlled version. Immonen [30] investigated the use of the gaze input in a racing game. The participants found gaze control method intuitive and easy to learn. Results suggest that automating some of the controls may help the people with disabilities for playing such games.

Vidal et al. [31] proposed gaze interaction as a game mechanic to enhance user actions and developed a game from scratch which the characters in game gave social feedbacks like getting annoyed by the gaze of the player. Their players reported that it was an intuitive experience; they felt more immersed and revealed their self-consciousness. Our game genre is not proper for this type of interaction; however, immersion factor is an important thing to consider in our game also.

Velloso et al. [32] used Manual and Gaze Input Cascaded (MAGIC) pointing techniques in a FPS game to adjust cursor speed according to the gaze point on the screen. They evaluated the performance and found no significant benefit but user preference in favor of the technique. Ejdemyr [33] implemented a gaze based interaction method into a first person adventure game to improve player performance and immersion. Participants played two versions of the game, the one with gaze and the one with not. The results revealed that performance of the players was not improved, yet most of them felt more immersed with gaze integrated game.

Petrini and Forslin [34] employed a brain computer interface as a complementary modality to gaze input. They used gaze or mouse input for camera rotation and aiming, and brain computer interface or mouse input to shoot a target; and all of the different combinations of these were evaluated. Their findings revealed that gaze and brain computer interface inputs resulted in a decrease of the player performance.

Velloso and Carter [35] reviewed the previous work on using gaze interaction method in games. They investigated the previous papers and theses from input type and game mechanics perspective. Input types they mentioned were discrete, continuous and combination of these. In the game mechanics perspective they chose to address the most common parts that all computer games have as these were navigation, aiming, selection, implicit interaction and visual effects. They contributed to design paradigms of these types of games and gave useful insights about common opportunities and pitfalls that researchers can benefit.

Van der Kamp and Sundstedt [36] investigated whether the gaze input and voice command can be used as a cursor and a command tool for drawing respectively in a computer drawing program. The paper shows that the participants of the study felt less control, speed and precision than mouse and keyboard. All of the participants suggest that it could be easier to use the new control method if they have more practice with it. They surely think that disabled users would take advantage of this new method for drawing. It can be seen that practicing is essential with novel control methods to have a better usage performance.

Wilcox et al. [37] made the first gaze and voice controlled game called "The Revenge of the Killer Penguins". It was a 3rd person adventure puzzle game and they used a focus group to measure the effects of this novel multimodal control method. They did not conduct a user study though; so their findings were limited only to a few topics like the importance of good game design in the games which use the eye tracking technology.

O'Donovan et al. [38] created a new game called "Rabbit Run" which could be controlled by both gaze and voice combination and also keyboard and mouse combination. They compared the gaze and voice multimodality with mouse and keyboard and evaluated these two methods statistically in this context. The participants in their study felt a higher level of immersion when they play the game with gaze and voice combined control method. Despite that, the participants performed worse than the first method. Their results showed that coupling the gaze commands with voice commands might be a good practice if it is applied rightfully, maybe with a different game setup or with a different game genre.

To conclude this chapter, our review of the literature suggests that there are divergent findings about the use of gaze as an input modality in games. One of the difficulties with gaze gaming is that the players do not control gaze easily since gaze control is more automatic, thus difficult; compared to alternative motor controls, such as hand control. The review of the literature, on the other hand, also reveals that complementary modalities may facilitate player engagement in gaze-based games. Therefore in this study, we employ voice commands as a complementary modality to gaze control. In the following chapter, the technical structure and the game environment will be presented.

CHAPTER 3

BACKGROUND AND DESIGN

This chapter consists of two parts: The introduction of the technical structure that were designed and employed to collect data and the design of game environment.

3.1 Game Infrastructure

The game infrastructure involves various aspects; such as the programming language that were used for the implementation, the game engine, eye tracking equipment and voice recognition setup as presented below.

3.1.1 Selected Programming Language and Game Engine

C# was used for the implementation of the game. It is a multi-paradigm programming language which encompasses strong typing, imperative, declarative, functional, generic, object-oriented, and component-oriented programming disciplines. It was developed by Microsoft within its .NET initiative. [39] C# is amongst the programming languages that Unity game engine supports; so it is selected the main programming language for this research.

Unity was used as a game engine in the present study. It is a cross-platform game engine developed by Unity Technologies and used to develop video games for nearly all of the gaming platforms including PC and mobile devices. [40] Unity-made games are installed 5 billion times and are played by 770 million people. There are 1.7 billion mobile devices which have at least one Unity-made game. It is one of the most popular game engines in the market. [41] [42] The development platform of Unity for our game is shown in Figure 3.1.

Eye tracking and voice recognition capabilities was not built-in on Unity game engine, so there was a need to develop some custom components. For eye tracking, a dynamic-link library (DLL) which developed by EyeTribe company was used. [43] For adding voice recognition capability, a new console application and a DLL file which provided intercommunication in the local network were developed by the author and added into the game structure. This application only recognizes the appropriate commands for the game environment.

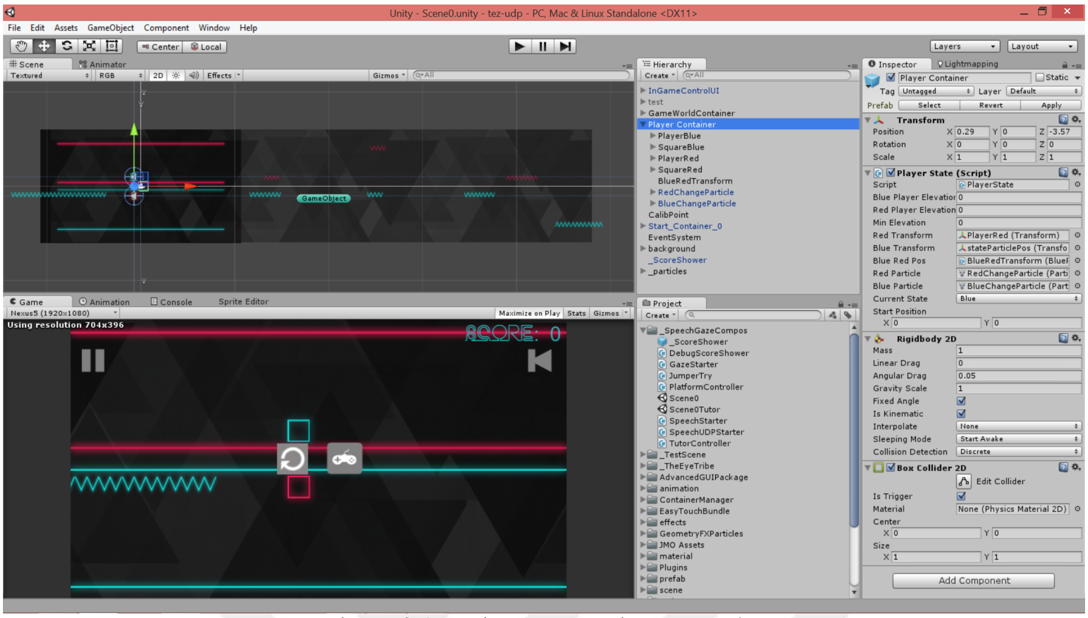

Figure 3.1: Unity game engine screenshot

3.1.2 Eye Tracking

Eye tracking is a sensor technology that enables a device to know exactly where your eyes are focused. An eye tracker is the device used in eye tracking technology. [44] An EyeTribe branded eye tracker device was used in the thesis *(30 / 60 Hz sampling rate, 0.5 - 1 degrees accuracy, 45 - 75 cm working range, 40 x 30 cm trackbox at 65 cm distance)*. There are two types of eye movement technique; measurement of eye's position relative to the head or eye's orientation in space. This device relies on infrared illumination and uses advanced mathematical models to determine the point of gaze. [45] [46]

An eye tracker device provides users to use their eye gaze as an input modality that can be combined with other input devices like mouse, keyboard, touchscreen or voice commands, which this usage called as active applications. For the purpose of tracking the user's gaze data and calculate coordinates of his look, the tracker must be placed below the device's screen and facing towards to the user. [47]

EyeTribe branded eye tracker device (Figure 3.2) is selected because of its modular technology, easy usage for experiment purposes and collaboration with the other technologies used in the research.

Figure 3.2: EyeTribe eye tracker device used in thesis

3.1.3 Voice Recognition

Speech recognition (SR) or voice recognition is the inter-disciplinary sub-field of computational linguistics which enables the recognition and translation of spoken language into text by computers. [48] Microsoft Speech Application Programming Interface (SAPI) was used in the thesis for making speech recognition more accessible and robust. The SAPI supplies a high-level interface between speech recognition engine and the application. The low-level details for controlling and handling real time operations of several engines are applied by SAPI. [49]

SAPI version 3.0 and .NET Framework version 3.5 are used to adjust the version levels with Unity game engine. SAPI works only with the Microsoft based computer devices. Because of this issue, a Lenovo laptop computer with touchscreen feature was used in the thesis to provide both a mobile and a desktop device.

