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Design of Attention-Feedback Games
Based on Face and Eye Tracking

MSc Computer Science
25 August 2017



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Dissertation Title: Design of Attention-Feedback Games Based on Face and Eye Tracking

Module: MSc Computer Science

Date: 25/08/2017

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Abstract

Attention Deficit Hyperactivity Disorder (ADHD) is a common and chronic disorder that starts from childhood and proceeds to adulthood. Individuals with this disorder face difficulties in paying attention and display impulsive behaviours. This project will exploit the computer vision field with the aim to investigate how the problem explored can be addressed with computerized sensing games that track the user's attention and give a reaction based on it. Such applications will be used to achieve interactions between the applications and the users as well as to collect data for generating statistical analyses that can be potentially used to test the user's ability to maintain their attention and follow a specific task.

The concept explored in this project was focused on developing vision based game applications based on the idea of having a target object alongside distractor objects. The task that the users were required to follow was to maintain their attention at the target object and not be distracted by the other objects. This way conclusions about the user's ability to keep their focus at the target stimuli were generated.

This idea was investigated by developing two computerized sensing game applications that interacted with the users with human gestures with the aim to gain insights on their attentional capacities. The first application utilized only a webcam for making interactions with the users from their head pose / blinks / mouth movements and gave a response based on their levels of attention. Furthermore, this application made off-line recordings of the subject's head pose, positions of the objects on the screen as well as saved webcam images for building statistical analyses and reaching conclusions on participants attentional capacities. The second computerized sensing game utilized an eye tracking device for allowing users to interact with the game only with their eyes and gave reactions depending whether the subjects had their attention at the target object or not. This application collected data from participants eye movements such as their gaze points, their blinks, whether the user was in front of the game view and it collected the positions of the target and distractor objects on the screen. Furthermore, a user evaluation study was conducted to establish statistical analyses on the attentional capacities of the participants based on their feedbacks given on an online form, based on the data captured from the eye tracking device as well as based on the user's performance on the game which was measured from the scores gained. In total, 30 participants were part of the study in which 15 were females and the other 15 were males. All the subjects were not diagnosed with ADHD and 30% of them required vision correction with glasses. However, as the application was properly implemented, the interaction with the game functioned perfectly and no calibration procedure was included.

The results obtained indicate that head/eye movements as well as facial expressions are the strongest indicators of ADHD, therefore utilizing these parameters in a vision based game application and especially in games that are based on the idea of displaying targets and distractors stimuli, can give important insights on ADHD features. From the results obtained on the user evaluation study, we can conclude that participants maintained their focus at the target object and were able to finish the game successfully. Participants rated the game somehow challenging as

they moved from one level to another and in most the cases, the distractors didn't affect their attention on the task. On the contrary, they were more motivated to keep their focus on the target stimuli, indicating that this game can be potentially used for training ADHD in long term. Moreover, the subjects gave very positive feedbacks on the application functionality and its design, suggesting that the game interaction and the features included were well implemented. In addition, it was acknowledged that there is no gender impact on the user's levels of attention. However, there is a negative weak correlation between age and attentional capacities, with lower levels of attention in older participants.

Overall, these results suggest that a vision based application can be a preferred technique for diagnosing ADHD and training this disorder in the long term. Differently from medication or trainings with no game elements, computerized sensing games do not have side effects and are known to be more entertaining for individuals. Finally, the results obtained indicate that computerized sensing games which utilize a webcam or an eye tracking device can be potentially used to gain insights on the user's levels of attention.

Acknowledgements

I would like to thank my supervisor, Professor Hans Gellersen for the excellent guidance he has given me throughout this project. Not only he has helped me learn about an unfamiliar topic in an intensive academic year but has also been able to provide help whenever called upon. Thanks to his expertise and his enlightenment I have been able to achieve my targets throughout the year and create this study.

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1.Introduction

The project at hand aims at exploring Attention Deficit Hyperactivity Disorder (ADHD) with predominantly inattentive presentation and tackles this common mental condition by exploiting the computer vision field for creating Vision Based User Interfaces (VBI) that will interact with the participants only with their gestures. The development of the vision based game application will be utilized to gain insights on the user's level of attention based on the data collected from the user evaluation study, from the eye tracking device and from their performance on the game.

Attention Deficit Hyperactivity Disorder (ADHD) is a mental disorder which is related to brain failure in monitoring inhibition and self-control. This impairs other important brain functions for maintaining attention which are termed as executive functions as discussed in Kelly (2003).

ADHD symptoms typically arise in childhood before the age of 7 (between 3 and 6 years old), and affect 11% of children in school. Children who suffer from ADHD often act immaturely compared to their friends and they also exhibit problems in language skills or in social activities.

Symptoms of this disorder persist into adolescence and adulthood in most cases with serious consequences such as school failure, driving problems, difficulty with peers, depression, substance abuse, relationship problems and often commit numerous offenses if not identified and treated properly at an early age. Kelly (2003) outlines that in adolescence, boys are more likely to be diagnosed with ADHD than girls whereas girls who suffer from ADHD are more predisposed to have eating disorders.

Adults who suffer from ADHD, face problems with their careers and with their private lives. These individuals, have executive functioning (EF) issues which relate to difficulties in completing tasks or may forget important things.

As explored in (Solianik, 2016; Fasanya, 2017; Teleb, 2012; Merritt, 2007; Ramtekkar, 2010), a topic of interest is to investigate if there is a difference between genders in individuals with ADHD and whether there is a gender impact on their levels of attention. Most of the results have revealed that there is no significant difference between genders when they are required to perform various tasks. On the contrary, Ramtekkar (2010) suggested that in participants with ADHD with predominantly inattentive presentation, the level of inattention was significantly higher in male participants compared to female participants.

Tun and Lachman (2008) conducted a study with a large number of participants to demonstrate the effects that age has in levels of attention based on their reaction time in performing various tasks. A wide range in age was included (32-85 years old) and the results showed that more complex tasks were associated with slower reaction times for older participants. Williams, et al (2016) outlined that elderly adults showed significant differences in dividing attention compared to adults in a young or in a middle age whereas between the adolescents and middle aged individuals, no differences were observed.

Medications are widely used to manage and normalize symptoms of ADHD. Around 70% to 80% of children with ADHD have positive reactions to medications. However, these

improvements show up in short-term and they carry the risk of side effects including depression, changes in subject's moods as well as effects on their blood pressures. Furthermore, stimulant medicines do not normalize the entire range of behavioural problems as considered elsewhere (Kelly, 2003).

1.1 Aim and Main Objectives of the Study

As mentioned in the beginning of this chapter of the problem explored, symptoms of ADHD typically appear in childhood, therefore diagnosing and treating this disorder in an early age is very important as the development of the brain occurs in these stages of life. This way, children can learn good behaviours in these early years so they can become successful in their future and live a healthy life without having problems in their social activities, educations or even in careers. Games based on vision are becoming highly desired as they are seen to be more entertaining and challenging than games controlled with a mouse or a keyboard. Therefore, the main aim of the study is to investigate how we can address the problem explored with games that retrieve the user's attention as input and return a response based on it. This study will be focused on gaining insights from user's behaviours and from their feedback while they will be interacting with the game and while they will be required to execute a specific task.

The study addresses the aim with focus on four objectives:

- 1- A survey on the indicators and games for diagnosing and treating ADHD: This objective will be explored in the "Background" chapter in which parameters used to detect the levels of inattention and hyperactivity as well as the most common methods practiced for decreasing such levels will be discussed.
- 2- An investigation on how a computerized sensing game can utilize only a webcam as input for reacting based on user's attention: In the next chapter, an attentional awareness application which was developed to discover ADHD features from only a webcam will be presented.
- 3- An extension of the game design with an eye tracker: The second vision based game developed and presented in this study will carry the same task as the previous application but it will be closer to a real game application and it will utilize an eye tracking device as an input for interacting with individuals and for capturing different ADHD features.
- 4- Evaluating the game design with healthy users: The final chapter of this study will answer with statistical analyses, all the established research questions based on the participants feedback, their performance on the game and on the data collected from the eye tracking device.

1.2 Chapter by Chapter Overview of the Report

This study will start by reviewing papers conducted for monitoring and training ADHD and will outline the most appropriate methods and solutions used to reveal and to tackle this disorder. The following chapter will present a vision based demo application which utilizes only a webcam for interacting with the participants through head pose / blinks / mouth movements and collects data from the subjects in an off-line fashion. The next section will discuss an extension of the main game design presented in the previous chapter that utilizes an eye tracker and takes only the user's eyes as input to interact with it. The game concept, the game design and the main implementation process of the application will be introduced in the same section. All the established research questions will be answered in the following chapter based on the data collected from the participants, from their performance on the game and from the eye tracking device. Finally, the last chapter will highlight the overall conclusions obtained from this study, the lessons learned and all the possibilities in which this study can be further explored in the future.

2. Background

This chapter will review different papers from previous experimental works which are related to diagnosing and training ADHD and will highlight significant findings that are taken into consideration for the development of the vision based game application for this project. This review will start by exploring the indicators that are used to detect the levels of inattention and hyperactivity in users that suffer from ADHD and continues by presenting the most common tasks and games used to effectively train this disorder.

2.1 Head Motions and Facial Expression for Diagnosing ADHD

Different studies were conducted to understand the number of head motions and facial expressions between ADHD groups and normal groups while participants were required to perform various tasks. In the following experimental papers, it was observed that head motions and facial expressions are strong indicators of ADHD with predominantly hyperactive-impulsive presentation.

2.1.1 Head Movements

From a hyperactive-impulsive perspective, it was hypothesized that the number of head movements was higher in the ADHD group due to impulsive behaviours. Epstein, et al (2007) applied a go/no-go task to ADHD and non-ADHD groups where participants were required to press a button for every letter in alphabet except for the letter 'X'. In this paper, it was concluded that the participants responded with increased head movements immediately after committing an error and the patient group that was more prone to head motion was the diagnostic category of ADHD. A Continuous Performance Task (CPT) was applied in Teicher, et al (1996) where participants were engaged in a go/no-go task and an infrared motion analyses system was used to track and record the movements of head, shoulder, back and elbow in children to reveal abnormalities of movement patterns in ADHD group as well as to distinguish them from the control group. It was concluded that on average, children with ADHD displayed 2 to 3 times more movements than control children on the CPT task. Furthermore, they were 10% less accurate and slower in their responses compared to the other group. Kong, et al (2014), applied an experiment with Magnetic Resonance Imaging (MRI) and the same conclusion was reached that the head movements were higher in subjects who suffered from ADHD compared to those in the other group because the psychological trait of impulsiveness is a strong factor that contributes to head motions causing the hyperactive subjects to move their heads more intensely.

