Improving Player Performance by Developing Gaze Aware Games

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Abstract

**Context.** Eye tracking technology has been applied to video games, mainly, as an offline analysis tool or as an input for game control. Nevertheless, eye tracking systems applied to video games is a topic considered to be on an infant state that requires further development. The following study explore a different approach in how eye tracking systems can be used for video game interaction.

**Objectives.** By implementing a gaze based interaction technique, a gaze aware space shooting game will be developed in order to provide in-game assistance that could improve player’s performance.

**Method.** With the help of a Tobii REX eye tracking system, a set of 26 volunteers played two video games in a controlled environment. Both of the games had the same mechanics and elements, but only one of them implemented the gaze based interaction technique. The player performance was calculated in terms of the time needed by the players to finish each of the games. A statistic significance analysis was done in order to determine if the testing data provided sufficient evidence to conclude a performance improvement.

**Results.** The results showed a reduction on the time needed to finish the game on the gaze aware prototype, having an average time difference of 74.03 seconds and overcoming a confidence level of 99.9% when submitting the testing data to a paired t-Test. Also, the majority of the players chose the gaze aware game as the most enjoyable, in terms of their personal preferences.

**Conclusions.** The testing results provided sufficient evidence to conclude that the gaze aware game improved the performance of all of the selected participants. This study provides a starting point for further development of eye tracking systems as a task assisting method on video game interaction.

**Keywords:** Gaze aware games, eye tracking, human-computer interaction, player performance.
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Chapter 1

Introduction

Chapter 1 offers a basic introduction to the topic and the extent of this study through four different sections. Section 1.1 focuses on the motivation and the current research gap. Section 1.2 addresses the research question. Section 1.3 summarizes the objectives for this study. Finally, Section 1.4 offers a general view over the dissertation layout.

1.1 Motivation

Eye tracking systems have been applied to video games in two different ways. First, they have been used as an off-line analysis tool to evaluate gaze behavior on players [Sundstedt, 2010]. Also, eye trackers have been introduced as game controlling devices, allowing players to interact with video games by just looking at them [Almeida et al., 2011]. Nevertheless, the use of this technology for video game interaction is considered to be in an infant state, referring to two main issues.

First, researchers have taken the approach of applying eye tracking technology to already existing games, focusing mainly in how the eye tracker could be integrated into a particular title [Isokoski et al., 2009]. As a result from this scope, most of the studies related the use of eye tracking systems as an alternative controlling input for video game interaction. Additionally, lack of support towards the integration of eye tracking technology in gaming, having just a few amount of games that have implemented the use this technology. This could be related to the hardware requirements, the low accuracy and the high selling price these systems used to have some years ago.[Almeida et al., 2011, Isokoski et al., 2009].

The first situation offers the opportunity for further studies, in order to explore the potential that eye tracking systems could have in video game interaction. A change in the approach of the current research on eye tracking technology applied to video games, could contribute to the development of novel, more intelligent, interaction techniques that might offer new possibilities for enhancing the game experience or even improve players performance, now that recent eye trackers
have started to overcome their previous limitations [Almeida et al., 2011].

1.2 Research Question

The approach of applying eye tracking technology to video game, in terms of gaze based interaction design, task assisting technology and gaze aware systems, is a scope that not many have used before and that might contribute to the further development of eye tracking research [Chang et al., 2013].

Therefore, this study will address the following research question:

- Can gaze based interaction and gaze aware games improve player performance, in terms of a reduction in the time needed to finish the game, when compared to normal video games in the space-shooting genre?

1.3 Objectives

The following tasks are introduced as objectives to be fulfilled within this study.

1. Analyze the suitability of some of the eye tracking systems available in the market, according to this research extent. Accuracy, compatibility with game development technologies and data management will be the some of the main selection criteria for choosing the most appropriate eye tracker.

2. Design a gaze based interaction technique that allows the game to offer task assistance to players.

3. Implement C# game scripts containing the algorithms for the gaze-based interaction technique.

4. Develop two video game prototypes. Both of the games will use an Xbox 360 gamepad as the controlling input, but only one of them will be featuring the gaze-based interaction technique.

5. Measure the player performance, in terms of the time needed to finish both of the game prototypes, by testing rounds in a controlled environment.

6. Apply a statistic significance test to determine if there is an improvement in players performance when using the gaze aware game prototype.
7. Provide a general perspective of the game experience in terms of enjoyment, task efficiency and mechanics, by applying a questionnaire after players have interacted with both of the game prototypes.

1.4 Dissertation Layout

The following dissertation contains six different chapters. Chapter 2 will collect some of the theoretical background and related studies, relevant to the topics involved in this research. Chapter 3 exposes the proposed methodology and experimental set up for this research. The design and implementation of the gaze interaction techniques and the video game prototypes will be covered in Chapter 4. The gathered results will be shown and analyzed in chapter 5. Finally, Chapter 6 delivers final conclusions and suggests options for future work.
Chapter 2

Related Work

During Chapter 2, a summary of some of the previous research done in the area of eye tracking applied to video games will be provided. Initially, Section 2.1 will introduce the general concepts around the visual attention process, a topic considered key in order to understand the decisions taken during the interaction design process. Section 2.2 offers a general overview about eye tracking technology. Finally, Section 2.3 offers some of the previous results in the field of eye tracking applied to video game interaction.

2.1 The Visual Attention Process

The human vision system is composed by two major elements: perception and cognition. The perception process is considered to be a pre-attentive mechanism, while cognition refers to the use of more demanding tasks, such as reasoning or memory [Sundstedt, 2012, Henderson and Hollingworth, 1999].

The vision system continuously provides a huge amount of information that exceeds the processing capabilities of the brain. To solve this problem, the visual attention process focuses on efficiently extracting the relevant information out of the bunch.

The visual attention is a complex process, that combine conscious and unconscious tasks in the brain. There are two different types of visual processes that could determine where humans could locate their attention: The bottom-up and the bottom-down processes. The bottom-up is a process that focus in capturing the visual attention of the observer in an unconscious way, better understood as an automatic response from the body to a particular visual stimuli. On the other hand, top-down processes focus the attention in terms of particular task. [Borji and Itti, 2014, Sundstedt, 2012].