Experiment laptop has touchscreen capabilities and its specifications listed as: *i7 2.00GHz 1600 MHz 4MB processor, Intel 4400 integrated graphic card, 13.3" FHD (1920 x 1080) multitouch display, 8GB DDR3 1600 MHz memory, 1 x USB 3.0 connector*.

3.2 Game Design

The game was a 2D platformer-runner game that was designed and developed by the author of the thesis in collaboration with a research team. A screenshot from the game is presented in Figure 3.3.

After the development of the game core, the changes in the code were implemented for adding the support for eye tracking and speech recognition. (See Appendix B.1 for main gameplay class code fragment) A preliminary review was conducted in the web for finding applications of speech recognition examples in Unity and C#. The review showed that the most frequently used method was a local network for passing the voice commands between the user and the game. [50]

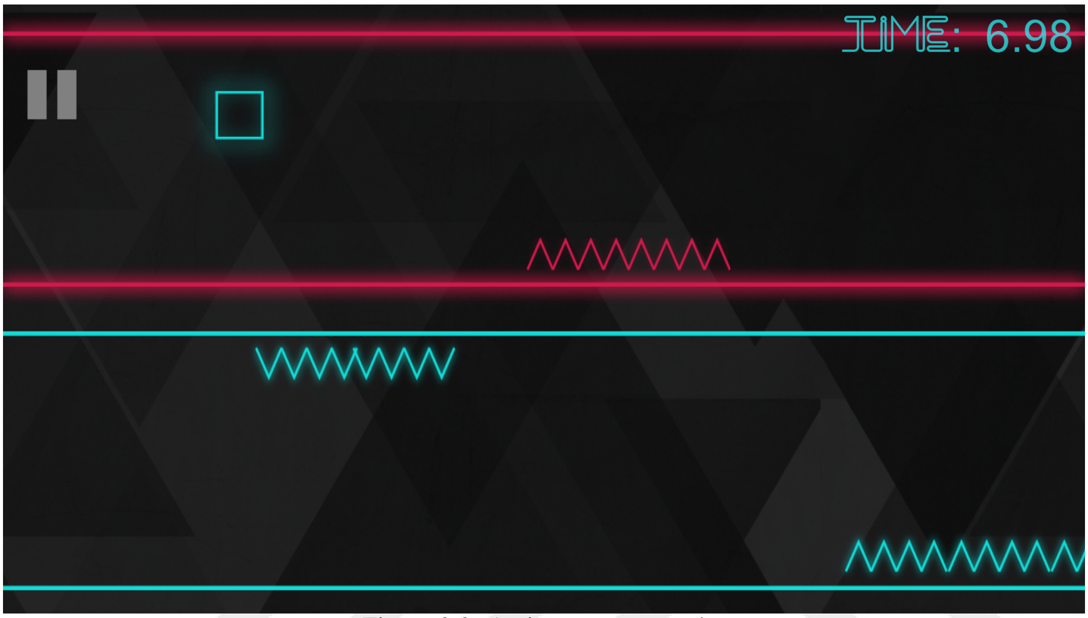

Figure 3.3: An in-game screenshot

Firstly transmission control protocol (TCP) was used for the communication between the participant's voice command and the computer. A DLL was built and added into the game structure. (See Appendix B.2 for source code of DLL) With this DLL file, "jump" and "double" voice commands were recognized by the game for the first time. After that, plugin of EyeTribe device added into the game structure of Unity.

With EyeTribe, changing platform groups in the game implemented and seen that it worked. (See Appendix B.3 for Unity code fragment that processes gaze commands) A "swap" voice command is added also the voice recognition part. Around this time, some problems have been found on the voice recognition application and resolved. The game is started with gaze and voice control method without problem after this resolution.

The code base was first divided into three branches: a solely gaze controlled game, a solely voice controlled game and a game controlled by the combination of both. Simple containers were added into all of these branches to adjust the game hardness. There was a problem about binding the voice recognition port and it was changed to a new port number due to this problem. The "double" voice command was also hardly recognized, so it was changed to "twice" command.

The initial game design involved delays in passing the commands uttered by the player before they activated in game control. We then found the source of the problem was the use of TCP. It has some bottlenecks, like it waits acknowledgment from the server side for recognizing the voice commands. [51] It was decided that user datagram protocol (UDP) would be faster than TCP, so a new project was reformed for UDP. The TCP-like additions have been done to this new project structure. There was a form based application for TCP; it was changed to a console application for UDP project. (See Appendix B.4 for source code of the console application) After this, changes in the levels were started to be aligned with this new software design.

Further issues were resolved, as well, such as an unintended jump of the player's gaze location to the bottom rightmost corner of the screen. Those problems were resolved by preventing to gaze at problematic positions on screen and a first demo was tested in a pilot study and then an experiment. The experiment design, the participants and the procedure are presented in the following chapter.

CHAPTER 4

METHODOLOGY

4.1 Experiment Design

The experiment setup was designed to acquire gameplay and survey data from the participants. They filled in a demographic questionnaire before the experiment session.

Firstly, the participants calibrated their gaze with the help of EyeTribe engine. A tutorial session (Figure 4.1) was designed to make the participants familiar with the game environment and the interaction controls.

Figure 4.1: Tutorial scene that helps participants for where to look and what to say

After the tutorial session, the participant started to play the game with one of the control methods, namely touchscreen.[1]

In touchscreen control, there were two actions which could be used, up and down actions. If the participant wanted to go up, he touched the bottom right side of the

[1] We used "touchscreen" expression for the name of this control method in the thesis, however the participants only used tapping to the screen as the touch command method.

screen. To go down, he touched the bottom left side of the screen. During the game session, game data and gaze data were collected.

After the game session, which took 2 minutes, the participant stopped playing and filled in the GEnQ.

In the second part of the experiment, the participant played the game with other control method, namely gaze and voice commands combined method. In this case, there were one command for gaze and two commands for voice.