2.1.2 Facial Expressions

Apart from head motions, ADHD patients also exhibit significant presentations in conveying and identifying facial expressions. Jaiswal, et al (2017) hypothesized that facial expressions and head motions could provide important cues for detecting psychological states in participants such as ADHD, therefore they used a normal 2D imaging camera and Dynamic Deep Learning to get classification rates of these disorders. Participants had to read and listen to 12 short stories followed by 2-3 questions and the subjects had to answer verbally. The results showed that their approach was accurate to predict ADHD. Other studies (Da Fonseca, 2008; Pelc, 2006; Williams, (2008); Yuill, (2014)) have investigated the ability of ADHD subjects to identify emotional facial expressions where four emotions (happiness, anger, disgust and sadness) were presented to a group of children that met the criteria for ADHD disorder. For these tests, different photographs that showed these emotions in varying intensities were used. It was deduced that the accuracy for detecting the anger and sadness emotional facial expressions was significantly lower in ADHD children compared to control subjects. Furthermore, children with ADHD had the tendency to mistake anger for disgust.

2.2 Eye Movements for Diagnosing ADHD

From the inattentive perspective of ADHD, eye movements and other ocular parameters can serve as indicators of the level of attention. Researchers have concluded that the microsaccadic rates, blink rates and pupil diameter indicate the level of arousal of the patient which is strongly linked to the level of attention. The following sections will explain the ways in which such ocular parameters can be potentially used for discovering the levels of inattention.

2.2.1 Microsaccades

Microsaccades are the small movements of the eye seen in prolonged fixations with amplitude around 1 degree. As outlined in Fried, et al (2014), the microsaccadic rates can potentially determine attention. It was also observed that such rates are reduced when a stimulus is presented and during the preparation of the response. Furthermore, when a patient is paying attention, the microsaccades are directed to one particular thing and when is not paying attention, the microsaccades are deflected away. ADHD patients have more microsaccadic rates as concluded in Pastukhov and Braun (2010) and studies have shown that tasks with fixed timing, are more demanding for ADHD subjects. Overton and Stafford (2017) outlined that microsaccadic rates can be affected by task difficulty where higher demanding cognitive tasks, are associated with reduced microsaccadic rates.

2.2.2 Blinks

Blinks are another indicator of attention. The higher the blink rates are, the lower the level of arousal and the attention. Throughout the tests (t.o.v.a session, go/no-go tasks) conducted in (Barbato, 2000; Barbato, 2007; Fried, 2014), it was concluded that the control group had no blinks before, during and after the stimulus appeared and they had highly synchronized blinks whereas in the ADHD group there are many blinks during this moment and are less synchronized. Furthermore, in the tasks that require high attention, the blink rates occur more frequently and an increase of the blinks increases the level of fatigue.

2.2.3 Pupil Diameter

Pupil tends to dilate when the user is faced with challenging activities or perceptual events. Fried, et al (2014) outlined that when the level of arousal is low in ADHD subjects, the pupil diameter abbreviates and gets smaller compared to the control group. As considered elsewhere (Daniels, (2012; Privitera, (2011)), larger dilations were associated in fewer targets and mostly with targets viewed in the start of the trial. The dilation is influenced by the requirement of a button pressed and when the user is asked to fixate to a target. Furthermore, the emotional content of the visual stimuli, triggers the pupil reaction. Highly aversive or interesting pictures are associated with large dilations.

2.3 Tasks and Games for Diagnosing and Training ADHD

Numerous computerized tests and games have been created for diagnosing and training ADHD. The following sections will present the most common methods used to effectively test and train the levels of inattention and hyperactivity in subjects that suffer from ADHD. The following methods will include: Simple Computerized Non-Sensing Techniques for Diagnosing and Training ADHD, Offline Recording and Tracking User's Interaction. Non-Sensing Techniques for Diagnosing and Training ADHD and Video Games Utilized as Computerized Sensing Techniques for Diagnosing and Training ADHD.

2.3.1 Simple Computerized Non-Sensing Techniques for Diagnosing and Training ADHD

Continuous Performance Test (CPT) (t.o.v.a) (see Figure 2.1) is the most frequently used method to measure inattention and hyperactivity during a sustained task. The idea is to present different

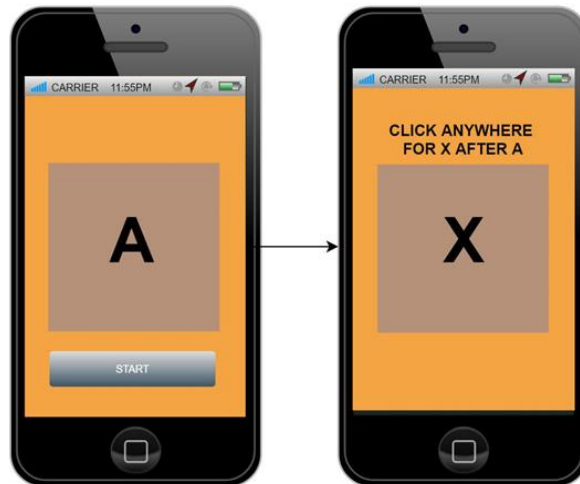


Figure 2.1: Continuous Performance Test (CPT). Used for Diagnosing and Training ADHD.

stimuli for a short duration of time in the screen and the subjects must respond to it (target and nontarget stimuli). A commonly used CPT displays a sequence of letters on the screen such that a response is required from the user when the letter X is presented only after the letter A as conducted in Greenberg and Waldmant (1993). Afterwards, indices are recorded including: omission errors (fail to detect the target), commission errors (responses to nontarget stimuli) and RT (reaction times). The omission errors are used to detect inattention whereas commission errors and RT are more often used to detect inhibition and impulsivity. As mentioned in (Michael, 2014; Greenberg, 1993; Young, 2014), the displayed time can vary and different CPT can also include distractions such as noises.

Michael and Madeleine (2015) presented several games which were based on psychological tests such as: Continuous Performance Tests, Go/No-go with Stop-signal tests that aimed to monitor and improve attention, inhibitory, motor activity. In the Go/No-go task, the appropriate response is required to each stimulus with a fast response to Go, null response to No-go and in the case of Stop signals, a null response is required at a variable time after a Go stimulus (see Figure 2.2). These tests provide reliable measures of attention (target detection, Reaction time variability) and impulsivity by measuring omission and commission errors.

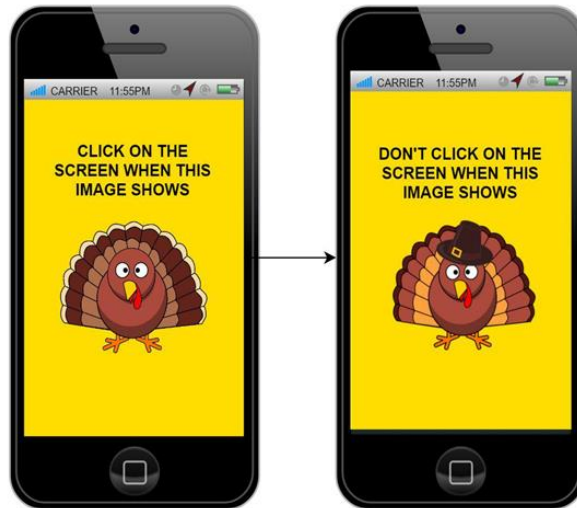


Figure 2.2: Go/No-go Test. Used for Diagnosing and Training ADHD.

2.3.2 Offline Recording and Tracking User's Interaction. Non-Sensing Techniques for Diagnosing and Training ADHD

In Fried, et al (2014) another t.o.v.a task with a target and a nontarget stimuli was created for offline recording and tracking. The task consisted of a white square with a black square positioned on top of the white square which was used for the target stimuli or in bottom which was known as the non-target stimuli. A small fixation dot was constantly displayed at the centre of the screen. The movements of the eyes were recorded during the sessions shortly after a calibration procedure for obtaining accurate gaze positions. With the eye tracking device, blinks, microsaccades and pupil diameters were detected. The results were obtained by using ANOVA test between the nonmedicated group with ADHD and the control group. It was concluded that in the control subjects there were no blinks before, during, and after the stimulus was displayed, whereas in the unmedicated ADHD subjects, many blinks were registered during this interval. Furthermore, the blink rates were significantly higher in the ADHD group compared to the control group. It was further observed that there were more microsaccades in subjects with ADHD whereas for the pupil, it was concluded that it dilates in high activity or perceptual events.

It has been acknowledged that the main deficits of ADHD are Working Memory (WM) as well as attention as they effect other mental actions. WM tasks include: stroop, memory, visuo-spatial memory, span board and choice reaction tasks. Several studies have been examining whether WM trainings that rely on games would boost motivation and performance in young subjects with ADHD compared to WM training with no game elements. Prins, et al (2011) reached to the conclusion that training the working memory with game elements displayed an increase in motivation, in better performance and better WM scores than children that underwent WM training

with no game elements. Furthermore, to achieve adherence and depth of engagement over the course of training, the program must be developed to engage users to personalize their own game and not feel isolated to play a pre-specified game as concluded in Mishra, et al (2016).