To manipulate viewers attention, the bottom-up approach implements a set of variations in size, contrast, color or shapes, among other features. But motion is considered one of the strongest stimuli for this task. Therefore, while designing
the gaze based interaction technique, this study will focus on the use of a bottom-up process, particularly motion stimuli, to guide the player’s visual attention in the game prototypes [Borji and Itti, 2014].

## 2.2 Eye Tracking Technology

Eye tracking is a method that identifies and follows, in space and time, a point that is being observed on the computer screen [Sundstedt, 2012].

Eye tracking technology can be classified into two major categories, according to the method used to capture the eye movements [Duchowski, 2007]. They can be:

- **Video-based corneal reflection eye tracker**: The corneal reflection eye trackers projects infrared light towards the viewer’s eyes. Then, a set of high-speed infrared cameras captures the reflected light from viewers corneas and estimate the gaze position in terms of the eye movements and the relative position of the head.

- **Electro-oculography (EOG) eye trackers**: EOG eye trackers uses skin electrodes around the eye area, to measure the electrical changes produced by the eyeball movements.

Since they are considered to be a less intrusive method to measure eye movements and gaze points on viewers, this study will use of a video-based corneal reflection eye tracker. Different eye tracking systems, such as Tobii monitors\(^1\) (Figure 2.1\(^2\)) are designed for a natural interaction with the monitor, and are a examples of this kind.

The information collected through eye tracking systems can be used for different purposes. For example, to create heat maps over images, referring to the points on the screen where observers stared for the longest periods of time. They may also indicate the followed paths and the order in which the elements are examined. This information can be valuable for analyzing gaze behaviors, stationary images or web pages [Renshaw et al., 2009].

Moreover, other research techniques even use data relating to flicker, movement speed and pupil dilation to infer the emotional involvement with what is

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\(^1\)http://www.tobii.com/en/eye-tracking-research/global/products/hardware/tobii-t60x1-eye-tracker/(Visited January 10th, 2014)

\(^2\)http://www.tobii.com/ImageVaultFiles/id_758/cf_60/Eye_Tracking_System\%20_Tobii_Image_T60_T120_Eye_Trac.jpg(Visited January 10th, 2014)
Chapter 2. Related Work

Figure 2.1: The Tobii T-60 as one example of a video-based corneal reflection eye tracker.

...being observed [Almeida et al., 2011]. This is the case of Emotion Tool iMotions technology, a Danish company specializing in the development of eye-tracking software.

In this particular study, the information from the eye tracker will be used to create a gaze aware game. This system will monitor the gaze behavior from the player, in order to provide assistance while playing the game.

2.3 Eye Tracking Applied to Video Games

Research related to the topic of eye tracking started in the late sixties, when most of the research was carried in the direction of analyzing and manipulating interfaces. In this period of time, the researchers were focused on analyzing the eye from a physiological perspective, to understand how to track the fixations times, the jittery motions and the gazes; and from this perspective relate the use of the eye tracking technology to analyze user interfaces.

One of the most important researchers in this field, whose contribution is still relevant up to day is Jacob, who was interested in establishing the theoretical grounds for measuring the eye movements, analysing its characteristics and the problems that this kind of technology was proposing when used as an input device for controlling and manipulating user interfaces [Jacob, 1990]. His previous work was more related to analyse and study user interfaces [Jacob, 1986], which was very related to his later work when using the eye-tracker as control input. In the same line of research, Ware and Mikaelian contributed to the field, centering their in the use of the eye tracker as an input for the computer [Ware and Mikaelian, 1987]. They explored new possibilities of using the eye tracker for computer interaction, compared to traditional use of keyboard and mouse.
More recently, Sundstedt has focused on the area of eye tracking technologies for control in games. Some of her contributions in the field are the prediction of the eye fixation behaviour of the players using saliency maps [Sundstedt et al., 2008] and her participation in the SIGGRAPH 2010 showing her research results when controlling virtual characters with eye-tracking technology [Sundsted, 2010]. Another important contribution, relevant to this topic, comes from Almeida, with his survey of gaze behaviour as an input for video games characters control [Almeida et al., 2011].

As a counterpart, eye-tracking technologies cannot be considered accurate enough in some special cases [Isokoski et al., 2009], for example when selecting everything that the payer looks at, an issue known as the Midas touch [Jacob, 1990], or interacting with distant objects. These features are considered to be distracting, affecting the interaction with the players and the game flow itself [Jimenez et al., 2008].

Another contribution comes from Nacke, which has several lines of research in the fields of usability in games and scientific measurement of game experience. One contribution is based on analyzing the game-play experience and the immersion that eye trackers can provide as an input for video games. His findings indicate that gazed control games offer a positive experience for players, due to the immersive sensation and the innovative camera control [Nacke et al., 2009]. These effects were measured by calculating and comparing game scores and also, with a questionnaire that was distributed among the participants.

An eye-tracking study by Renshaw deepens the theory previously exposed in relation to engagement, game experience and game flow [Nacke et al., 2009], [Jimenez et al., 2008]; providing also a methodology for using the eye tracker to help game designers to overcome design problems during the development phase [Renshaw et al., 2009].

Finally, given the popularity and the release of more affordable eye-trackers, there is an opportunity to explore other ways of game experience, in which all the aspects in the game are integrated with the eye-tracker [Chang et al., 2013]. This article is the novelty of integrating the narrative, the characters and design elements with the eye-tracker, which seems to arise new opportunities to explore different game-play mechanics.
Chapter 3

Method

The different methods used for design, implementation and experimentation are covered on the following Chapter 3. It is divided into three different sections. Section 3.1 exposes the set of general parameters, established to carry out this study. Section 3.2 focuses on the guidelines used for experimental set up and Section 3.3 gathers the information regarding the procedures used during the testing rounds.