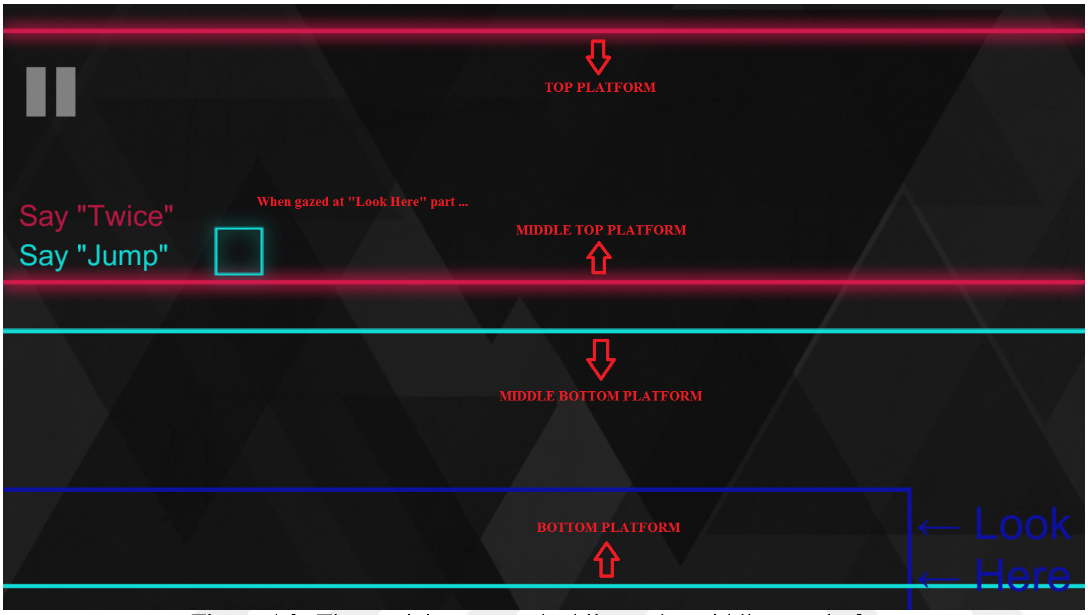

Figure 4.2: The participant gazed while on the middle top platform

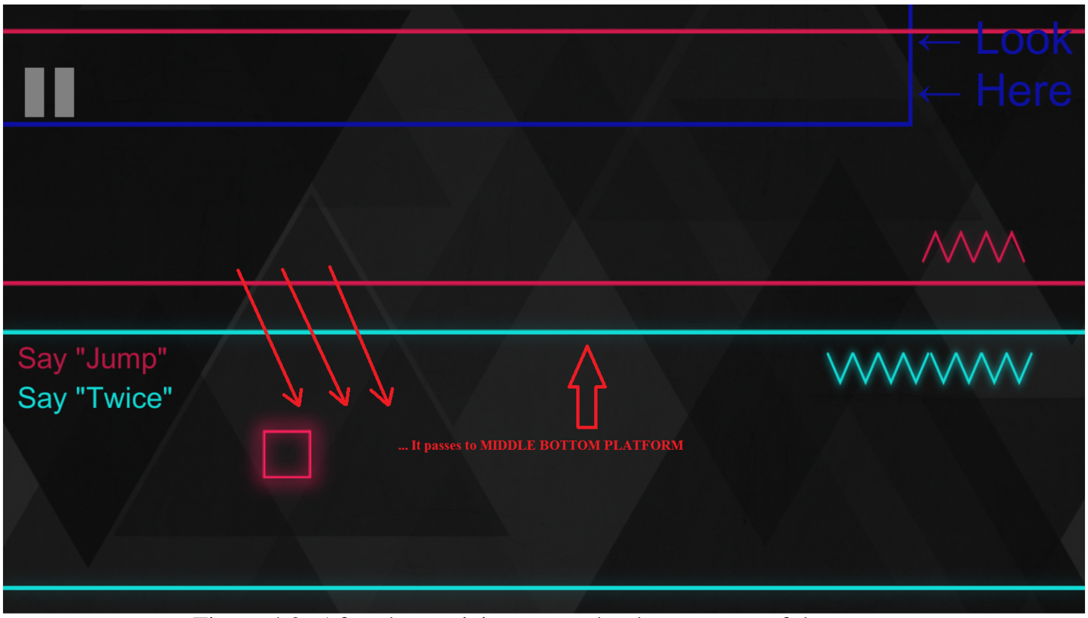

Figure 4.3: After the participant gazed to bottom part of the screen

If the participant wanted to pass to the *middle bottom platform* while he was on the *middle top platform*, he/she gazed the bottom "Look Here" part of the screen (Figures 4.2 4.3).

If the participant wanted to pass to the *middle top platform* while he was on the *middle bottom platform*, he/she gazed the upper "Look Here" part of the screen (Figures 4.4 4.5).

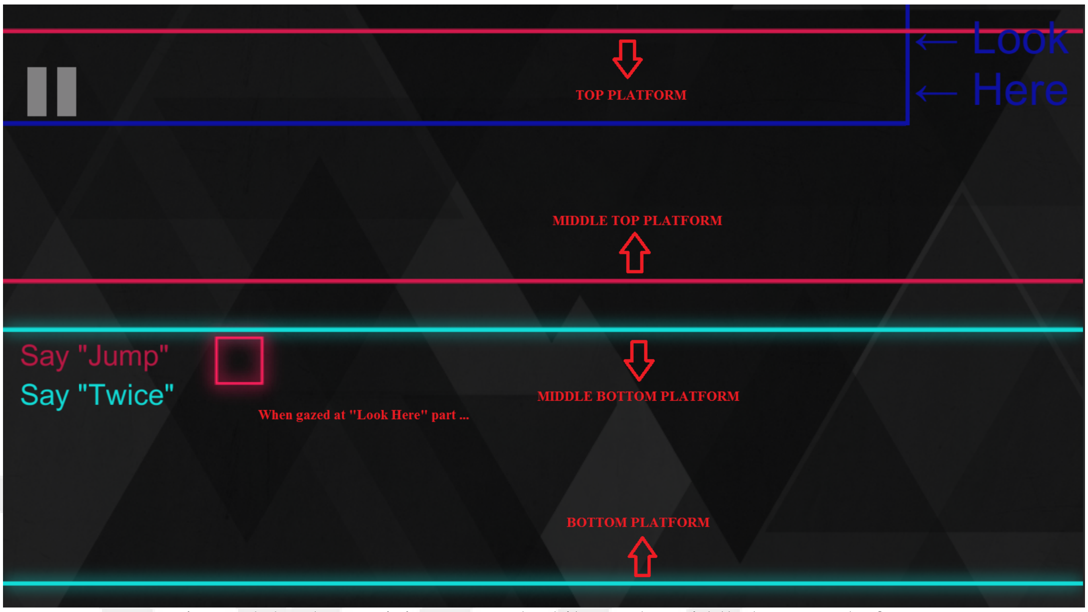

Figure 4.4: The participant gazed while on the middle bottom platform

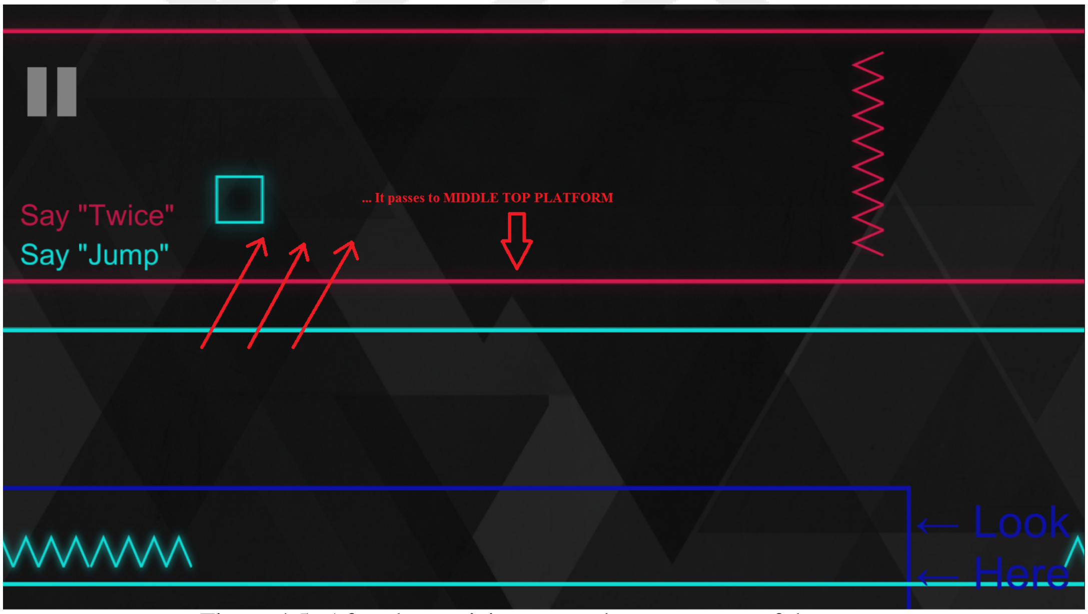

Figure 4.5: After the participant gazed to upper part of the screen

The participant could not pass to *middle bottom platform* while he was on the *top platform* or could not pass to *middle top platform* while he was on the *bottom platform* (Figures 4.6 4.7).

Figure 4.6: Gaze does not matter on the top platform

Figure 4.7: Gaze does not matter on the bottom platform

If the participant wanted to jump once at the same platform, he uttered "jump" (Figures 4.8 4.9).

Figure 4.8: When the participant uttered "jump" command

Figure 4.9: After "jump" command activation

If the participant wanted to jump and change the platform that he was on, then he uttered "twice" (Figures 4.10 4.11).

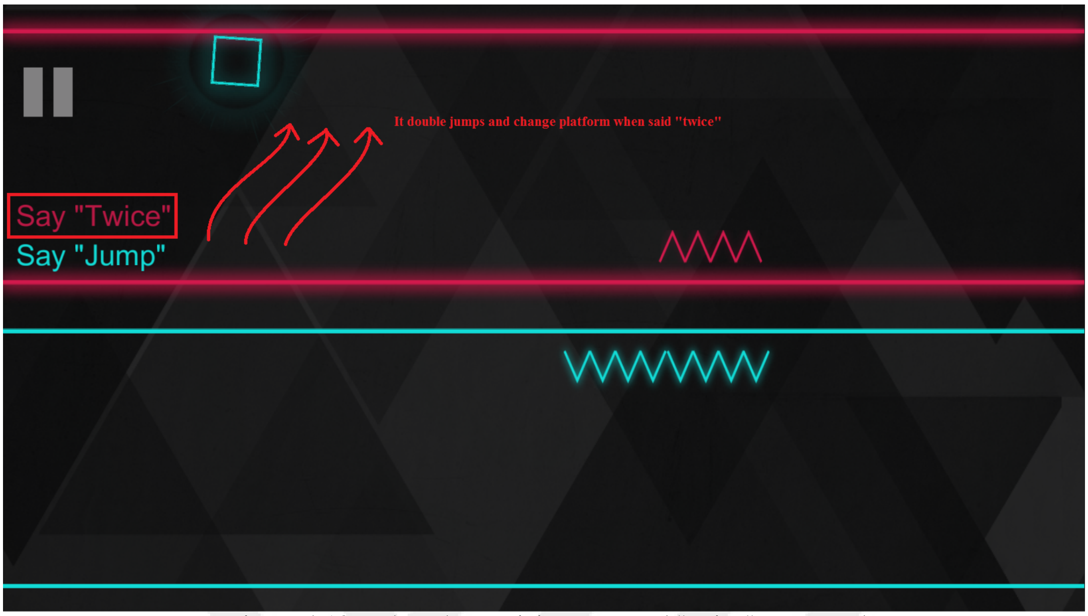

Figure 4.10: When the participant uttered "twice" command

Figure 4.11: When the participant uttered "twice" command again

After the game session with this method, which also took 2 minutes, the participant stopped playing and filled in the GEnQ. This was the end of the experiment for one participant. The procedure was repeated for all the participants throughout the experiment.