Commonly used games, include Stroop tests (*reasoning tasks*) that have been applied to study how participants use their rational thinking to select the appropriate responses and resolve conflicts as suggested in Vakil, et al (2016). In these tests, participants are required to pay attention to the target shown in one side of the screen and not get distracted from stimuli presented on the other side of the screen. One Stroop example shows a rectangle in a colour in the left side of the screen whereas in the right side of the screen, it presents a word and the player must name the color of the rectangle and ignore the word. The Stroop effect is used to reveal if ADHD subjects have the ability to pay attention to the target and how many shifts between the target and the distractor they make compared to the non-ADHD subjects. In (Marotta, 2017; Klingberg, 2002; Zagal, 2008) it was reached to the conclusion that ADHD group have low capability to ignore the distracter stimuli. Similar to the Stroop test, the Flanker test has been used to study how the participants recognize the target in the presence of a distracting stimuli. Flanker test include: *memory tasks* such as the matching cards game and *spatial memory tasks* that requires the player to recall the locations of the objects in the grid. Such tests are used for storing visual and colour information.

In Martinez et al (2016), a game called 'KAPEAN' was created to observe and understand the levels of attention, cognition and memory where children would play and practice memory, attention and reasoning skills tasks. This game included the following tasks:

- Reasoning Training Tasks - Subjects were required to read the name of the colours which were written with different colour inks (Stroop effect).
- Attention Training Tasks - Participants were required to identify a target in the presence of a distractor (Flanker test).
- Memory Training Tasks - Participants were required to remember the cards presented for a few seconds.
- Spatial Memory Training Tasks - Subjects were required to recall information about the spatial positions of objects in the grid.

The webcam was used to record facial gestures along with help of the EEG in order to review the child states. From the four brainwaves, it could be detected Engagement/Boredom, Frustration, Meditation, Instantaneous Excitement. The results displayed that children faced difficulties to keep their focus on the tasks. However, all children in the treatment group showed significant progresses and displayed an increase of WM capacity.

2.3.3 Video Games Utilized as Computerized Sensing Techniques for Diagnosing and Training ADHD

Ceranoglu (2010) reported that remedial results appeared sooner when games were applied, compared to traditional therapies. It was also concluded that training with games was a beneficial way to immediately strengthen newly skills. As considered elsewhere (Oei and Patterson (2013)), action video games, enhances several cognitive and perceptual abilities. A comparison between Video Game Players (VGP) with Non Video Game Players (NVGP) was conducted to determine how the action games increase attentional capacity. In Green and Bavelier (2003), it was concluded that VGP have higher attentional capacities compared to NVGP. Furthermore, it was observed that VGP have better visual acuity thresholds than NVGP as they could tolerate smaller spacing between targets and distractors. However, when NVGP were trained on action video games, they exhibited improvements.

As outlined in Shathri, et al (2013), gaze controlled games are in their infancy but they are becoming highly desirable for people with and without disabilities. As discussed in Isokoski, et al (2009), eye tracking experiments based in game applications can be utilized to record the viewer's reaction in order to understand various aspects of attention and cognition. Beside eye trackers, the usage of a standard webcam in recording the subject's eye location can be another method for achieving decent performances as considered in Zhang, et al (2012).

In Smith and Graham (2006), it was explored the use of an eye tracker as a sensing device for video games. Two different video games were created and for each of them two conditions were tested, the interaction with the game with the user's eyes with the help of a mouse compared to interaction with the game only with a mouse. In the first game "Neverwinter nights", the character of the game was located in a large room and participants were required to move the character and open/close two boxes positioned at known places before exiting the room. To move the character on the screen, the players looked with their eyes at the desired point and the avatar walked there whereas to open the boxes the players first pointed with their eyes and clicked on the two chests with their mouse. The time it took the players to complete the task, was recorded. The second game was called "Lunar Command" and consisted of three levels. The users were required to destroy the missiles presented on the screen as they descend from the top of the screen down to the cities. Players were rewarded with points each time they would point to the missiles with their eyes and if successfully managed to shoot them by clicking with the mouse. At the end of the game, the application stored the scores for each player. In both games, control with the game only with a mouse was simply to click on the desired point and move or shoot again by using the mouse. The results obtained showed that the user's found the eye tracker more enjoyable to use when playing a game compared to controlling the game only with the mouse.

In Manresa, et al (2013), Vision Based Interaction (VBI) field was exploited to create an interface which worked with head movements for people with disabilities. The tool used was called 'SINA' and captured user's head movements through a webcam in order to control the positions of the mouse pointer. After the face and nose of the participant was detected, the nose pointing was

transformed to the mouse's pointer position and mouse's event. For rehabilitation purposes, the applications offered immediate feedback based on the user's actions. The first two applications developed aimed at training head control and increasing the neck range movements. In these applications, users had to pass over the blocks to uncover the image. The Second developed applications were called "Movement applications" which allowed the users to practice vertical and horizontal head movements. They recorded users and observed physical and cognitive improvements in head control, in coordination and body posture, decrease of fatigue and improvements in spatial orientation.

In Vidal (2014) a vision based game called "Shynosaurus" was developed in which the players interacted with it only with their eyes in order to direct and aim the mouse. At the beginning of the game, a small number of cuties along with the "safe zone" were displayed on the screen and the users were required to move the targets into the safer area only by looking at them with their eyes before the Shynosaurus arrived. The players had the option to stare with their eyes the enemies which were the shynosaurus (like one would intimidate another person in real life), to make them go away. But while they look at a shynosaurus, it is harder to aim at the "cuties" therefore, the players had to develop strategies. As the levels got harder, the shynosaurus were faster and the safe zone got smaller. They used an eye tracking device to detect the users gaze and they processed the eye images to get the position of the pupils from the cameras. This game was developed to observe the natural behaviours of the subject's eyes. However, it can also be used for attention training, as the user's need to focus on the targets (cuties) and not to the distracters in order to finish the game successfully.

In Ballieux, et al (2016), a computerized sensing game was developed to test and train inattention in infants. The first task displayed a butterfly on the screen which was the target object and in the opposite side of the screen distractor objects were displayed such as a house, a tree and clouds. When the infants looked at the butterfly, the target moved across the screen. When kids fixated the distractor objects, they vanished from the screen. When the infants re-looked at the target object, the butterfly started re-moving whereas the distractor objects were displayed again on the game view. Animations were given to the children as rewards every time they kept their focus at the target. The second task displayed five targets alongside eight distractors and again the child was required to fixate at the target objects in order to gain rewards. The game included different scenes with low difficulty levels in first scenes and higher difficulty levels to the next scenes. As the child went from one level to another, the distractor objects were more similar to the target objects as well as more varied. In the third task, different animals were presented to four windows and when the child fixated at these animals, they disappeared from the screen and the curtains of the window closed. When the children looked back at the same window, they gained rewards. The last task presented in this paper, included a game with two target objects (an elephant and a chicken) along with distractor objects. When the children looked at the targets, they were rewarded with an animation. An eye tracking device was used to test the cognitive control and the reaction times of the infants. The results showed an increase in performance and in their reaction times at the second phase of the training.

From these findings, it was acknowledged that the most appropriate method for monitoring and training ADHD was the development of a sensing computerized video game that interacts with the user's only with human gestures. As such games are becoming highly desired from people, the papers reviewed in this section, have been taken into consideration for this project. The main idea in which the game has been built, was based on the inclusion of a target object alongside distractor objects with the aim to gain insights from people's behaviours as well as to diagnose their level of attention based on their performance and the data collected. Unlike the video games reviewed in this subsection, the application developed will be more entertaining and will offer more features. The game will consist of three levels and as the user will move from one scene to another, the difficulty of the game will increase by raising the number of distractors. The task that the users are required to follow is to keep their attention at the target object in order to make it move in a constant speed and not be approached or touched by the distractors. The game will reward the players with points each time they keep their eyes at the target and will penalize them by ending the game if one of the distractors manages to touch the target object. The application developed will capture data from the user's eyes such as their gaze points, blinks, user presence in front of the screen as well all the target and distractors coordinates on the screen. Furthermore, more data will be collected from the user evaluation study and will be used for statistical analyses in order to better understand the user's ability to maintain their attention on the target object, to answer the research questions as well as to reveal whether a vision based game application is more entertaining than applications controlled with a mouse or a keyboard.

2.4 Conclusions

This chapter reviewed previous experimental works that have been conducted to investigate and the main indicators that can effectively diagnose ADHD and the most appropriate methods used to train such disorder. Overall, these findings suggest that head/eye movements and facial expressions give insights on ADHD traits whereas games are seen as interesting tools for engaging subjects in remedial trainings for stimulating positive behaviours. Such applications aren't commonly used but are starting to be taken into consideration. Finally, this chapter discussed the implications for this project and the improvements on the design, interaction and data collection. The following chapter discusses the developed computerized sensing game with the webcam.

3. Computerized Sensing Game with Webcam

This section will present a vision based game application developed with the aim to discover what features of relevance to ADHD can be captured by using only a webcam as input for the interaction and the data collection process. The following paragraphs will explain the application design, its implementation, how the interaction was made and what data was collected.