3.1 General Parameters

Initially, an eye tracking system needed to be selected to carry out this study. The parameters for choosing a suitable eye tracker were its accuracy, sample rate, precision, operating distance, movement range, binocular tracking, blinking recovery, supported screen size and cost. In addition, features that could be used for video game interaction on compatibility with game development tools will be considered on this selection process [Isokoski et al., 2009]. Also, additional features that could provide compatibility with different game development technologies will be considered.

Since this study aims for a change in the way eye tracking technologies have been applied to video games, a gaze based interaction technique will be designed with the purpose of providing task assistance to players. In order to provide coherence and consistency, the visual perception theory for humans and the most representative features from the selected video game genre will be taken into consideration to determine the design parameters. Once this interaction technique is designed, it will be implemented in a C++ game script.

Two video games will be developed further on. Both of the games will use an Xbox 360 gamepad as the controlling input and will have the same mechanics, elements and objectives. However, only one of the games will implement the gaze based interaction technique.

Afterwards, a set of volunteers will test both of the games under a controlled
environment. During the testing rounds, players' performance will be measured in terms of the time required to finish the game, and will be recorded for both of the prototypes. Finally, volunteers will answer a post-test inquiry after playing both of the games, in order to get their general opinion regarding the game experience when using the gaze based interaction technique.

The gathered data from the testing rounds will lead to two different types of evaluation:

- **Player performance**: to determine if players had a performance improvement when using the gaze aware game, the time measurements from both of the games will be analyzed by the use of a statistic significance test [Smith and Graham, 2006, Isokoski et al., 2009, O'Donovan, 2009].

- **Game experience**: In addition to the player performance measurement, which is the main objective from this experimentation, a post-testing inquiry will be carried out once the volunteers finished playing both of the games. The intention behind this is to get a general overview of how the players felt when interacting with the gaze based video game. [Renshaw et al., 2009, Nacke et al., 2009, Jönsson, 2005].

Finally, by performing the previous evaluations, final conclusions will be delivered from this study.

### 3.2 Experimental Set Up

To guarantee a controlled environment for the setup and testing rounds, an area inside the BTH motion capture laboratory was provided, specially for setting up the equipment for this experimentation.

An AOC e2752v 27" monitor was used as main screen for this experimentation. It was placed at 30 cm from the edge of the given desk to set up the testing equipment. Two magnetic holders, specially design for the Tobii REX, where placed on the lower area of the monitor to hold the eye tracking system. This offered the possibility of adjusting the eye tracker to a more suitable position according to the height of the volunteer, without moving the monitor itself. The magnetic holders can be seen on Figure 3.1.

The testing games were running on a Sony Vaio VGN-FW560F laptop, with the following specifications:

- Intel Core 2 Duo Processor, 2.13 GHz.
Figure 3.1: Magnetic holders for the Tobii REX eye tracking system.

- 6 GB of RAM Memory.
- 1 GB AMD Radeon Graphic Card.

The testing laptop was placed behind the monitor in order to avoid distractions that volunteers might have with the laptop screen or its sound system while running the games.

Finally, an Xbox 360 wireless gamepad was given to the volunteers as main controlling device for the testing games. A picture of the experimental setup can be seen under Figure 3.2.

### 3.3 Testing Rounds

A set of volunteers will test both of the game prototypes under a controlled environment. In order for the testing group to be highly relevant to this study's
Chapter 3. Method

Figure 3.2: Experimental setup.

approach, volunteers were submitted to the following selection criteria to participate in the experimentation [Shim et al., 2011, Klimmt et al., 2009]:

- **Game genre experience**: Volunteers must have previous experience playing the game genre that will be selected for the game prototypes.

- **Controller experience**: volunteers must have previous experience playing video games with the Xbox 360 game pad.

- **Physical and mental condition**: volunteers must have an appropriate mental and physical condition to play the game prototypes. Being under the effects of alcohol, psychoactive substances or having a physical disability that will not allow the volunteer to use the Xbox 360 game pad or the eye tracker will be the main criteria to deny the participation in the testing rounds.

Each of the volunteers selected one of the time spots scheduled for the experimentation. Every time spot was limited to 20 minutes in order to control fatigue on players, and to avoid the loss of calibration over the time.

To avoid any external distractions and to ensure a more stable reading from the eye tracker, all windows blinds were closed during each testing round, mobile
phones were asked to be turned off and access doors were locked. During a testing round, only one volunteer and the author were allowed inside the laboratory.

The testing rounds began by welcoming the volunteers in the lab and thanking for their help and time. The volunteers took the seat in front of the computer while the author sat next to the desk. Then, the Xbox 360 game pad was handed over to the volunteer.

The testing round was composed by four phases:

1. **Tutorial**: On the tutorial phase the game mechanics were introduced to the volunteers. For this purpose, an additional tutorial level was developed. In this phase, the volunteers had the opportunity to learn and adapt to the controllers, the game mechanics and also ask question regarding the overall functioning of the game.

2. **Normal Level**: On the normal level, volunteers played the game prototype that has no help from the eye tracker. The time required to finish the game will be displayed in the middle of the screen when the game is done.

3. **Gaze Aware Level**: On this level, volunteers played the gaze aware game prototype. Like the normal level, the time needed to finish the game was displayed in the middle of the screen when the game was completed.

4. **Inquiry**: A set of four different questions were asked during the inquiry phase. These questions aimed to get a general opinion from the player regarding the enjoyment, mechanics and performance on the game, while using the eye tracker system. The question asked to the players were:

   - Do you consider that the eye tracker influenced your overall results?
   - Which version of the game did you enjoy the most?
   - In terms of task efficiency, which version do you think is best?
   - According to your personal preferences towards game mechanics, which version of the game do you prefer?