The following sections introduce the participants and the experiment procedure.

4.2 Participants

There were 18 male and 6 female participants who conducted the experiment. The average age of the participants was 32 $(M = 32.35)$ and the ages were ranged from 14 to 46 $(SD = 7.07)$. All of the participants at least attended the secondary school. Neither of them was using glasses.

25% of the participants played computer games daily and 38% of them played games at least once a week. The rest of them played computer games not very often. A two-way ANOVA was conducted that examined the effect of control method and playing habit on success rates of the participants; and it was not found a statistically significant main effect of playing habits on success rates $(F(4, 38) = 1.559, p = .205)$. The game genres that played by the participants most were action games and casual games. Sports, action/adventure, adventure and strategy games lined up as the other most frequently played genres. 75% of the participants played games on mobile platforms and nearly 70% of them played games on a computer. Console players were in the minority (20.8%).

4.3 Procedure

The modalities were presented to the participants in the random order. Touchscreen controlled gameplay setup is shown in Figure 4.12 and gaze and voice controlled gameplay setup is shown in Figure 4.13.

Two data sets recorded during the experiment: gameplay and questionnaire. Gameplay data included player's success rate and count of player's actions. Questionnaire data involved survey results. After the experiment, gameplay data and survey results were analyzed statistically.

If the differences were significant; and mean value of players' success rate with gaze and voice controls higher than the success rate with touchscreen controls; then it can be said that the participants were more successful playing with gaze and voice controls than playing with touchscreen controls.

Survey questions were analyzed in four modules as introduced in Section 2.1.1. Our H_0 hypothesis for GEnQ was "The players who play the game with touchscreen control method are more engaged than the ones who play it with gaze and voice control method." If null hypothesis is falsified after the experiment, then it can be said that the engagement level of mobile game playing is increased with more humanely cognitive control methods, gaze and voice commands combined in particular.

The following chapter presents the results of the experiment conducted.