3.1 Game Application

Based on the above literature review, there are abundant ADHD presentations in head motions (e.g. head pose change), eye movements (e.g. blink, saccade), and facial expressions (e.g. mouth movement). Also, exploring the usage of pervasive devices (e.g. the webcam) instead of expensive and professional lab equipment (e.g. eye-tracker, EEG, EOG, MRI) has great potential to reach and benefit the general public. Again, computer games are a good option for maintaining the interests of the participants. Following these considerations, a simple hands-free demo game was created which used only a standard webcam, to demonstrate the capability of the webcam-based system in capturing and utilizing these ADHD related presentations. In the game, the user's facial pose, eye-blink status and mouth-open status are detected in real-time and are deployed as parameters for interaction with the game. As shown in Figure 3.1, two cars (blue and pink) are placed in the road. When the game begins, the two cars are located at opposite positions in the path. The pink car moves in constant speed along the capsule path clock-wisely in the game. The movement of the blue car is controlled by the user through the head pose/ blink/ mouth status. The goal of the game is to prevent the pink car from approaching to the blue car. This demo application exploits the computer vision field by estimating the facial pose, blink, and mouth open status, from webcam images. Firstly, as the user is supposed to concentrate on the game, his head/face should point to the screen area. Considering this, in the game design, when the user's head/face is not pointing to the screen, two cars stop moving. This design carries the idea that ADHD users tend to have more head motions and are more easily distracted from the current task. Secondly, the user is supposed to open the eyes to interact with the game. When the user closes either eye, the blue car stops (as a moderate penalty), while the pink car continues the movement. This design reflects the idea that the ADHD users are higher in blink rate. Thirdly, the user is required to keep mouth closed during game (e.g. not talking). When the mouth is open, a higher dosage of penalty is given, which makes the blue car move to the opposite direction. This design targets the fact that ADHD users may exhibit a hyperactive-impulsive symptom of excessive talking. For better understanding of the control logic, the following as pseudocode is presented:

```
WHILE (ESC not pressed)
  IF (Head Pose in screen)
    IF (Left/Right eye open)
      IF (Mouth open)
        Blue car moves Anti-clock-wisely
      ELSEIF (Mouth closed)
        Blue car moves Clock-wisely
    ELSEIF (Left/Right eye closed)
      Stop only the blue car
  ELSEIF (Head Pose off screen)
    Stop both cars
```

Technically, here the head/face pose refers to the relative rotation and translation of the face coordinate system with respect to the camera coordinate system. In this application, we estimate the facial pose coarsely using a simple method given in Mallick (2016), which finds the optimal projection of several detected facial landmarks in the face image to a generic adult 3D face model, and takes the resulted translation and rotation as the answer. OPENCV and DLIB libraries were used in the implementation for face detection and facial landmarks detection, and the RANSAC protocol was used to make the resulted rotation/translation more accurate. In the game, the estimated facial pose is further mapped to the display, to determine whether the face/head is pointing in the screen area or not. To this end, a calibration step before playing the game is added to the design, which plots a 5*5 grid of markers evenly distributed on the display and enables the registration of users' facial pose when they are facing each position on the screen. When playing the game, real-time pose of the face is estimated and compared with these registered poses, to determine coarsely whether the user's face is off the screen. For detection of eye-blink and mouth-closed status, the facial landmarks provided by DLIB face landmark detector were used. The distance between two eyelids or two lips are calculated first. Eye-blink and mouth-closed status are detected when the distances are close to zero (less than designed thresholds).

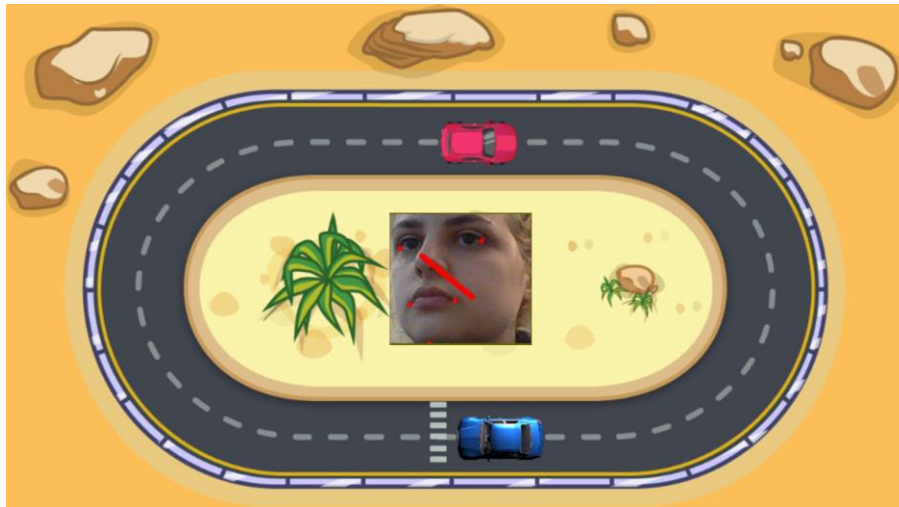


Figure 3.1: VBI Game-Based Application. (The user controls movement of the blue car along the road, using his/her head pose/ blink/ mouth status, to avoid reaching by the pink car which moves in constant speed along the path. For illustration purpose, the user's face and the detected facial landmarks which are used to estimate the facial pose, are displayed in the centre of the screen. The red line stemming from the nose tip signifies the pose of the face. When working in true scenario, the face isn't displayed)

In addition to the interactive functions, the demo application also makes full recording of the game, from the beginning to the end. The positions of the cars, the estimated rotation/translation, the estimated facing point on the screen, together with the webcam image, are synchronized and saved in files. In this way, the interaction between the game and the user can be replayed and be studied in an off-line fashion. The ways of investigating webcam based systems for ADHD are still open question, and have many possibilities. Preferably, in the future, a topic of interest is to study the accurate pupil centre detection from webcam video, and integrate it to interact with the game. If the pupil centre can be accurately detected from webcam image, it may serve as a better indicator of attention than face pose and eye-blink, as it's directly related to the gaze/attention of the user. Promisingly, there have been several works in the literature which estimate pupil centre from webcam images (Timm, 2011; Valenti, 2012, Garg, 2016). Also, in HCI domain, there have been several works exploring the usage of pupil centre from webcam, to interact with systems as discussed in (Lin, 2005; Zhang, 2013).

3.2 Conclusions

This chapter presented a vision based game application in which the usage of a webcam was exploited for allowing the users to interact with it only through their head pose, their blinks and their movements of the mouth. Furthermore, the application was developed for making a full recording of the game including the car positions, the face points of the users on the screen as well as the images from the webcam for analyses purposes. Overall, the results gained from this VBI application indicate that creating a computerized sensing game with only a webcam can be potentially used for capturing ADHD features as it is very reliable, accurate and inexpensive to implement at the same time. The next chapter will present an extension of this vision based game application but this time, an eye tracking device will be utilized for the interaction and the data collection process. The following game was created based on the same idea presented in this application of displaying a target object (blue car) besides distractor objects (other cars) on the screen.

4. Extending the VBI Game with an Eye-Tracker

This chapter will start by presenting the concept of the game followed by its design where it will be explained how the software works in a typical session with the user. The examples on this subsection will display all scenarios of the game such as when the user starts the game, when the target car gets touched by another car causing the game to end, when the user presses the reply or the quit button to restart the level or to end the game as well as when the players manage to successfully finish the game. Lastly, in the “Implementation” subsection, it will be discussed the initial user interface which will be followed by the overall architecture of the game design and the architecture of the data collected from the eye tracking device.

4.1 Game Concept

The application developed was simply called “Car Racing” and required from the player to use only their eyes to interact with it. As mentioned in the “Background” chapter, including a target object besides non-target objects in a game application, can give important cues on the user’s level of attention as well as on their hyperactivity behaviours by checking whether they have the ability to keep their focus on a specific object while various distractions are being displayed. As the game is developed to test attention, its design included distractor objects alongside one target object. The game contained three levels where each of them lasted 60 seconds and consisted a path in a top-down view with cars that followed that path. For each level, the path didn’t change but their backgrounds differed making the game more attractive as well more challenging for the user by including more objects on the screen. The target object was a blue car which changed the speed depending if the user was looking at it or not whereas the distractor objects included on the game view, were other cars that followed the same path in a constant speed. Other distractors that were part of the game excluding the cars, were unmoving objects in the field outside of the path, moving clouds across the screen, audio sounds of the other cars such as car horns, traffic sounds and the police alarm sound as well as its siren lights on top which went on and off throughout the third level of the game. Such sounds were included to make the game more entertaining and possibly more challenging for the users who get distracted easily even when a sound is being played. Furthermore, at the beginning and at the end of the game as well as when the users were informed about their scores and their performance, another racing sound was played simply to make the game more interesting for the user. Rewards such as achieving good scores and penalties such as ending the game were part of the game design. If the user looked at the blue car, the score increased with 5 points for each second, otherwise it increased only with one point. If the user didn’t pay attention to the target object and subsequently was touched by another car (a crash occurred), the game ended, requiring from the user to restart the level. This game can potentially detect and decrease the levels of inattention and hyperactivity in long-term as firstly it tests the user’s ability to keep their attention on the target object and secondly it imposes the participants to look at the

target object in order to gain points and not be touched by a distractor. Furthermore, by raising the numbers of distractors on the game, it forces players to become more focused on the task and subsequently it increases their attentional capacities.

4.2 Design of the Game

The design of the “Car Racing” game was created with Unity (see Figure 4.1) which is a powerful cross-platform engine for developing games. This platform was developed by Unity Technologies for establishing video games and simulations through different computers and mobile devices. Unity is commercialized to be an all purpose tool which supports 2D and 3D scene graphics, functionalities for drag and drop as well as 2 custom languages for scripting including C# and JS syntax which are essential components for responding to input from the player or to arrange for events when they are supposed to occur in the gameplay. Unity web page also offers a great amount of tutorials, developer manuals, live trainings as well as a community support to help programmers learn how to build game applications from scratch.



Figure 4.1: Software developed in Unity (level 3).

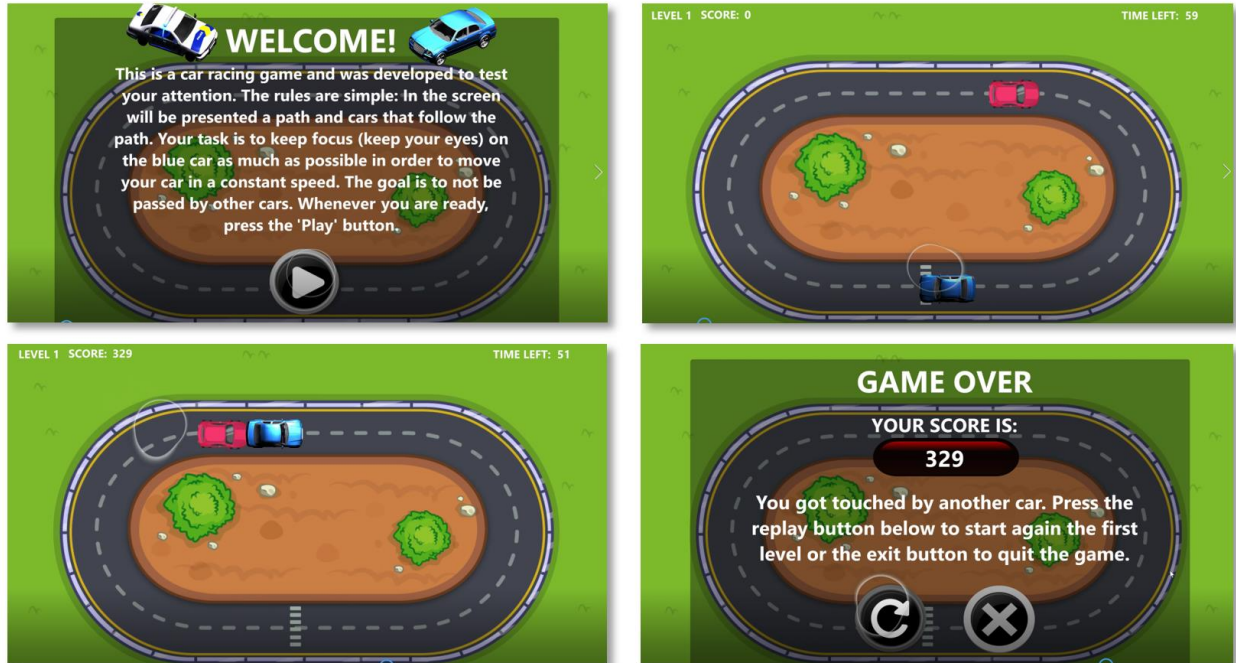


Figure 4.2: Game design and software in operation in the first level.