Since both of the games were exactly the same on elements and mechanics, the playing order of the normal level and gaze aware level changed from one volunteer to another. In other words, if volunteer A played the normal level first, volunteer B will play the gaze aware level first. In this way, we can argue that the different results obtained in this experimentation, are influenced by gaze-based interaction a not memorization from the level that was played first.
Chapter 4

Implementation

Chapter 4 covers the different design and development processes used to implement both of the game prototypes. It is divided into four different sections. Section 4.1 addresses the search and selection of the eye tracking system for this study. Section 4.2 explains the interaction design process used to create the gaze aware game, while section 4.3 covers the aspects regarding the game design. Finally, section 4.4 describes how the gaze-based interaction and the game prototypes were developed.

4.1 Selecting the Eye Tracking System

With multiple options available in the market, a set of guidelines were needed to determine which eye tracking system would be the most suitable for this research extent. Three different eye trackers were compared in terms of their accuracy, sample rate, precision, operating distance, movement range, binocular tracking, blinking recovery, supported monitor size, cost and compatibility with game development tools [Isokoski et al., 2009].

The eye trackers selected for this comparison are:

- RED-M by SensoMotoric Instruments SMI$^1$.
- REX by Tobii AB$^2$.
- MyGaze eye tracking system$^3$.

Table 4.1 gathers the technical specifications from the previous eye tracker systems, in order to compare their capabilities and suitability for this study.

### Table 4.1: Eye trackers comparison in terms of their technical specifications.

<table>
<thead>
<tr>
<th>Feature</th>
<th>RED-M</th>
<th>REX</th>
<th>MyGaze</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>0.5°</td>
<td>0.5°</td>
<td>0.5°</td>
</tr>
<tr>
<td><strong>Sample Rate</strong></td>
<td>60 - 120 Hz</td>
<td>60 Hz</td>
<td>30 Hz</td>
</tr>
<tr>
<td><strong>Precision (RMS)</strong></td>
<td>0.1°</td>
<td>0.34°</td>
<td>0.1°</td>
</tr>
<tr>
<td><strong>Operating Distance (Max.)</strong></td>
<td>75 cm</td>
<td>90 cm</td>
<td>75 cm</td>
</tr>
<tr>
<td><strong>Movement Range at 60 cm</strong></td>
<td>32 x 21</td>
<td>50 x 36 cm</td>
<td>32 x 21 cm</td>
</tr>
<tr>
<td><strong>Binocular Tracking</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Blinking Recovery</strong></td>
<td>N/a</td>
<td>Immediate</td>
<td>250 ms</td>
</tr>
<tr>
<td><strong>Supported Monitor Size (max.)</strong></td>
<td>22&quot;</td>
<td>27&quot;</td>
<td>22&quot;</td>
</tr>
<tr>
<td><strong>Compatibility with Game Dev. Tools</strong></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td>N/a</td>
<td>595€</td>
<td>790€</td>
</tr>
</tbody>
</table>

After reviewing the technical specifications of the three selected eye trackers, the Tobii REX eye tracker came out as one of the bestsuiting options for this research extent.

The REX is one of the latest eye tracking systems released by Tobii, one of the leading companies in the development of this type of technology. This eye tracking system is being highly recommended for video game development. Thanks to its specifications, documentation, SDK, price and compatibility with the Unity game engine, the REX eye tracking system was selected as the best suiting option and was ordered for this study. The Tobii REX is shown on Figure 4.1.

### 4.2 Game Design

For designing the video game prototypes, the aesthetics guidelines, the game mechanics and the game elements were implemented by following some key concepts from the selected video game genre. This process will be explained along the following Section.

#### 4.2.1 Selecting the Game Genre

Selecting a video game genre was the starting point of the game design.

Eye tracking systems have been introduced in different video game genres, but first person shooters (FPS) and real time strategy (RTS) games are the most commonly used for implementing this type of technology [Almeida et al., 2011]. FPS and RTS games offer a set of mechanics that allow a natural and intuitive
gaze control than most of the other game genres. On a battlefield, the players can easily select several game units or aim towards a target or by just staring at it [Isokoski et al., 2009].

However, the previous examples focused on gaze controlled interaction. Since the aim of this study is to developed a gaze aware video game that provide in-game assistance to players, there is an opportunity to explore a different type of video games. Then, different game genres, other than FPS and RTS, were analyzed under the following criteria: the relevance of the gaze information to the tasks development and mechanics of the game.

A space-shooting video game was the selected genre for this research. Just like FPS, space-shooting video games offer an open space where players constantly search and attack different targets around the screen area, making the gaze information of great utility for this type of games. The true advantage of using space shooting video games is the simplicity of its game mechanics. Unlike the FPS and RTS, which implement a wider range of movements and options, the
space shooting game mechanics can be simplified in order to reduce the learning curve for new players. Having in mind that volunteers will attend to a controlled experimentation without any previous experience with the game prototypes, this feature is considered to be an advantage for this study. Starfox 64 (Figure 4.2) by Nintendo, or rogue squadron by Factor 5 and LucasArts, are some examples of the space shooting genre.

![Image of Starfox 64](http://i11c.3djuegos.com/juegos/6223/star_fox_64/fotos/analisis/star_fox_64-1777798.jpg)

Figure 4.2: Starfox 64 by Nintendo.

### 4.2.2 Aesthetics

Following the aesthetic patterns of the space-shooting genre, the look and feel of the game aimed for a futuristic science-fiction style.

The game is set on a space colony, near an alien planet deep in space. The aesthetics will aim to be consistent with this concept, offering a dusky environment based on green and yellow colors. Also, the models of the game suggest a technologically advanced environment, according to the science-fiction style established by the video game genre.

Since the game is a time based assault mission, the soundtrack will aim to provide fast and dynamic experience without losing the consistency towards the technologically advanced environment. Electronic music genres, like drum and bass or bit-pop are consider suitable for this task.