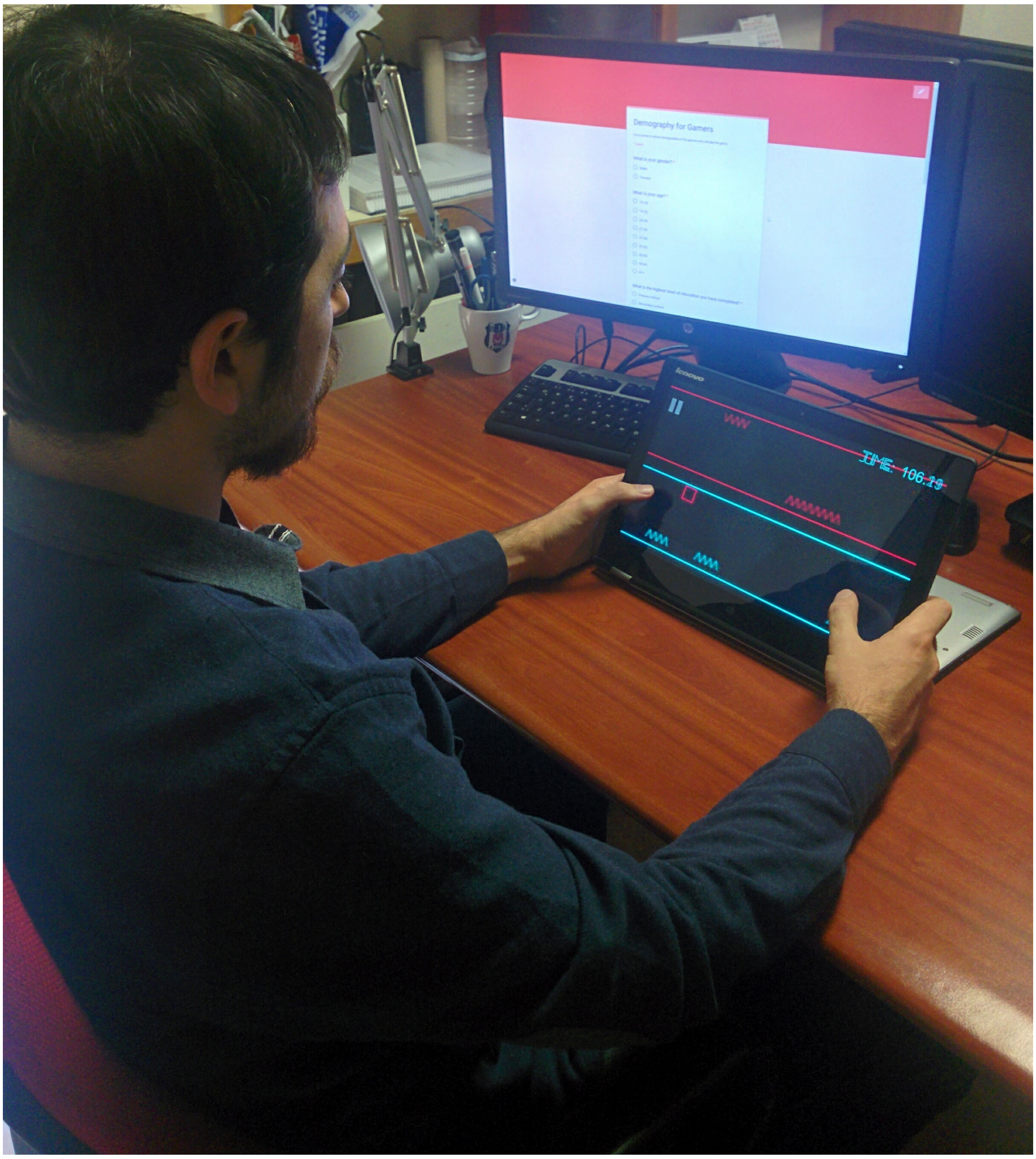

Figure 4.12: A participant playing game with touchscreen control method

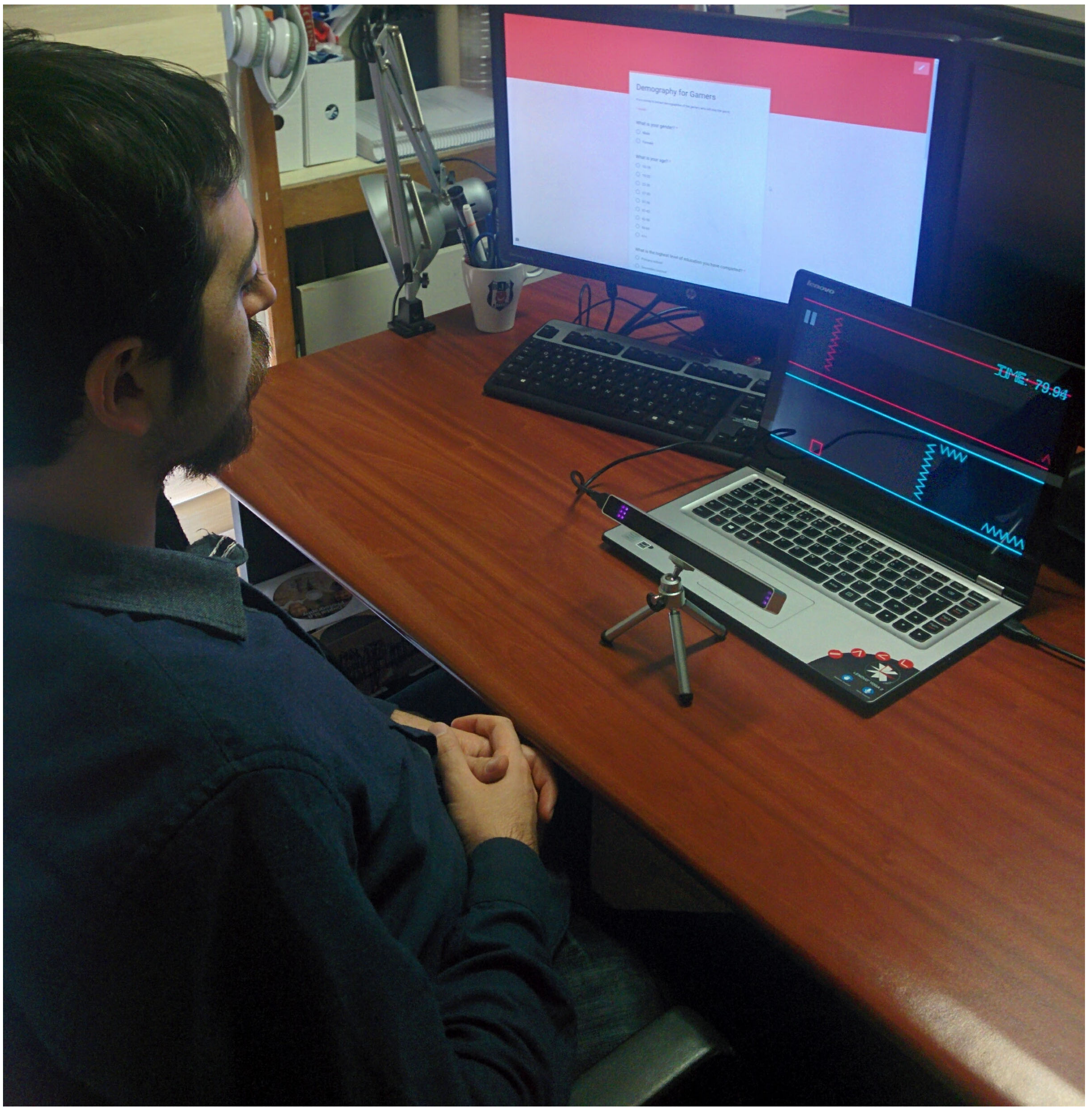

Figure 4.13: A participant playing game with gaze and voice control method

CHAPTER 5

RESULTS

In this chapter, the data were analyzed in two parts; analysis of objective data which were extracted from gameplay and questionnaire data which were extracted from survey results.

5.1 Gameplay Data

There were two types of data in this section that were analyzed statistically: success rate of the participants and the number of actions that participants performed in the game.

5.1.1 Success Rate

We used the following formula to calculate the success rate of the players:

$$(1 - (deathCount/totalObstacle)) * 100 \tag{5.1}$$

where *deathCount* is the number of obstacles that a participant tackled and *totalObstacle* is the number of obstacles that a participant encountered in the level.

Table 5.1: Paired samples t-test result for the success rates of participants

	Control Methods			
	Touchscreen	**Gaze-Voice**	***t***	***df***
Success Rate	$96.30\%(2.50\%)$	$87.86\%(4.05\%)$	9.55*	23

Note. *=$p \leq .05$*, The numbers in parentheses show standard deviation.*

There was a significant difference between the score of touchscreen controlled game's success rates $(M = 96.30\%, SD = 2.50\%)$ and the score of gaze-voice controlled game's success rates $(M = 87.86\%, SD = 4.05\%)$; $t(23) = 9.55, p \ll .05$. The participants who played the game with touchscreen controls were more successful than the ones who played it with gaze and voice controls.

5.1.2 Actions

There are three actions that a participant was able to take in both conditions: *jumping, changing platform and changing platform group*. A two-way ANOVA was conducted that examined the effect of control method and action types on number of actions. $F(2, 138) = 48.65, p \leq .05$, so there was a statistically significant interaction between the effects of control method and action types on number of actions. In order to understand individually which actions had significant difference between control methods, we analyzed the number of actions with a series of paired samples t-tests. Table 5.2 below sums up these results for the actions.

Table 5.2: Paired samples t-test results for the actions of the participants

	Control Methods			
Actions	**Touchscreen**	**Gaze-Voice**	***t***	***df***
Jump	58.33(11.88)	10.04(5.77)	20.25*	23
Platform Change	41(17.35)	13.92(8.42)	6.38*	23
Platform Group Change	20.08(9.09)	15.92(9.57)	1.31**	23

Note. *=$p \leq .05$, **=$p = .20$, *The numbers in parentheses show standard deviation.*

A participant was able to jump with the "jump" voice command in gaze and voice controlled game; and he/she was able to jump by touching the rightmost bottom corner or the leftmost bottom corner of the screen according to which direction he wanted to jump in touchscreen controlled game.

There was a significant difference between the count of jump actions with touchscreen controls ($M = 58.33, SD = 11.88$) and the one with gaze and voice controls ($M = 10.04, SD = 5.77$); $t(23) = 20.25, p = 0$ (Table 5.2). The results suggest that the participants used the "jump" command more frequently with the touchscreen controls. It was not used so frequently as a voice command.

A participant was able to change platform by using the "twice" voice command in gaze and voice controlled game; and he/she was able to change platform by touching two times consecutively the rightmost or the leftmost bottom corner of the screen depending on the direction he wanted to change the platform in touchscreen controlled game.

$t(23) = 6.38, p \ll .05$ (Table 5.2) where the count of platform changing actions with touchscreen controls was $M = 41, SD = 17.35$ and the one with gaze and voice controls was $M = 13.92, SD = 8.42$. There was a significant difference between the usages of platform changing actions for two different playing conditions. The "twice" command was not used very often in gaze and voice controlled game.

Less usage of "jump" and "twice" voice commands in the game might mean that it was hard to control the game with this method and the participants were challenged by it.

The participant was able to advance on four platforms; one platform group was on the top, and the other one was on the bottom with each of them had two platforms to advance on.

If the participant wanted to change his platform group in touchscreen controlled game, he basically touched the correct side of the screen while he was on one of the middle platforms: left side for down direction and right side for up direction.

If the participant was on the top platform of the bottom platform group or the bottom platform of the top platform group, then he/she was able to change his platform group by gazing at the top or the bottom of the screen respectively. Gaze-voice control method was explained thoroughly in Section 4.1.

$t(23) = 1.31, p = .203$ (Table 5.2); so there was not a significant difference in the platform group changing action between touchscreen ($M = 20.08, SD = 9.09$) and gaze-voice ($M = 15.92, SD = 9.57$) conditions. This could mean that the participants could use eye tracker device easily for this action and they internalized this control method as they were using touchscreen control method.

A three-way ANOVA was also conducted that examined the effect of control methods, playing habits and action types on count of actions; however there was not found a statistically significant three-way interaction between these three variables ($F(8, 114) = .86, p = .56$).

The usages of the *jumping* and the *platform changing* actions were significantly different; touchscreen controls were used more compared to "jump" and "twice" voice commands. However, the usage of the *platform group changing* action was not significantly different for two control methods.

As voice commands, "jump" and "twice" were not so successful to help the player for achieving higher success rates in gaze-voice controlled game version. On the contrary, the usage of the gaze commands was not significantly different than the usage of its counterpart in touchscreen controlled game. Hence, it could be said that the players were comfortable at using an eye tracker.

5.2 Questionnaire Data

There are nineteen questions in GEnQ and these questions belong to four different modules, as explained in the previous chapters. For comparing modules, GEnQ answers of the participants were analyzed by a repeated measures mixed ANOVA test for two different game control methods. If it was found a statistical significant difference between the modules, the modules and the questions which created these modules would also be analyzed individually for further results.

We used *modules* as "within subject factors" and two *control methods* as "between subject factors" of mixed ANOVA test. Bonferroni correction was applied for the test. The assumption of sphericity was not met, as Mauchly's test was significant ($p = .00$); therefore we used Greenhouse-Geiser corrected degrees of freedom to assess the significance.

When we used Greenhouse-Geiser corrected degrees of freedom, we saw that there was a significant interaction between modules and control methods as $F(2.207, 101.541) = 3.42, p = .032$ (Figure 5.1). This interaction told us that the evaluations for four different modules of GEnQ significantly differed in gaze-voice and touchscreen control methods.

We also checked the effect of control methods, playing habits and modules on GEnQ scores; and we did not found a statistically significant three-way interaction between these three variables ($F(12, 152) = .27, p = .99$).

Mauchly's Test of Sphericity[a]

Measure: Score

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Module	,524	28,879	5	,000	,736	,791	,333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + ControlMethod
Within Subjects Design: Dimension

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: Score

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Module	Sphericity Assumed	84,013	3	28,004	50,193	,000	,522
	Greenhouse-Geisser	84,013	2,207	38,060	50,193	,000	,522
	Huynh-Feldt	84,013	2,374	35,392	50,193	,000	,522
	Lower-bound	84,013	1,000	84,013	50,193	,000	,522
Module * ControlMethod	Sphericity Assumed	5,717	3	1,906	3,415	,019	,069
	Greenhouse-Geisser	5,717	2,207	2,590	3,415	,032	,069
	Huynh-Feldt	5,717	2,374	2,408	3,415	,029	,069
	Lower-bound	5,717	1,000	5,717	3,415	,071	,069
Error(Dimension)	Sphericity Assumed	76,996	138	,558			
	Greenhouse-Geisser	76,996	101,541	,758			
	Huynh-Feldt	76,996	109,196	,705			
	Lower-bound	76,996	46,000	1,674			

Figure 5.1: Mauchly's test for sphericity and tests of within-subjects effects

In order to understand individually which modules had significant difference between control methods, we analyzed the mean values of participants' answers for appropriate modules of GEnQ with a paired samples t-test. These results were presented module-wise and question-wise below.