As shown in the first subset in the Figure 4.2, the first level started by instructing the user about the game and about the task that the user was required to execute. When the user clicked the “Play” button with the mouse, the game commenced. In this example and in the following ones, I have included the gaze trace (the white transparent circle) to better visualize the interaction with the application with the user’s eyes. The first level was comprised by the path, the blue car which was the target object, the pink car which was the distractor object and a simple background. It was developed this way to be less challenging for the player’s and to introduce them with the main idea of the game. On top of the screen, information about the level, the score and the time were displayed. Both of the cars started in parallel with each other and moved in a clockwise cycle. If the user had the focus on the blue car, its speed was same as the pink one and the score incremented with 5 points for each second, otherwise the speed of the blue car would decrease, making the other car approach to the blue one whereas the score incremented only with one point for each second. From the above example, the gaze was focused on the other areas of the screen which led to the speed drop down until the blue car was touched by the other one and subsequently the game was over whereas the user collected only 329 points. In this case, the player had the opportunity to restart the game or to quit it. If the users would manage to keep their focus on the blue car for 60 seconds without being touched by the other car, the game continued to the second level.

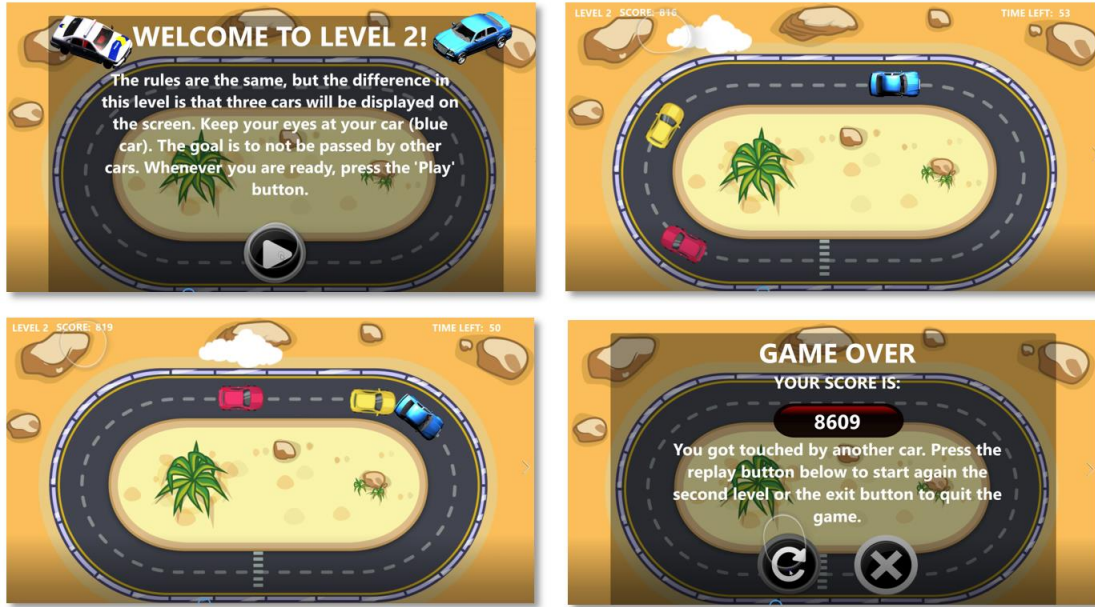


Figure 4.3: Game design and software in operation in the second level.

When the second level initiated, the user was required to perform the same task and similar to the previous figure, the first scene in this level, informed the user about the objects that would be presented on the screen (see Figure 4.3). As the task remained the same, the number of distractors was increased including two cars that followed the path in a constant speed, a cloud that moved across the scene throughout the game and the objects of the main background outside the path which remained still. Another characteristic of this level was that the yellow car wasn't in parallel with the blue one when the game started like in the first level, instead it was placed in a shorter distance from the target car in order to make the level more challenging for the player. From the above example, the user's gaze was focused in another object of the screen which caused the game to end as the blue car was touched by the yellow one. Afterwards, on the screen it was presented the score which was calculated as the sum of the score from the first level with the score in the second level. Alike the first level, the user was asked either to restart the level or to quit the game.

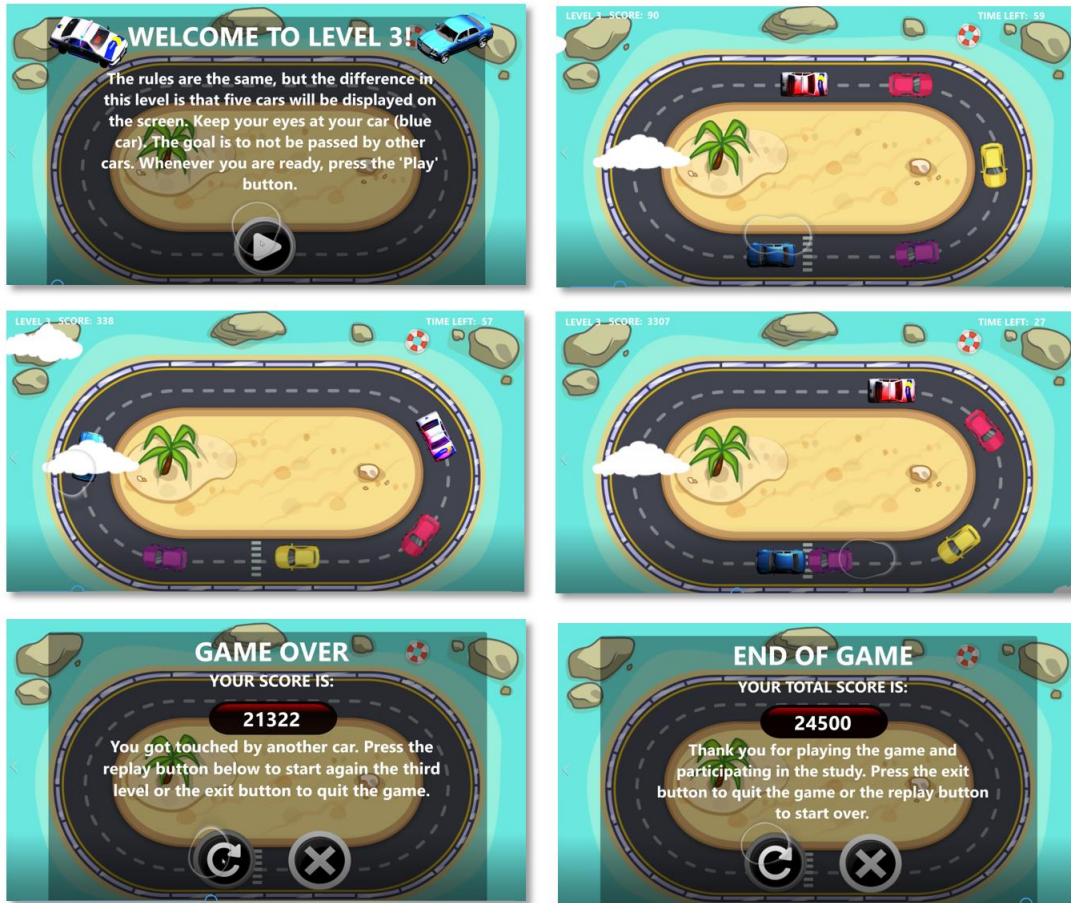


Figure 4.4: Game design and software in operation in the third level.

Same as in the previous levels, in this level (see Figure 4.4), the user was first instructed about the third scene and the distractors that would be displayed on the game view. The path was the same and the player's had to keep their attention at the blue car. This time, the number of the distractor cars was four including a police car with flashing lights on top which went on and off throughout the 60 seconds and its alarm sound in the background. Except form the distractor cars, a moving cloud was included which followed a specific path on the screen as well as one unmoving cloud that covered a small part of the road. This cloud was included to gain insights on the user's ability to keep tracing the blue car even if it was being covered from another object. Other distracting and unmoving objects included stones in the sea and the tree in the field. In this level, the purple car was in a shorter distance of the blue car compared to the previous levels. As shown in Figure 4.4, the user starts by looking at the blue car whereas the score gets incremented and reaches 90. Afterwards the user keeps tracing at the blue car as it gets hidden from the cloud. After 33 seconds, the player car gets touched by the purple car and the game ends, requiring from the user to restart the level. When the player had managed to finish the third level successfully, another

message was displayed, informing them about their total score and thanking them for participating in the study. In this case, the user had two options: either to quit the game, or to press the restart button and play the whole game from the beginning.

4.3 Implementation

This subsection discusses the major design decisions used for building the software including the initial user interface and the procedure for interacting with the eye tracking device. Next, the procedure followed for the implementation of the software will be explained in detail. In this subsection, all the tools utilized from Unity gaming engine and from its programming language will be described such as: the connection between the scenes and how this was achieved, the programming language used for making the interaction with the game, how each component was included on the scenes and how the reward as well as the penalty was established (this subsection will be followed by a pseudocode and a diagram of the overall architecture). Finally, the data collection process from the eye tracker device followed by another pseudocode will be discussed.