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4Source: [http://i11c.3djuegos.com/juegos/6223/star_fox_64/fotos/analisis/star_fox_64-1777798.jpg](http://i11c.3djuegos.com/juegos/6223/star_fox_64/fotos/analisis/star_fox_64-1777798.jpg) (Visited April 17th, 2014)
4.2.3 Game Mechanics

The game prototype uses an Xbox 360 (Figure 4.4) game pad as the player control input and implements the following mechanics:

- **Objective**: The goal of the game is to free the space colony of Dorst from a surrounding force field, by destroy 13 energy generators placed in different locations on a ring-shaped alien space station. The game will be completed when the player has destroyed all of the generators and the total amount of time required to finish the game, will be displayed in the middle of the screen. In short the game objective is a time based assault mission.

- **Launch**: At the beginning of the game, the player spaceship will be inside of a space transboader. By pressing the Start button, the spaceship will be launched into space, the game time and the target countdown will be triggered and the eye tracker system will be initialized on the gaze aware version of the game.

- **Movement**: The spaceship movement has five degrees of freedom, one degree for pitching (tilt forward), two degrees for yawing (swivels left and right) and two degrees on rolling (pivots side to side). The left thumb stick will controls the pitching and yawing movements, while the Right button (RB) and Left button (LB) control the rolling movements.

- **Attacking**: The space ship will shoot lasers by pressing the A button.

- **Hazards**: The game does not have any enemy bots, but players may die if they crash with the alien space station or the force field.
• **Restarting**: If players die, they are able to restart the level by pressing the Back button.

![Xbox 360 game pad](image)

Figure 4.4: Xbox 360 game pad.

### 4.2.4 Game Elements

The following is the list of elements used to create the video game for this study. They were classified into two different categories: 3D elements, audio elements and UI elements.

#### 3D Elements

The video game level was developed by the use of five different 3D models. They were:

• Player ship model (Figure 4.5).
Chapter 4. Implementation

- Space transboarder model (Figure 4.6).
- Alien space station model (Figure 4.7).
- Energy Generator model (Figure 4.8).
- Space colony model (Figure 4.9).

Due to schedules and time limitations, all of the previous 3D models were acquired through the website turbosquid.com, under a royalty-free license. Also, to preserve consistency in the aesthetics, the models were bought from the same 3D artist identified by the user name of Angryfly.

Audio Elements

Three different types of audio elements were used for developing the video game: the sounds effects, the soundtracks, and the voice instructions.

Using the free distribution prefabs that came by default with the unity game engine, the sounds effects were used for the shooting lasers and the explosions. Following the parameters from the aesthetics and the general look and feel of the game, a set of 8-bit drum and bass songs were provided by the Mexican artist
NitroFun, to be used as the sound tracks for the game under a royalty free license.

Lastly, the voice instructions provided tips and guidelines in the game. They were done by a recording a reading bot and modifying the audio files with the help of the audacity software.

**UI Elements**

The UI (user interface) elements are composed by a set of text messages, used to provide information regarding the player performance. While the game is being played, the elapsed time and the amount of energy generator that are left to finish the game will be displayed on upper-left corner of the screen.

Additionally a score text will be displayed, giving 100 points for each generator destroyed. Even if the score value does not have any effect on the game or in the performance measurements, it is shown to offer players a consistence in the game elements that are typically found on the UI elements.

For the UI elements, the capella font by Iconian Fonts and the Xirod font by Typodermic Fonts, were acquired through the website dafont.com, under a freeware license.
Chapter 4. Implementation

Figure 4.7: Alien space station model.

Figure 4.8: Energy generator model.
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Figure 4.9: Space colony model.

Figure 4.10: The UI elements were placed on the upper-left side of the screen.
Figure 4.11: Once the game is completed, the time required to finish it is shown in the middle of the screen.

4.3 Interaction Design

For designing the interaction method, three key concepts were taken into account:

- Creating a gaze aware game means that the system will always have the capability to know what point on the screen is the player looking, at a given time. The gaze information will always be available for the game.

- Since goal of the interaction technique is to use the eye tracking system for in-game assistance, an effective way to attract the attention of the players was needed.

- The goal of this study is to test if gaze aware games and gaze based interaction could provide a performance improvement in terms of play time reduction. Therefore, the interaction design must take into consideration all the task that players need to perform in order to complete the game.

The previous ideas were used to established the parameters for the further design of the gaze based interaction technique. This parameters were the key concepts applied to the PACT framework.

PACT is a framework that specializes in designing and creating human-computer interaction methods. PACT is an acronym that relates the four criteria that are taken into account for designing interaction techniques with this framework: People, Activities, Contexts and Technologies. All the related ideas and elements around will be classified in terms of these four criteria and will used in several
brainstorming sessions to develop design ideas [Benyon, 2010].

As result from this analysis, the gaze based interaction was based on the following procedure:

1. The gaze aware game will relate the position of the players’ gaze point, with the game elements that were displayed on the screen.

2. The game will compare the position of the player and the position of the energy generators. If an energy generator is inside of a determined shooting range, the game evaluates if it had been perceived in terms on a two second fixation time.

3. If an energy generator has not been perceived, the game will animate the size of the generator model, making it ten times bigger over a one second time lapse.

4. Once the generator is perceived, the the game will animate the generator model back to its original size.

5. A generator model, within the shooting range, will not be animated again if it has been perceived. A generator can be animated again, if it has been previously out of the shooting range.

Animating the size of the models was the selected method to attract player attention, since motion is considered to be one of the strongest cues for this purpose [Borji and Itti, 2014]. The game assisting hint was then, based on motion.

4.4 Game Development

The Unity 3D game engine, on its 4.3.4 free version, was chosen as the developing platform for both of the games, thanks to its compatibility with the Tobii REX eye tracking system and C# game scripts.

4.4.1 The GameObject class as a programming method

The video game prototypes were implemented using the advantages of the GameObject class. In Unity, a GameObject item could be define as a programmable container for a set of game elements (models, audio tracks, cameras, lighting,  

scripts, colliders, etc). A GameObject items can inherit properties from another GameObject elements, create or modify its own properties, manipulate or being manipulated by other GameObject items or even hosting and executing several game scripts at the same time.

Thanks to the flexibility of the GameObject class, programming algorithms in Unity can be done in several different ways. They can be programmed using a single game script and a single GameObject item, a single script and several GameObject items, several scripts on a single GameObject item or, like in this case, several scripts and several GameObject items.