5.2.1 Modules

The results of paired samples t-test for the modules of GEnQ are presented below at this order: *immersion, presence, flow* and *psychological absorption*. The immersion module have only one question: "*I really get into game*". "*Things seem to happen automatically, My thoughts go fast, I play longer than I meant to, I lose track of time*" are in the presence module. "*I don't answer when someone talks to me, I can't tell I'm getting tired, If someone talks to me I don't hear them, I feel like I can't stop playing, The game feels real, I get wound up, Playing seems automatic, I play without thinking* *how to play, Playing makes me feel calm*" are in the flow module and "*I feel different, I feel scared, Time seems to kind of stand still or stop, I feel spaced out, I lose track of where I am*" are in the psychological absorption module of GEnQ.

Table 5.3: Paired samples t-test results for GEnQ modules

	Control Methods			
	Touchscreen	**Gaze-Voice**	***t***	***df***
Immersion	5.63(1.10)	5.42(1.44)	.84	23
Presence	4.93(1.01)	4.82(1.06)	.45	23
Flow	4.51(1.01)	4.26(.98)	1.05	23
Psy. Absorption	3.42(1.25)	4.02(1.32)	-2.23*	23

Note. *=$p \leq .05$, *Psy.=Psychological, The numbers in parentheses show standard deviation.*

5.2.1.1 Immersion

There was only one question in this module *(I really get into game)*, so the results for 18th question ($t(23) = 0.84, p = .41$) was same with this module's results (Table 5.3). The participants did not feel more immersed while playing the game with either of the control methods.

5.2.1.2 Presence

If the questions in the presence module would be analyzed statistically *(Things seem to happen automatically, My thoughts go fast, I play longer than I meant to, I lose track of time)*, it could be seen that there was not a significant difference between touchscreen control method and gaze-voice commanded control method where $t(23) = 0.45, p = .66$ (Table 5.3)

5.2.1.3 Flow

Flow module questions *(I don't answer when someone talks to me, I can't tell I'm getting tired, If someone talks to me I don't hear them, I feel like I can't stop playing, The game feels real, I get wound up, Playing seems automatic, I play without thinking how to play, Playing makes me feel calm)* were analyzed with a paired samples t-test and found no significant difference between two control methods since $t(23) = 1.05, p = .30$ (Table 5.3).

5.2.1.4 Psychological Absorption

It could be seen from Figure 5.2, mean values of participants' answers for psychological absorption module were approximately normally distributed for two different control methods; so we used paired samples t-test to analyze the difference.

If the psychological absorption module would be analyzed statistically *(I feel different, I feel scared, Time seems to kind of stand still or stop, I feel spaced out, I lose track of where I am)*; it could be seen that $t(23) = -2.23, p = .036$ (Table 5.3) and there was a significant difference between two playing conditions. The participants who used gaze and voice control method to play the game were more psychologically absorbed than the ones who used touchscreen control method to play it.

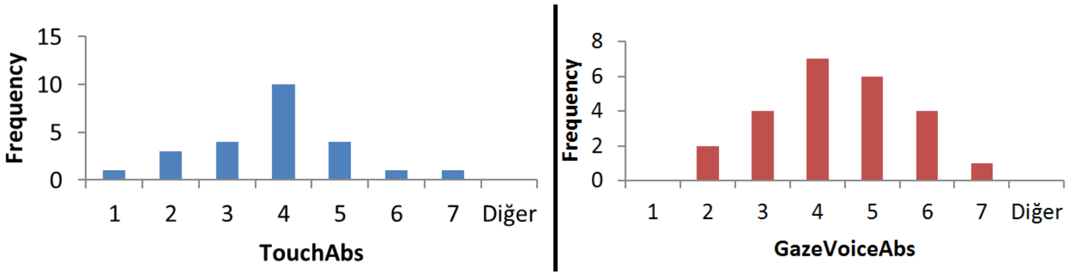

Figure 5.2: Frequency histograms of GEnQ answers for two different control methods: touchscreen (left) and gaze-voice (right)

The question modules of GEnQ was analyzed above and the psychological absorption module was the only one that had a significant difference between two conditions. In the next section, the questions which created these modules will be analyzed statistically.

5.2.2 Questions

The summary of the statistical results according to the paired t-tests for the questions of GEnQ is shown in Table 5.4. The details of for these questions are presented below.

5.2.2.1 I lose track of time

This question was in the presence module of GEnQ. $t(23) = -0.95, p > .05$ (Table 5.4); so there was not a significant difference between two conditions.

5.2.2.2 Things seem to happen automatically

This question was also in the presence module of GEnQ. $t(23) = -0.19, p > .05$ (Table 5.4); therefore there was no significant difference between two conditions.

5.2.2.3 I feel different

This question was in the psychological absorption module of GEnQ. $t(23) = -2.23, p = .036$ (Table 5.4), so there was a significant difference between two conditions.

The participants felt emotions that gave the impression of being different while they were playing the game with gaze and voice control method ($M = 5.5, SD = 1.69$).

Table 5.4: Paired samples t-test results for GEnQ questions

Module	Questions	Touchscreen	Gaze-Voice
Presence	*I lose track of time*	M=5.42 (1.74)	M=5.75 (1.36)
Presence	*Things seem to happen automatically*	M=4.21 (2.23)	M=4.29 (2.03)
Psy. Absorption	*I feel different*	M=4.46 (1.87)	**M=5.50 (1.69)**
Psy. Absorption	*I feel scared*	M=1.88 (1.23)	**M=2.75 (2.21)**
Flow	*The game feels real*	M=4.83 (1.86)	M=4.92 (1.56)
Flow	*If someone talks to me, I don't hear them*	M=3.54 (1.69)	M=3.88 (1.80)
Flow	*I get wound up*	M=5.17 (1.24)	M=5.17 (1.69)
Psy. Absorption	*Time seems to kind of stand still or stop*	M=3.21 (2.02)	M=3.13 (2.15)
Psy. Absorption	*I feel spaced out*	M=3.96 (1.66)	**M=4.75 (1.39)**
Flow	*I don't answer when someone talks to me*	M=3.63 (1.50)	**M=4.67 (1.69)**
Flow	*I can't tell that I'm getting tired*	M=5.17 (1.63)	M=4.63 (1.66)
Flow	*Playing seems automatic*	**M=4.33 (2.06)**	M=3.29 (1.83)
Presence	*My thoughts go fast*	M=4.63 (1.74)	M=4.33 (1.76)
Psy. Absorption	*I lose track of where I am*	M=3.58 (2.00)	M=3.96 (1.71)
Flow	*I play without thinking about how to play*	**M=4.00 (2.02)**	M=3.04 (1.81)
Presence	*Playing makes me feel calm*	M=4.33 (1.58)	M=4.08 (1.50)
Presence	*I play longer than I meant to*	M=5.46 (1.29)	M=4.92 (1.82)
Immersion	*I really get into game*	M=5.63 (1.10)	M=5.42 (1.44)
Flow	*I feel like I just can't stop playing*	**M=5.54 (1.72)**	M=4.63 (2.20)

Note. M=Mean, Psy.=Psychological, The numbers in parentheses show standard deviation, $p \leq .05$ in bolded columns.

5.2.2.4 I feel scared

This question was also in the psychological absorption module of GEnQ. $t(23) = -2.16, p = .041$ (Table 5.4); so the participants felt more scared while they were playing the game with gaze and voice control method.

If the means of two conditions were examined which were 1.88 ($SD = 1.23$) for touchscreen and 2.75 ($SD = 2.21$) for gaze and voice, it could be seen that the means were very low for both conditions. The value 3 means "slightly disagree", so the difference was significant but it could not be said the participants who used gaze and voice control method were not so much scared in that condition.

5.2.2.5 The game feels real

This question was in the flow module of GEnQ. $t(23) = -0.27, p > .05$ (Table 5.4), so there was not a significant difference. Value 5 means "agree" on the questionnaire scale; so the participants reported that the game was authentic for both control methods according to the means of both conditions ($M = 4.83, SD = 1.86$ for touch-screen and $M = 4.92, SD = 1.56$ for gaze-voice).

5.2.2.6 If someone talks to me, I don't hear them

The sixth question of GEnQ was also in the part of flow module. $t(23) = -0.67, p > .05$ (Table 5.4); and there was not a significant difference.