4.3.1 Initial User Interface

The application is closer to a real game application compared to the previous one and the interaction with the user was made through Tobii EyeX which is a professional lab equipment. Tobii EyeX is a portable eye tracker commonly used in game applications which allows users to communicate with games only through their eyes by utilizing its eye tracking features to allow interactions as well as to capture data in real-time from user's gaze points. It consists of projectors which create Near Infrared (NIR) light reflection patterns on the user's eyes, cameras that capture in higher frame rates images of the reflection patterns and algorithms for image processing of the user's eyes and its reflection patterns. Based on all these, mathematical algorithms calculate and retrieve the position of the player's eyes and where their gaze point is directed (see Figure 4.5).

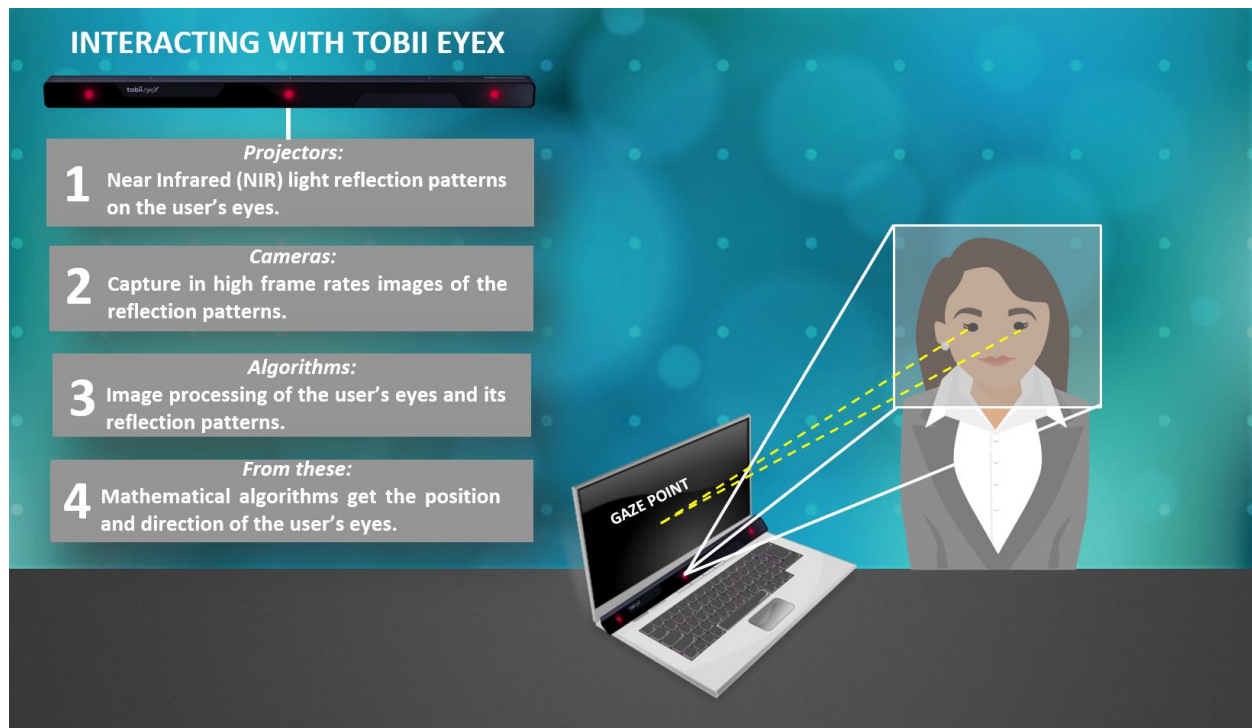


Figure 4.5: Initial user interface (interacting with Tobii EyeX).

As explained in the background of the problem explored, eyes give important cues on individuals mental health issues, in particular attention deficits. Therefore, eye tracking is a proper way to diagnose such disorders as well as gain insights from users behaviours. Therefore, by utilizing Tobii EyeX in a vision based application, we can allow the players to interact with the game as well as we can understand where the user's gaze is directed on the screen in order to make a good estimation about their attentional capacity. To interact with the device, Tobii EyeX must be well arranged in the computer as shown in the above figure and must be facing the user. For an ideal interaction, the user must be sitting on a chair and be in a leaned back position. A calibration process is essential in applications where data collection is voluminous and is the main objective of the project. However, as the purpose of this application was to achieve a functional interaction between the user and the game as well as to collect a small adequate amount of data from Tobii EyeX and a large amount of data from the user evaluation study, the calibration process wasn't necessary and therefore it wasn't included.

4.3.2 Design Architecture of Application

For this application, 10 scenes in Unity were created and by placing buttons in “Instructions”, “Game Over” and “End of Game” scenes, I connected them with each other through C# programming language. Furthermore, by including the time, it was possible to switch from one scene to another again with C# syntax by first adjusting it with 60 seconds and by decrementing it with one for each second until it reached 0. The texts were first placed on the screen by taking the UI Objects in Unity in which I wrote my own text whereas the 2D images such as field, path, stones, trees, clouds and cars excluding the target car and the police car, were taken as individual sprites from Unity where I managed to merge them in different layers to make a unique game background. The 3D objects such as the target car and the police car, were more complicated to create as 3D objects are constituted by individual pieces and they demand for a directional light otherwise the objects won't show on the screen. By joining all the pieces together and by including the directional lights for the two 3D cars, the objects were displayed on the scene. Furthermore, the police car required two additional siren lights on top which switched on and off in a loop throughout the game and this was achieved by including a Spot Light from the Light objects in Unity and by clicking the loop option in the inspector tools of the Spot Light. The clouds required for extra coding as they were 2D objects and they couldn't be layered on top of the 3D cars to make it look like the objects were hidden from the cloud. To achieve this, I created an “Image Effect Shader” script and I linked it to the clouds. In order to allow the cars to drive across the path in a clockwise rotation, a path in a capsule form was included and was hidden from the scene by utilizing the Unity inspector tools. The placements of the cars in the path as well as their speed, their directions and their loop movements, were adjusted in the beginning of the scene again by using Unity inspector features. For the movement of the cloud across the scene, a rectangle path was created and for its placement on the path, it was followed the same procedure as for the cars. The adjustment of the speed for the target car differed from the other cars as it was changed depending whether the user was looking at it or not. To arrange this interaction, a C# code was written and linked to the car by utilizing Tobii API. The “Gaze Aware” component which came with Tobii package for Unity, was included in the scene as well as in the C# script. From the Gaze Aware component, the “Gaze Focus” was retrieved and it returned a “Boolean” (true or false) depending if the user was looking at the specific object on the screen or not. In my C# script, a reference of the blue car object was called from the Unity and a check was made that if the user was looking at this target object, its speed would increase and would be equal to the other cars speed, otherwise it would move 2 times slower. The score was first set in Unity as a text object on top of the interactive scenes and was initialized to 0. Afterwards, I created 3 scripts that contained the score for the three levels by retrieving the reference from these texts and converting them to integer values before linking them to the target car object. The score would increment 5 times faster for each second if the user's had their gaze on the target car. Unity offers collider components which are part of the invisible physics objects in Unity package and define the shape of that object for creating physical collisions. To cause the game to end whenever the blue car was touched by another car, 2D and 3D colliders were positioned and sized on all the cars. Next, three scripts for

detecting the collisions were created for the three levels and were linked to the distractor cars. When these cars detected another collider which in our case was the target car, the game would end, requiring from the user to restart the level or quit the game. To show users their score whenever the game was over due to the fact of being touched by another car, three more scripts were written for each level and were linked to the text created in the “Game Over” scene. In this script, float variables were created that took all the scores from the previous levels and were added together before converting them to a string variable and displaying them on the screen. For the “End of Game” scene where the user completed all the levels successfully, another script was written which retrieved all the previous scores, added them together as float variables, converted them as string variables and finally presented them on the text of this scene. The timer was included on top of the interactive game scenes as a text in Unity and was linked with the “Countdown Timer” script where it was initially set to 60 seconds and was decremented throughout the level. If it reached 0, another scene was played. In this script, I included a public string that would take the level name that would be played after it reached 0 which I linked it to the text in Unity. This string would show in the Unity inspector where I was able to enter the level name. Finally, two audios were included simply by dragging and dropping them to the all the scenes of Unity Editor and the loop option was checked to make the audios play infinitely. The following pseudocode and the diagram (see Figure 4.6) explains all the game interaction and the architecture of the application mentioned above:

```

While (Car Racing Game == Enter Play Mode) {
    If (Scene == “Instructions for Level 1 Scene”) {
        Play Audio 1;
        Show Background 1 Image;
        Show Blue Car;
        Show Police Car;
        Show text “Welcome”;
        Show text “Explain Game Instructions 1”;
        Show button “Play”;
        If (user == “Clicks Play button”) {
            GoTo “Play Level 1 Scene”;
        } ENDIF
    } else if (Scene == “Play Level 1 Scene”) {
        Play Audio 2;
        Show Background 1 Image;
        Show Target car “Blue Car”;
        Show Distractor car1 “Pink Car”;
        Show text “Level 1”;
        Show text “Score”;
        Show text “0”;
        Show text “Time Left”;
        Show text “60”;
        If (user Gaze == “Blue Car”) {