All of the game mechanics and game elements were programmed and distributed through GameObject items. The following list provide further information about the components (different game elements contained by the GameObject item) and the functions of the eight GameObject units that were used for the implementation of the video game prototypes.

**GameObject Transbordert**

- Components: Transbordert mesh, shader and respawn point.
- Functions: Provide the 3D coordinates to respawn the player space ship.

**GameObject Force Field**

- Components: Sphere mesh, force field shader, sphere collider and spin script.
- Functions: Destroys player space ship on collision and provides a stationary rotation animation for the sphere mesh.

**GameObject Game Controller**

- Components: Game controller script.
- Functions: The game controller monitors is the most complex item in the game and manages all of the game elements. It keeps track of the elapsed time, controls the GUI texts, verify the amount of energy generator left, synchronizes the EyeX engine for the eye tracker initialization, stops and restarts the game. Additionally, the game controller manages all of the events that are triggered by collision, determining if a game element should be destroyed or not.

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GameObject GUI Texts

- Components: Crash, final time, generator, score, retry and start GUI text elements.
- Functions: Stores the position for each of the GUI texts elements that would be displayed on the screen.

GameObject Lighting

- Components: Main light, rim light, fill light.
- Functions: Stores the position for each of the light elements in the game.

GameObject Player Ship

- Components: Capsule collider, player controller script, player space ship mesh, player space ship shader, main camera, engine light, laser spawn points, audio listener and all of the sound effects, sound tracks and voice recordings in the game.
- Functions: The player ship holds the player controller script, which contains the functions to establish a communication (through the game controller) with Xbox 360 game pad. It allows the player to manipulate the movements and attacks of the space ship. Also, it has a capsule collider that trigger collision events on the game controller. The player ship also holds the game camera, which follows the player ship mesh along the game environment. Finally, all of the sound management is done by this GameObject item, since it holds the only audio listener in the game.

GameObject Energy Generator

- Components: Box collider, energy generator mesh, energy generator shader and the destroy by laser script.
- Functions: The energy generators are the elements that players must destroy in order to complete the game. Their function is to detect collision with player lasers in order to trigger the destroy function on the game controller script.

GameObject Alien Space Station

- Components: Aline space station mesh, alien space station shader, mesh collider.
- Functions: Stores the position for each of the energy generator and triggers the player collision event in the game controller.
4.4.2 Using the Tobii EyeX engine

The EyeX engine is a high level API that provides basic functions for eye tracking interaction, such as clicking, scrolling or zooming\(^7\).

In order to implement the use of the Eyex engine in Unity, an additional plug-in needed to be referenced. The EyeX engine is a .dll library that requires to be included into the game assets of Unity, in order to function correctly. This library provides a communication channel between the game engine script compiler and the eye tracker drivers.

An additional script was added in the game controller, implementing some of the functions from the EyeX engine. The game controller will constantly receive information about the players gaze point on the screen. Then, the EyeX engine will evaluate if the gaze point is covering any of the game elements that are currently being displayed. If so, the EyeX will identify the object to the game controller. Then, in the case of the energy generators, the game controller will scale ten times the size of the mesh, creating a grow animation during a one second time period. Nevertheless, all of the other components of the GameObject energy generator will remain the same for both of the games.

In this way, the gaze based interaction is implemented on the energy generators, modifying the size of the mesh without offering any other advantages since the colliders and shaders remained the same for both of the prototypes.

Chapter 5

Results

The following Chapter 5 gathers the testing results after applying the methods and parameters described in Chapter 3. It will be divided into three different sections. Section 5.1 covers the time measurements and the initial assumptions that can be inferred by analyzing these data. A further statistic significance test will be explained in Section 5.2. Finally, Section 5.3 focuses on the results obtained from the post-test inquiry applied to the players.

5.1 Time Measurement Data

A total of 26 volunteers, 23 men and 3 women between the age range of 21 and 31 years old, participated in the experiment. Since the player performance will be measured in terms of the time needed for each volunteer to destroy all of the 13 targets, the time measurements were divided into two categories: the time required to finish the normal game and the time needed to finish the gaze aware game, both measured in seconds.

Table 5.1 displays the time needed for each of the volunteers to finish both of the game prototypes, along with time difference between the normal game and the gaze aware game measurements. For an easier visualization, Figure 5.1 offers a graphic representation of these time measurements. Additionally, some statistical values, such as averages, standard deviations and range values, were calculated from this data and are shown in Table 5.2.

By analyzing the time measurement data, the following initial observations could be established:

1. Players required an average 285 seconds (4 minutes and 45 seconds) to finish the game on the gaze aware version. On the other hand, an average 359 seconds (5 minutes and 59 seconds) were needed to finish the normal game.

2. The highest time required to finish the game was 610 seconds (6 minutes and 10 seconds) on the normal version and 425 seconds (7 minutes and 5
### Time Measurements

<table>
<thead>
<tr>
<th>Volunteer</th>
<th>Normal Game</th>
<th>Gaze Aware Game</th>
<th>Time Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>321</td>
<td>217</td>
<td>102</td>
</tr>
<tr>
<td>2</td>
<td>227</td>
<td>193</td>
<td>34</td>
</tr>
<tr>
<td>3</td>
<td>452</td>
<td>327</td>
<td>125</td>
</tr>
<tr>
<td>4</td>
<td>610</td>
<td>410</td>
<td>200</td>
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<tr>
<td>5</td>
<td>408</td>
<td>332</td>
<td>76</td>
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<tr>
<td>6</td>
<td>329</td>
<td>278</td>
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<td>7</td>
<td>413</td>
<td>292</td>
<td>121</td>
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<td>374</td>
<td>284</td>
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<td>253</td>
<td>225</td>
<td>28</td>
</tr>
<tr>
<td>10</td>
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<td>12</td>
<td>382</td>
<td>320</td>
<td>62</td>
</tr>
<tr>
<td>13</td>
<td>487</td>
<td>425</td>
<td>62</td>
</tr>
<tr>
<td>14</td>
<td>256</td>
<td>164</td>
<td>92</td>
</tr>
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<td>24</td>
<td>403</td>
<td>327</td>
<td>76</td>
</tr>
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<td>25</td>
<td>273</td>
<td>190</td>
<td>83</td>
</tr>
<tr>
<td>26</td>
<td>320</td>
<td>245</td>
<td>75</td>
</tr>
</tbody>
</table>

Table 5.1: Time measurements results from each of the volunteers.