5.2.2.7 I get wound up

"I get wound up" question was in the flow module of GEnQ. $t(23) = 0, p = 1$; the means were identical for both conditions ($M = 5.17$; $SD = 1.24$ for touchscreen and $SD = 1.69$ for gaze-voice), thus there was no difference. The participants got wound up in the same manner for two conditions.

5.2.2.8 Time seems to kind of stand still or stop

This question was in the psychological absorption module of GEnQ. $t(23) = 0.16, p > .05$ (Table 5.4) and the difference was not significant. Means of two conditions ($M = 3.21, SD = 2.02$ for touchscreen and $M = 3.13, SD = 2.15$ for gaze-voice) was close to value 3 which means "slightly disagree". The participants did not think that their time perception was changed with the help of the experience they had.

5.2.2.9 I feel spaced out

The participants felt more spaced out with gaze and voice control method as it could be seen from $t(23) = -2.36, p = .027$ (Table 5.4). This question was in the psychological absorption module of GEnQ. It could be said that they were disassociated from the environment while they were playing the game with the gaze-voice control method.

5.2.2.10 I don't answer when someone talks to me

This question was in the flow module of GEnQ. There was a significant difference ($t(23) = -2.46, p = .022$) between two conditions and the participants favored gaze and voice control method (Table 5.4).

The participants used voice commands in gaze and voice condition, so naturally they could not answer when someone talked to them. This matter was explained before the experiment and the participants answered this question by thinking the meaning of it as "If I could tell anything other than the voice commands, then I don't answer when someone talks to me."

5.2.2.11 I can't tell that I'm getting tired

This question was in the flow module of GEnQ. The difference between two conditions was not significant; because $t(23) = 1.36, p > .05$ (Table 5.4).

5.2.2.12 Playing seems automatic

This question was also in the flow module of GEnQ. $t(23) = 2.83, p = .010$ (Table 5.4); thus the participants who used touchscreen to play the game reported that playing the game with touchscreen seemed more automatic than playing it with gaze and voice control method.

5.2.2.13 My thoughts go fast

This question was in the presence module of GEnQ. $t(23) = 0.81, p > .05$ (Table 5.4), thus it could not be said that there was a significant difference between two conditions.

5.2.2.14 I lose track of where I am

This question was in the psychological absorption module of GEnQ. There was not a significant difference between two conditions; because $t(23) = -1.06, p > .05$ (Table 5.4).

5.2.2.15 I play without thinking about how to play

The participants were more familiar with touchscreen control method and probably because of this; they played the game with less thinking how to play with this method. This question was in the flow module of GEnQ and there was a significant difference between two conditions ($t(23) = 2.06, p = .05$).

5.2.2.16 Playing makes me feel calm

This question was in the presence module of GEnQ. $t(23) = 0.78, p > .05$ (Table 5.4), so there was not a significant difference between two conditions.

5.2.2.17 I play longer than I meant to

This question was also in the presence module of GEnQ. $t(23) = 1.5, p > .05$ (Table 5.4), so the difference was not significant.

5.2.2.18 I really get into game

This question was the only question which was in the immersion module of GEnQ. $t(23) = 0.84, p > .05$ (Table 5.4), thus it could not be said that there was a significant difference between touchscreen and gaze-voice conditions.

5.2.2.19 I feel like I just can't stop playing

From the participants' survey data analyzed on Table 5.4, $t(23) = 2.11, p = .046$ in this last question of GEnQ which was in the flow module. Henceforth, their gameplay experience was better with the touchscreen controls. The participants who played the game with touchscreen control method felt like they did not want to stop playing the game.

As it could be seen from the statistical analysis, the null hypothesis was falsified after the experiment. There were differences in the results of GEnQ between touchscreen and gaze-voice control method. Seven questions which answered by the participants had significant difference and the rest of the questions had no significant statistical difference. The gameplay and the questionnaire results were discussed in the next chapter.

CHAPTER 6

DISCUSSION

In this chapter, we discuss the findings, by interpreting the results obtained in the experiment.

The analysis on the gameplay data revealed that the participants were more successful when they used touchscreen control method.

Touchscreen is a traditional control mechanism in mobile devices for quite some time. A closer look at data shows that there was a participant in the experiment whose success rate was 100%, whereas the best success rate from the participants' gameplay data was 94.44% in the gaze-voice controlled game version. Therefore, the higher success rate of the touchscreen control might be the outcome of more frequent use of it by the participants in daily life. On the contrary, the high success rate of gaze-voice controlled interaction suggests that it is a promising human computer interaction modality in gaming.

A closer look at the usage count of the platform group changing action shows that the difference between the two conditions was not significant. This result is valuable, since it suggests that the participants may not have faced significant technical challenges in using the gaze commands of the gaze-voice control method during the course of playing the game. If we go back to the previous article [19] we mentioned in Section 2.2, we can say that negative indicator we have in our game did not affect the usage of gaze commands by the participants.

Survey data analysis provided us a better understanding of the players' experience about the game. In the questionnaire part of the experiment, there were seven questions that exhibited statistical significance. In four of them, gaze-voice controlled game had more positive results; and in three of them, touchscreen controlled game had more positive results. The other twelve questions did not exhibit a statistical significance. Player engagement is an important factor in novel game control methods like we applied to the game in our thesis. For the gaze-voice method, three of the five questions which belongs to psychological absorption module and one question belongs to the flow module also have a positive significant difference.

Spakov and Miniotas (2005) used dwell time for their research; and as we saw in our experiment that dwelling time for making gaze control based actions was an effective method to control the character between platform groups.

As a complementary method to the gaze, the participants had some difficulties in the usage of voice commands in game. They were better doing those actions with touchscreen controls. However, in our game genre, there were not so many application examples of the gaze-voice method. Nonetheless, the participants uttered voice commands easily and gaze-voice method was successful in some perspectives.

Gaze and voice combined control method is a tiresome method to play the game according to the touchscreen control method. One uses two different muscle types (vocal and eye muscles) while the other uses one type of muscle (motor muscles). The participants may felt interrupted because of this reason and differences between control methods could be originated from this.

Overall, these results suggest that using touchscreen controls was a more successful way to control a mobile game. However, the gaze-voice control method was promising for mobile game control since the participants were more engaged at some aspects into the game while using it.

CHAPTER 7

CONCLUSION AND FUTURE WORK

The aim of this thesis was to investigate the level of engagement in gaze and voice controlled mobile games and touchscreen controlled mobile games, by means of a comparative analysis between the two, through an experimental investigation. The results showed that the players were more engaged into the game in some aspects and they *felt psychologically absorbed* with this new control method. However, they did not feel *at present, fully immersed* or *in the flow of game* as specified by the survey results.

The results also revealed that the gameplay performance of the players who used touchscreen control method is better than the gaze-voice control method. This could be originated from the novelty effect. [53] The participants played a game with gaze-voice game control setup for the first time in their life and they did not have a previous experience with this method. Further studies should address how this effect should be overcome. One of the other reasons of these unsuccessful performance might be the gaze load which the participants might experienced as well. A more comprehensive study that includes gaze load topic might be needed to fully understand all aspects of the success rate in gaze controlled gaming.

Only platform group change action's statistical analysis result is not significant for two different conditions. This insignificance may support the statement that they felt comfortable at using gaze as a command tool. In future, second input method can be changed to another modality than voice input. Body movements, brain computer interface or EMG may be used. Using touchscreen with gaze commands may become one of the new studies if mobile devices are taken into account. Future research may also address how skill learning in gaze gaming will influence the perception of the players about game engagement.[1]

Not all of the participants are accustomed to giving commands with touchscreen controls for playing mobile games. And surely, some participants do not play mobile games very often. In further studies, all participants can be familiar with this technology and by this way; the difference may be detected more clearly.

The participants were native speakers of Turkish. They use two English words, however, ("jump" and "twice") to control the interaction with the environment. Recently, there is no freely available speech recognizer for Turkish that we can use in our setup;

[1] The participants told that key mappings were hard to accommodate; to be get used to control the game with gaze-voice method effectively took much more time than traditional control methods.

therefore, it was a practical limitation of the screen to use a speech recognizer for English.

The technology level to implement gaze and voice inputs together in gaming is not sufficient enough. This situation caused a lag between the actual time which voice commands told and the interpreted time of these commands in the game interface. It should be concentrated on minimizing this lag in further studies.

Our findings are bound to a specific game and its methods of interaction. Therefore, it is not possible to make generalization at this stage. Further research is needed to investigate the generalization of these findings.

As a result, there were some divergent findings in the literature for using gaze as an input modality for games. We want to contribute to these findings in our study. In this context, this thesis focused on the usage of gaze as one of the multimodal input methods and showed that it coupled with voice commands effectively in the chosen game.