### Statistic Values

<table>
<thead>
<tr>
<th>Value</th>
<th>Normal Game</th>
<th>Gaze Aware Game</th>
<th>Time Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>359.80</td>
<td>285.76</td>
<td>74.03</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>97.00</td>
<td>71.70</td>
<td>47.52</td>
</tr>
<tr>
<td>Highest</td>
<td>610</td>
<td>425</td>
<td>200</td>
</tr>
<tr>
<td>Lowest</td>
<td>215</td>
<td>164</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 5.2: Statistical calculations and range values from the testing results.

3. The fastest players finished the game in 164 seconds (2 minutes and 44 seconds) on the gaze aware version.
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Figure 5.1: Time needed by each of the volunteers to finish the normal game (blue bar) and the eye aware game (orange bar).

seconds) when using the gaze aware version, and 215 seconds (3 minutes and 35 seconds) in the normal version respectively.

4. The time needed for the player to destroy all the targets was reduced in 200 seconds (3 minutes and 20 seconds) on the best round and 18 seconds on its worst round, when playing the gaze aware game.

5. All of the volunteers needed less time to destroy all the targets while playing the gaze aware game, having an average time difference of 74 seconds (1 minute and 14 seconds) when compared to the results with the normal game.

5.2 Statistic Significance Test: Paired t-Test

The previous section showed that there was a reduction in the time needed to finish the game when comparing the results of the gaze aware with the normal game prototype. Does this time difference provide significant evidence to assume that there was an improvement in the player performance? To answer this question, a statistic significance test will be performed in order to establish the confidence level from these measurements.

To select the most appropriate significance test, some aspects from the testing needed to be considered, in particular that:

- The sample size was 26 volunteers.
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- Each of the volunteers was tested twice, one time for the normal game and the other one with the gaze aware game.
- The data is considered to be dependent, due to the requirements established to participate in the experimentation.

Taking these aspects into account, a paired t-Test was chosen as the most appropriate statistic significance test for this study. The paired t-Test require data to be in pairs and has to be dependent. Also, it is typically used when the same subject was tested twice. Additionally, it is recommended to use t-Test when the sample sizes are up to 30 subjects. If the sample is bigger a z-Test is recommended [Mowery, 2011, Daya, 2003].

In order to apply the paired t-Test to the testing results, a four steps process was used. This will be explained in the following subsections.

5.2.1 Step 1: Statistical Data and Hypotheses

Initially, some statistical data is required from the testing results, in order to carry out the paired t-Test calculations. Specifically, the size of the sample, the mean value (average value) and the standard deviation from the time differences are needed.

The sample size \( n \) was previously mentioned on Table 5.1 and, by reviewing Table 5.2, the mean value \( \bar{X}_d \) and the standard deviation \( S_d \) for the time difference are also provided. The respective values for this variables are shown on Equation 5.1.

\[
\bar{X}_d = 74.0384
\]

\[
S_d = 47.5247
\]  
\[ (5.1) \]

\[
n = 26
\]

By assigning the values for \( n \), \( \bar{X}_d \) and \( S_d \), the only thing remaining is establishing the hypothesis for the paired t-Test.

Two different hypotheses are proposed for this study. The first one is the null hypothesis and suggest that there is no significance difference between the time required to finish the gaze aware game, compared with the time needed for the normal game, to consider an improvement in players’ performance. The second
one will be the alternative hypothesis and suggest that there is a significance
difference in the time measurements to consider a performance improvement.

Both of the hypothesis for this paired t-Test are shown on Equation 5.2, where
\((H_0)\) represents the null hypothesis, \((H_a)\) the alternative hypothesis and \((\mu)\) the
true mean difference in the testing data. It is worth to mention that this will
be right tail test, since all of the time differences are positive values due to the
setting for this statistical analysis.

\[
H_0 : \mu = 0 \tag{5.2}
\]
\[
H_a : \mu > 0
\]

5.2.2 Step 2: Test Statistics
The test statistic step focus the calculation of the respective \((t)\) value for the
experimentation. To do so, the general formula for the paired t-Test, exposed on
the Equation 5.3, will be calculated with the values established on the previous
step.

\[
t = \frac{\bar{X}_d}{\frac{S_d}{\sqrt{n}}} \tag{5.3}
\]

\(t = 7.9437\)

By solving the equation, the calculated test statistic \((t)\) has a value of 7.94.

5.2.3 Step 3: Setting Up Rejection Regions
In order to determine the statistic significance of the previous \((t)\) value, the re-
jection region needs to be determined. The rejection region represents a range of
values from the t-Distribution that are considered to be statistically sufficient to
reject the null hypothesis \((H_0)\) and conclude the alternative hypothesis \((H_a)\).

The rejection region is determined by the critical value \((t_\alpha)\). This value is
established in terms of two variables: the degrees of freedom \((df)\) and the given
value of \((\alpha)\).

The degrees of freedom \((df)\) are calculated by solving the Equation 5.4. For
this study, it has a value of 25.

\[
df = n - 1 \tag{5.4}
\]
The variable $(\alpha)$ is a given value that determines the confidence level to which the testing results will be submitted. For this statistical analysis, two values of $(\alpha)$ will be used. The value for $(\alpha_1)$ will be 0.05 and determines a confidence level of 95%, being this the most common value used for this variable. The value for $(\alpha_2)$ will be 0.0005 and determines a confidence level of 99.9%.