It can be stated that integrating an eye tracker on a mobile device with purpose of using it as a game controller is in early stages and still needs so much progress. The present study contributes to this domain, and mobile game control methods will evolve with time towards more usable and efficient interaction methods. This may also help the people with disabilities to play mobile games, lead to new gameplay experiences, increase the fun and challenge in games.

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APPENDIX A

GAME ENGAGEMENT QUESTIONNAIRE

	Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree
I lose track of time.	1	2	3	4	5	6	7
Things seem to happen automatically.	1	2	3	4	5	6	7
I feel different.	1	2	3	4	5	6	7
I feel scared.	1	2	3	4	5	6	7
The game feels real.	1	2	3	4	5	6	7
If someone talks to me, I don't hear them.	1	2	3	4	5	6	7
I get wound up.	1	2	3	4	5	6	7
Time seems to kind of stand still or stop	1	2	3	4	5	6	7
I feel spaced out.	1	2	3	4	5	6	7
I don't answer when someone talks to me.	1	2	3	4	5	6	7
I can't tell that I'm getting tired.	1	2	3	4	5	6	7
Playing seems automatic.	1	2	3	4	5	6	7
My thoughts go fast.	1	2	3	4	5	6	7
I lose track of where I am.	1	2	3	4	5	6	7
I play without thinking about how to play.	1	2	3	4	5	6	7
Playing makes me feel calm.	1	2	3	4	5	6	7
I play longer than I meant to.	1	2	3	4	5	6	7
I really get into the game.	1	2	3	4	5	6	7
I feel like can't stop playing.	1	2	3	4	5	6	7

Figure A.1: Game Engagement Questionnaire Items

The scale given above provided for you to understand the engagement of the game that you have just played. Please answer the questions as honestly as possible by using the table that the table's first row represent the meaning of the number of each cell. Please try use the character (X) to mark your choice that other marks are going to be ignored as wrong response. You can feel free to ask question about the statement above if you find the statement ambiguous.

APPENDIX B

SOURCE CODES

B.1 Main Gameplay Class Code Fragment

```
public class PlayerID : MonoBehaviour
{
    .
    .
    .
        void FixedUpdate()
        {
        if (playing)
        {
          score += Time.fixedDeltaTime;
          Jump = (canJump && onGround);
          if (Jump || (onGround && SpeechUDPStarter.command == "jump"))
          {
            SpeechUDPStarter.command = "C";
            rigidbody2D.AddForce(new Vector2(0, jumpForce * jumpDirection *
                IDfactor));
            canJump = false;
            onAir = true;
            jumpCount++;
            StartCoroutine(WaitForTriggerEvent());
          }

          if ((onAir && canJump && !onGround) || (SpeechUDPStarter.command == "
              twice"))
          {
            if (SpeechUDPStarter.command == "twice")
              SpeechUDPStarter.command = "D";

            changeGravity = (changeGravity == false) ? true : false;
            twiceCount++;
            onAir = false;
            canJump = false;
            SquareAnim.SetTrigger("FlipT");
            changeGravityParticle.Play();
          }
          .
          .
          .
}
```

B.2 Voice Recognition DLL Source Code

```
namespace SpeechProjDLL
{
    public class Connector
    {
        const int READ_BUFFER_SIZE = 255;
        const int PORT_NUM = 10012;
        private TcpClient client;
        private byte[] readBuffer = new byte[READ_BUFFER_SIZE];
        public string strMessage = string.Empty;
        public string res = String.Empty;
        private string pUserName;

        public Connector() { }

        public string fnConnectResult(string sNetIP, int iPORT_NUM, string
            sUserName)
        {
            try
            {
                pUserName = sUserName;
                iPORT_NUM = PORT_NUM;
                client = new TcpClient(sNetIP, iPORT_NUM);
                client.GetStream().BeginRead(readBuffer, 0,
                    READ_BUFFER_SIZE, new AsyncCallback(DoRead), null);
                return "Connection Succeeded";
            }
            catch (Exception ex)
            {
                return "Server is not active.  Please start server and try 
                    again.      " + ex.ToString();
            }
        }


        public void fnPacketTest(string sInfo)
        {
            SendData("CHAT|" + sInfo);
        }

        public void fnDisconnect()
        {
            SendData("DISCONNECT");
        }

        private void DoRead(IAsyncResult ar)
        {
            int BytesRead;
            try
            {
                BytesRead = client.GetStream().EndRead(ar);
                if (BytesRead < 1)
                {
                    res = "Disconnected";
                    return;
                }
                if (BytesRead - 2 > 0)
                {
```

```
                    strMessage = Encoding.ASCII.GetString(readBuffer, 0,
                        BytesRead - 2);
                    ProcessCommands(strMessage);
                }
                client.GetStream().BeginRead(readBuffer, 0,
                    READ_BUFFER_SIZE, new AsyncCallback(DoRead), null);

            }
            catch
            {
                res = "Disconnected";
            }
        }

        private void ProcessCommands(string strMessage)
        {
            string[] dataArray;

            dataArray = strMessage.Split((char)124);
            switch (dataArray[0])
            {

                case "CMD":
                    res = dataArray[1].ToString();
                    break;
                case "NOCMD":
                    res = "";
                    break;

            }
        }

        private void SendData(string data)
        {
            StreamWriter writer = new StreamWriter(client.GetStream());
            writer.Write(data + (char)13);
            writer.Flush();
        }
    }
}
```

B.3 Unity Code Fragment That Gets Gaze Commands

```
public class PlayerState : MonoBehaviour
{
  .
  .
  .
    void Update ()
  {
    .
    .
    .
        if (currentState == State.Blue && CalibCamera._GazeIndicator.
            transform.position.y < -3f
                && CalibCamera._GazeIndicator.transform.localPosition.x < 6
                    f)
        {
            if (CollisionTest.canChangePlatform == true &&
                bluePlayerElevation < 1.50f)
            {
                if (blueRedPos.red.transform.position.x < blueRedPos.blue.
                    transform.position.x)
                    blueRedPos.red.transform.position = new Vector2(
                        blueRedPos.blue.transform.position.x, blueRedPos.
                        red.transform.position.y);

                currentState = State.Red;
                .
        .
        .
            }
        }
        else if (currentState == State.Red && CalibCamera._GazeIndicator.
            transform.position.y > 3f
                    && CalibCamera._GazeIndicator.transform.localPosition.x
                         < 6f)
        {
            if (CollisionTest.canChangePlatform == true &&
                redPlayerElevation > -1.50f)
            {
                if (blueRedPos.blue.transform.position.x < blueRedPos.red.
                    transform.position.x)
                    blueRedPos.blue.transform.position = new Vector2(
                        blueRedPos.red.transform.position.x, blueRedPos.
                        blue.transform.position.y);

                currentState = State.Blue;
        .
        .
        .
            }
        }
    .
    .
    .
  }
}
```

B.4 Voice Recognition Application Source Code

```
namespace SpeechUDPConsoleApp
{
    class Program
    {

        public static string reception = "#";
        public static string endWord = "Terminer";

        public static string localhost = "127.0.0.1";
        public static byte[] dataSent = new byte[512];
        public const int PORT_NUM = 26000;

        public static double validity = 0.70f;

        SpeechSynthesizer sSynth = new SpeechSynthesizer();
        PromptBuilder pBuilder = new PromptBuilder();
        public static SpeechRecognitionEngine sRecognize;

        static void Main(string[] args)
        {
            sRecognize = new SpeechRecognitionEngine();

            Choices sList = new Choices();
            sList.Add(new string[] { "jump", "swap", "twice"});
            Grammar gr = new Grammar(new GrammarBuilder(sList));

            try
            {
                sRecognize.RequestRecognizerUpdate();
                sRecognize.LoadGrammar(gr);
                sRecognize.SpeechRecognized += sRecognize_SpeechRecognized;
                sRecognize.SetInputToDefaultAudioDevice();
                sRecognize.RecognizeAsync(RecognizeMode.Multiple);

            }
            catch (Exception ex)
            {
                throw ex;
            }

            Socket udpServerSocket = new Socket(AddressFamily.InterNetwork,
                 SocketType.Dgram, ProtocolType.Udp);
            IPEndPoint ipEnd = new IPEndPoint(IPAddress.Parse(localhost),
                PORT_NUM);

            Console.WriteLine("Ready.....");

            while (true)
            {
                if (reception != "#")
                {
                    dataSent = Encoding.ASCII.GetBytes(reception);
                    udpServerSocket.SendTo(dataSent, ipEnd);
                    Console.WriteLine("Sending : " + reception);
                    reception = "#";
                }

                Thread.Sleep(2);
```

```
            }

        }

        private static void sRecognize_SpeechRecognized(object sender,
            SpeechRecognizedEventArgs e)
        {
            if (e.Result.Confidence >= validity)
            {
                reception = e.Result.Text;
            }
            else
            {
                reception = "#";
            }
        }
    }
}
```