By knowing the values for the degrees of freedom $(df)$ and $(\alpha)$, the t-Table\(^1\) can be referred to determine the critical values on the t-distribution. With 25 degrees of freedom, $(\alpha_1)$ establishes a critical value $(t_1)$ of 1.708 and $(\alpha_2)$ establishes a critical value $(t_2)$ of 3.725.

The rejection region then, is determined by all of the values that are on the right of (greater than) the critical values $(t_1)$ and $(t_2)$ on the t-Distribution.

**5.2.4 Step 4: Decision**

By calculating the test statistic value $(t)$ and, by determining the rejection regions for a 95% and a 99.9% confidence level, a final decision regarding whether or not to reject the null hypothesis $(H_0)$ can be taken.

To do so, the test statistic value $(t)$ and the critical values $(t_1)$ and $(t_2)$ will be placed on a t-Distribution graph. As shown on Figure 5.2, $(t)$ is greater than $(t_{alpha1})$ and $(t_{alpha2})$, and falls into the rejection regions.

Figure 5.2: Critical values $(t_1)$, $(t_2)$ and the Test Statistics value $(t)$ on the t-Distribution.

According to these results, the null hypothesis $(H_0)$ is rejected and the following conclusions can be delivered:

\(^1\)http://www.stat.tamu.edu/~lzhou/stat302/T-Table.pdf (Visited May 24th, 2014)
The data provided sufficient evidence, at an \( \alpha_1 \) value of 0.005 and an \( \alpha_2 \) value of 0.0005, to conclude that the gaze aware prototype improved players performance in terms of the time needed to finish the game.

5.3 Post-test Inquiry

To provide a general perspective about the game experience, volunteers were asked a four question inquiry after interacting with both of the game prototypes. The results of this inquiry can be seen under Figure 5.3.

![Figure 5.3: Results from the post-test inquiry.](image)

For the first question, 22 players (84.61\%) considered that the assistance of the eye tracker influenced the improvement in their performance, while 4 players (15.38\%) considered that their improvement was due to a different factor. On the second question, 16 players (61.53\%) consider the gaze aware version the most enjoyable, while 10 players (38.46\%) enjoy the normal version the most.

In terms of task efficiency, 21 players (80.76\%) considered the gaze aware version to be better over the normal version, who was chosen in this matter by 5 players (19.23\%). Finally, taking into account their preferences towards game mechanics, 21 players (80.76\%) preferred the gaze aware version of the game, while 5 players (19.23\%) considered the normal version to suit them best.
This study proposed a change on the approach of how eye tracking systems has been applied to video games, introducing this technology as a task assisting method instead of an input for game control. It has tested the player performance by comparing the time needed to finish two similar game prototypes. Both of them used a traditional control method through a Xbox 360 gamepad, but only one offered the gaze based interaction.

The testing results showed that all of the 26 volunteers required less time to finish the gaze aware game. In average, there was a 74.03 second (1 minute in 14 seconds) difference when comparing the result from the normal game. Also, the highest and lowest time values from the gaze aware game were lower than those from the normal prototype.

A paired t-Test was done with the testing data, in order to determine the statistic significance from the results. The t-Test showed that the testing results provide sufficient evidence to reject the null hypothesis and overcome confidence of 95% and 99.9%.

According to the previous results, the following final conclusion can be delivered:

- Under a controlled environment, the testing results provided sufficient evidence to conclude that the gaze aware prototype improved the performance of all of the selected participants, in terms of the time needed to finish the game.

Nevertheless, the post-test inquiry showed that volunteers had divided opinions about the experience of playing with gaze aware game.

Even if the majority (22 volunteers) considered that the time difference was influenced by the eye tracker assistance, four players considered that their improvement was due to a different factor such as memorization, better controlling
or luck.

In terms of enjoyment, opinions were divided. 16 volunteers preferred the gaze aware game, because it made the game easier. The 10 remaining players liked the normal game better, because the gaze interaction was not clearly identified by them, and the changing size of the targets was, perhaps, a little distracting. It is worth to mention that the gazed based interaction was designed to work independently from players. Also, the fact that players got distracted by the growing animation on the energy generators, suggest that movement was indeed an effective stimuli to capture the attention of players.

Regarding task efficiency and personal preferences, 21 players selected the gaze aware game as their best suiting option. They considered that the interaction with an eye tracker was very innovative and provided an advantage to finish the game faster. However, 4 volunteers preferred the normal game prototype, since the familiar mechanics were consistent with their preferences towards a more traditional interaction with games.

The Tobii REX eye tracking system was selected for this study, thanks to its technical specifications and compatibility with game development tools such as the Unity 3D game engine. Nevertheless, the author consider that similar results could be obtained if a different eye tracker is used. Even if the Tobii REX has better technical specifications than the other eye trackers compared in this study, there was not a great difference between them to expect different results if the game prototypes were tested under a controlled environment. Additionally, the gaze based interaction technique does not require any special feature to be implemented. In fact, it only uses the gaze point on the screen, a feature that all of the eye tracker are able to perform.

A space shooting game was the selected genre for this study thanks to the simplicity of the game mechanics and the rich open spaces for gaze interaction. Further studies may consider the introduction of eye tracking interaction as a task-assisting method in different game genres. Platform games, like Rayman origins by Ubisoft, or adventure games, like The Legend of Zelda by Nintendo, are considered interesting possibilities in terms of game mechanics. One example of this is the upcoming title Son of Nor\footnote{https://www.youtube.com/watch?v=OxxDjW0cS-Y (Visited May 24th, 2014)} developed by Still Alive Studios.

This study offered a glimpse of the potential that eye tracking technology has, to enhance interaction with players in the space-shooting video games. Additionally, the design and development more complex and more intelligent game stimuli, also provide an interesting trend for further research. Desktop VR or
blink gesture interaction are some of the possibilities that could be explored.

Eye tracking systems applied to video games is a research field that offers further development. With the introduction of different technologies that might enhance game interaction, more intelligent, challenging and engaging experiences can be delivered to players, by implementing task assisting systems and sense aware games.
References