```

```

        "0" = "0" + "5";
    } else {
        "0" = "0" + "1";
    } ENDF
"60" = "60" - "1";
If (Pink Car == Blue Car) {
    GoTo "Game Over Level 1 Scene";
} else if ("60" == "0") {
    GoTo "Instructions for Level 2 Scene";
} else if (Scene == "Game Over Level 1 Scene") {
    Play Audio 1;
    Show Background 1 Image;
    Show text "GAME OVER";
    Show text "YOUR SCORE IS:";
    Show "Score in level 1";
    Show text "Why the level 1 is over";
    Show button "Replay";
    Show button "Quit";
    If (user == "Clicks Replay button") {
        GoTo "Instructions for Level 1 Scene";
    } else if (user == "Clicks Quit button") {
        QUIT GAME;
    } ENDF
} else if (Scene == "Instructions for Level 2 Scene") {
    Play Audio 1;
    Show Background 2 Image;
    Show Blue Car;
    Show Police Car;
    Show text "Welcome";
    Show text "Explain Game Instructions 2";
    Show button "Play";
    If (user == "Clicks Play button") {
        GoTo "Play Level 2 Scene";
    } ENDF
} else if (Scene == "Play Level 2 Scene") {
    Play Audio 2;
    Show Background 2 Image;
    Show Target car "Blue Car";
    Show Distractor car1 "Yellow Car";
    Show Distractor car2 "Pink Car";
    Show Distractor cloud1 "Moving Cloud";
    Show text "Level 2";
    Show text "Score";
    Show text "0";
    Show text "Time Left";
    Show text "60";
    If (user Gaze == "Blue Car") {
        "0" = "0" + "5";
    } else {
        "0" = "0" + "1";
    } ENDF
}

```

```

“60” = “60” – “1”;
If (Yellow Car == Blue Car) {
    GoTo “Game Over Level 2 Scene”;
} else if (“60” == “0”) {
    GoTo “Instructions for Level 3 Scene”;
} else if (Scene == “Game Over Level 2 Scene”) {
    Play Audio 1;
    Show Background 2 Image;
    Show text “GAME OVER”;
    Show text “YOUR SCORE IS:”;
    Show “Score in level 2”;
    Show text “Why the level 2 is over”;
    Show button “Replay”;
    Show button “Quit”;
    If (user == “Clicks Replay button”) {
        GoTo “Instructions for Level 2 Scene”;
    } else if (user == “Clicks Quit button”) {
        QUIT GAME;
    } ENDIF
} else if (Scene == “Instructions for Level 3 Scene”) {
    Play Audio 1;
    Show Background 3 Image;
    Show Blue Car;
    Show Police Car;
    Show text “Welcome”;
    Show text “Explain Game Instructions 3”;
    Show button “Play”;
    If (user == “Clicks Play button”) {
        GoTo “Play Level 3 Scene”;
    } ENDIF
} else if (Scene == “Play Level 3 Scene”) {
    Play Audio 2;
    Show Background 3 Image;
    Show Target car “Blue Car”;
    Show Distractor car1 “Purple Car”;
    Show Distractor car2 “Yellow Car”;
    Show Distractor car3 “Pink Car”;
    Show Distractor car4 “Police Car”;
    Show Distractor Police Lights “Police Car Siren Lights”;
    Play Distractor Police Sound “Police Car Alarm Sound”;
    Show Distractor cloud1 “Moving Cloud”;
    Show Distractor cloud2 “Unmoving Cloud”;
    Show text “Level 2”;
    Show text “Score”;
    Show text “0”;
    Show text “Time Left”;
    Show text “60”;
    If (user Gaze == “Blue Car”) {
        “0” = “0” + “5”;
    } else {
        “0” = “0” + “1”;
    }
}

```

```

    } ENDF
    "60" = "60" - "1";
    If (Purple Car == Blue Car) {
        GoTo "Game Over Level 3 Scene";
    } else if ("60" == "0") {
        GoTo "End Game Scene";
    } else if (Scene == "Game Over Level 3 Scene") {
        Play Audio 1;
        Show Background 3 Image;
        Show text "GAME OVER";
        Show text "YOUR SCORE IS:";
        Show "Score in level 3";
        Show text "Why the level 3 is over";
        Show button "Replay";
        Show button "Quit";
        If (user == "Clicks Replay button") {
            GoTo "Instructions for Level 3 Scene";
        } else if (user == "Clicks Quit button") {
            QUIT GAME;
        } ENDF
    } else if (Scene == "End Game Scene") {
        Play Audio 1;
        Show Background 3 Image;
        Show text "End of Game";
        Show text "YOUR SCORE IS:";
        Show "Total score when the game is finished";
        Show text "Thank user for playing the game";
        Show button "Replay";
        Show button "Quit";
        If (user == "Clicks Replay button") {
            GoTo "Instructions for Level 1 Scene";
        } else if (user == "Clicks Quit button") {
            QUIT GAME;
        } ENDF
    } ENDF
} ENDWHILE

```

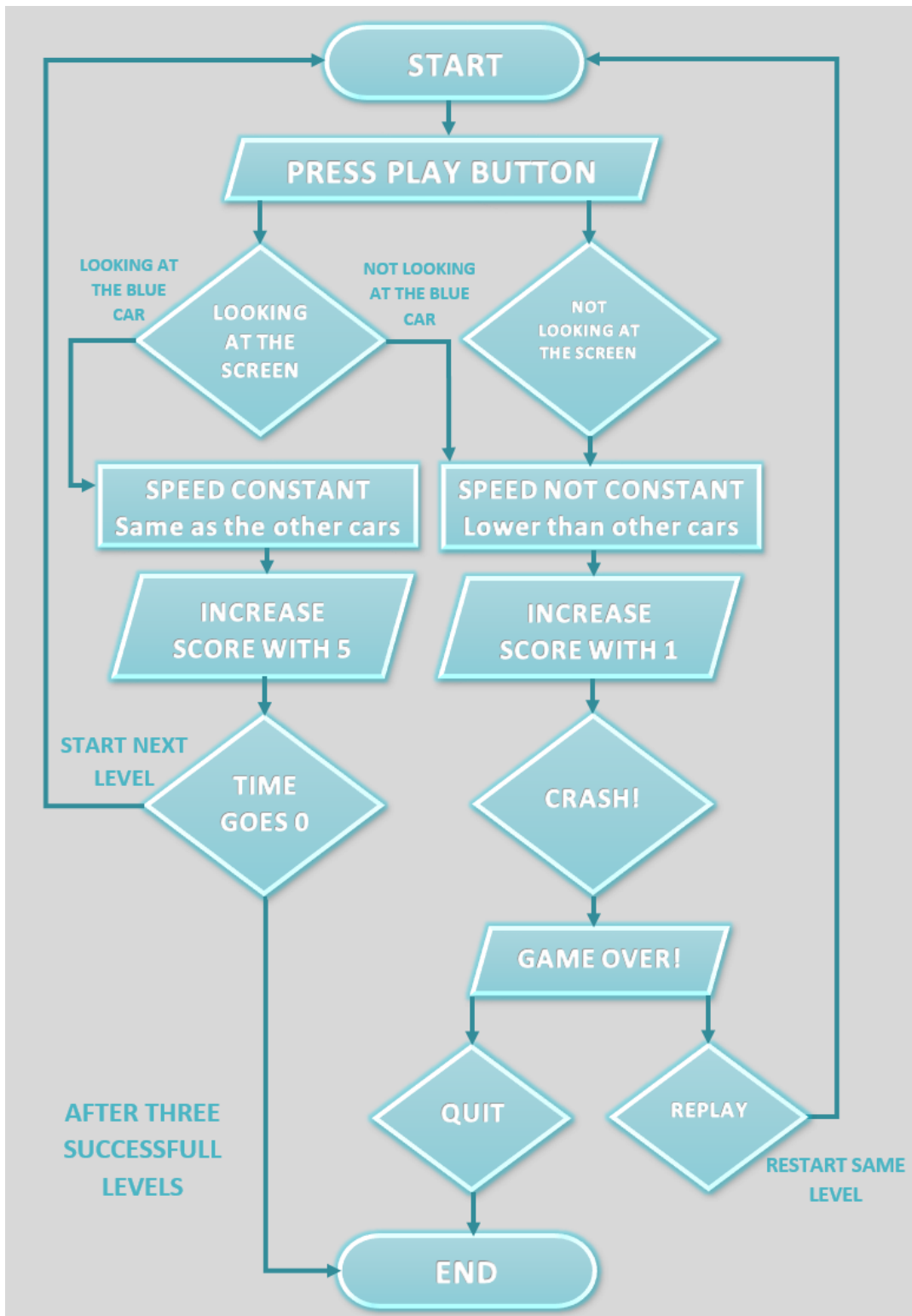


Figure 4.6: Diagram of the overall architecture of the game.

4.3.3 Data Collected from the Eye Tracking Device

By including the Tobii API class from the Tobii Unity SDK and by utilizing its features in my scripts, it was possible to access the API functions such as getting the users gaze points, their blinks, their presence as well as the coordinates of the objects on the screen throughout the game. This way data could be collected and could be used to gain insights from the user's behaviours while they were playing the game. In the same script used for changing the target car speed depending on the user's focused object, one Excel file was open and written for each level. In the first column of the excel files, a timestamp in seconds was included. The second and the third columns consisted of the user's gaze point coordinates on the screen which were retrieved by using "TobiiAPI.GetGazePoint()" function. This function returned a negative value of the gaze points if the user looked outside of the screen or a positive value in the opposite case. By collecting data on the coordinates of the user's gaze points on the screen, insights could be generated on their level of attention which could then be used to determine the presence of ADHD based on the inattentive presentation. In the fourth column, blinks were detected by checking if the current and the previous gaze points were the same, meaning that no new gaze points were registered and a blink was occurred. As a low level of arousal is linked with higher blink rates and as patients with ADHD tend to have the characteristics of being "day-dreamy", the data collected on the number of blinks, could be used to make comparisons as well to build conclusions on the attention deficits for user's who suffer from ADHD. The user presence, which checks whether the user is in front of the Tobii device or in other words, in front of the screen, was retrieved and written in the fifth column of the file. As patients who suffer from ADHD with predominantly hyperactive-impulsive behaviours have difficulties in remaining seated and are quick tempered, it was assumed that by including the user presence data, conclusions could be established on the levels of ADHD. While an average blink lasts approximately 0.2-0.3 seconds, a threshold of 0.7 seconds was used to check if the user was blinking or if the user wasn't in front of the screen. This was achieved by first checking if the current gaze point was equal to the previous gaze point and if this was true then it was checked if the difference between the previous and the current timestamp was more than 0.7 seconds. If the last check would return true, the file wrote that the user was not present, otherwise the user had a blink. If none of the cases were true, then the user was in front of the screen but no blink was detected. For the other columns, in the file, it was written all the x and y coordinates of the cars which were included to check if the user's focus was in the target car, in the distractor cars or anywhere else on the screen. The following pictures (see Figure 4.7) display the data collected from Tobii device for each level:

| 1 | A | B | C | D | E | F | G | H | I |
|----|---------------|----------------|----------------|-----------|---------------|--------------|--------------|-------------------|-------------------|
| 1 | Timestamp | GazePoints (X) | GazePoints (Y) | Blinks | User Presence | Target Car X | Target Car Y | Distractor Car1 X | Distractor Car1 Y |
| 2 | 1501861992917 | 1535.819 | 337.903 | 0 Present | 0 Present | 0.312417 | -3.485 | 1.511198 | 2.285 |
| 3 | 1501861993218 | 1486 | 354.9037 | 0 Present | 0 Present | -0.02091637 | -3.485 | 1.612749 | 2.285 |
| 4 | 1501861993242 | 1480.78 | 357.1477 | 0 Present | 0 Present | -0.1015002 | -3.485 | 2.612749 | 2.284999 |
| 5 | 1501861993268 | 1500.866 | 362.6527 | 0 Present | 0 Present | -0.173745 | -3.485 | 2.693333 | 2.284999 |
| 6 | 1501861993290 | 1500.866 | 362.6527 | 1 Present | 1 Present | -0.2865716 | -3.485 | 2.765278 | 2.284999 |
| 7 | 1501861993318 | 1495.654 | 353.4883 | 0 Present | 0 Present | -0.3297874 | -3.485 | 2.838404 | 2.284999 |
| 8 | 1501861993359 | 1484.85 | 340.0581 | 0 Present | 0 Present | -0.4465508 | -3.485 | 2.92162 | 2.284999 |
| 9 | 1501861993399 | 1482.194 | 329.6569 | 0 Present | 0 Present | -0.5719314 | -3.485 | 3.038383 | 2.284999 |
| 10 | 1501861993419 | 1489.212 | 331.8515 | 0 Present | 0 Present | -0.6296276 | -3.485 | 3.163764 | 2.284999 |
| 11 | 1501861993452 | 1490.242 | 349.0976 | 0 Present | 0 Present | -0.7275559 | -3.485 | 3.22139 | 2.283273 |
| 12 | 1501861993484 | 1483.396 | 343.5508 | 0 Present | 0 Present | -0.828149 | -3.485 | 3.319002 | 2.275397 |
| 13 | 1501861993518 | 1468.604 | 319.7663 | 0 Present | 0 Present | -0.9284575 | -3.485 | 3.419269 | 2.267306 |
| 14 | 1501861993552 | 1465.518 | 307.4779 | 0 Present | 0 Present | -1.029395 | -3.485 | 3.519252 | 2.259238 |
| 15 | 1501861993586 | 1468.844 | 321.4833 | 0 Present | 0 Present | -1.131732 | -3.485 | 3.619863 | 2.25112 |
| 16 | 1501861993632 | 1462.396 | 330.9555 | 0 Present | 0 Present | -1.272542 | -3.485 | 3.720474 | 2.234307 |
| 17 | 1501861993653 | 1435.033 | 329.6797 | 0 Present | 0 Present | -1.32857 | -3.485 | 3.8572 | 2.200638 |
| 18 | 1501861993685 | 1415.53 | 333.0879 | 0 Present | 0 Present | -1.429463 | -3.485 | 3.911602 | 2.187241 |
| 19 | 1501861993734 | 1391.505 | 323.1654 | 0 Present | 0 Present | -1.579701 | -3.485 | 4.009568 | 2.163116 |

| 1 | A | B | C | D | E | F | G | H | I | J | K |
|----|---------------|----------------|----------------|-----------|---------------|--------------|--------------|-------------------|-------------------|-------------------|-------------------|
| 1 | Timestamp | GazePoints (X) | GazePoints (Y) | Blinks | User Presence | Target Car X | Target Car Y | Distractor Car1 X | Distractor Car1 Y | Distractor Car2 X | Distractor Car2 Y |
| 2 | 1501862061062 | 1454.051 | 354.668 | 0 Present | 0 Present | 0.7958342 | -3.485 | 0.05999999 | 2.285 | 4.629129 | 1.898863 |
| 3 | 1501862061073 | 1464.692 | 356.9821 | 0 Present | 0 Present | 0.7616685 | -3.485 | 0.1624972 | 2.285 | 4.716217 | 1.844813 |
| 4 | 1501862061160 | 1528.313 | 454.753 | 0 Present | 0 Present | 0.7016685 | -3.485 | 0.2649944 | 2.285 | 4.803304 | 1.790762 |
| 5 | 1501862061178 | 1528.313 | 454.753 | 1 Present | 1 Present | 0.6507245 | -3.485 | 0.3249944 | 2.285 | 4.854283 | 1.759121 |
| 6 | 1501862061206 | 1492.598 | 492.0976 | 0 Present | 0 Present | 0.5655105 | -3.485 | 0.3759383 | 2.285 | 4.897568 | 1.732257 |
| 7 | 1501862061244 | 1510.241 | 472.2544 | 0 Present | 0 Present | 0.4529934 | -3.485 | 0.4611524 | 2.285 | 4.962915 | 1.677689 |
| 8 | 1501862061273 | 1511.3 | 453.9862 | 0 Present | 0 Present | 0.3643424 | -3.485 | 0.5736696 | 2.285 | 5.048317 | 1.604432 |
| 9 | 1501862061305 | 1509.486 | 484.519 | 0 Present | 0 Present | 0.2677384 | -3.485 | 0.6623205 | 2.285 | 5.115604 | 1.546713 |
| 10 | 1501862061324 | 1509.486 | 484.519 | 1 Present | 1 Present | 0.2099946 | -3.485 | 0.7589244 | 2.285 | 5.188927 | 1.483815 |
| 11 | 1501862061356 | 1520.815 | 509.7648 | 0 Present | 0 Present | 0.116467 | -3.485 | 0.8166682 | 2.285 | 5.232755 | 1.446219 |
| 12 | 1501862061389 | 1669.219 | 557.8457 | 0 Present | 0 Present | 0.01724488 | -3.485 | 0.9101959 | 2.285 | 5.29468 | 1.376262 |
| 13 | 1501862061423 | 1524.053 | 368.5771 | 0 Present | 0 Present | -0.08500579 | -3.485 | 1.009418 | 2.285 | 5.359281 | 1.300951 |
| 14 | 1501862061457 | 1390.925 | 140.2563 | 0 Present | 0 Present | -0.1852846 | -3.485 | 1.111669 | 2.285 | 5.425855 | 1.223342 |
| 15 | 1501862061489 | 1400.783 | 146.2357 | 0 Present | 0 Present | -0.284219 | -3.485 | 1.211948 | 2.285 | 5.491144 | 1.14723 |
| 16 | 1501862061523 | 1561.609 | 382.7317 | 0 Present | 0 Present | -0.3844143 | -3.485 | 1.310882 | 2.285 | 5.55039 | 1.068351 |
| 17 | 1501862061557 | 1570.61 | 419.6295 | 0 Present | 0 Present | -0.4860314 | -3.485 | 1.411077 | 2.285 | 5.603227 | 0.98322 |
| 18 | 1501862061589 | 1532.409 | 438.4377 | 0 Present | 0 Present | -0.5845003 | -3.485 | 1.512694 | 2.285 | 5.656814 | 0.896806 |
| 19 | 1501862061623 | 1528.632 | 431.8678 | 0 Present | 0 Present | -0.6842535 | -3.485 | 1.611163 | 2.285 | 5.70874 | 0.8132161 |

| 1 | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|----|---------------|----------------|----------------|-----------|---------------|--------------|--------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| 1 | Timestamp | GazePoints (X) | GazePoints (Y) | Blinks | User Presence | Target Car X | Target Car Y | Distractor Car1 X | Distractor Car1 Y | Distractor Car2 X | Distractor Car2 Y | Distractor Car3 X | Distractor Car3 Y | Distractor Car4 X | Distractor Car4 Y |
| 2 | 1501862125333 | 1548.203 | 646.7209 | 0 Present | 0 Present | 0.7969302 | -3.485 | 0.05999999 | 2.285 | 4.629129 | 1.898863 | 5.838778 | -2.125942 | -3.1456 | 2.285 |
| 3 | 1501862125341 | 1548.203 | 646.7209 | 1 Present | 1 Present | 0.7638604 | -3.485 | 0.1592094 | 2.285 | 4.713423 | 1.846546 | 5.886461 | -2.121023 | -3.046391 | 2.285 |
| 4 | 1501862125416 | 1571.128 | 712.4233 | 0 Present | 0 Present | 0.7438804 | -3.485 | 0.2584188 | 2.285 | 4.797171 | 1.794229 | 5.534143 | -2.294529 | -2.947181 | 2.285 |
| 5 | 1501862125444 | 1568.524 | 719.402 | 0 Present | 0 Present | 0.6596714 | -3.485 | 0.3184188 | 2.285 | 4.848696 | 1.762589 | 5.496435 | -2.341063 | -2.887182 | 2.285 |
| 6 | 1501862125468 | 1567.999 | 734.5833 | 0 Present | 0 Present | 0.5885501 | -3.485 | 0.4026078 | 2.285 | 4.918488 | 1.715806 | 5.441621 | -2.404964 | -2.802993 | 2.285 |
| 7 | 1501862125491 | 1559.144 | 703.0031 | 0 Present | 0 Present | 0.5159805 | -3.485 | 0.4737292 | 2.285 | 4.972462 | 1.669501 | 5.395316 | -2.458946 | -2.731871 | 2.285 |
| 8 | 1501862125523 | 1552.349 | 682.1104 | 0 Present | 0 Present | 0.4192396 | -3.485 | 0.5462987 | 2.285 | 5.027543 | 1.622252 | 5.348067 | -2.514026 | -2.659302 | 2.285 |
| 9 | 1501862125557 | 1549.667 | 682.9514 | 0 Present | 0 Present | 0.3226542 | -3.485 | 0.6430497 | 2.285 | 5.100977 | 1.559259 | 5.285074 | -2.587461 | -2.562551 | 2.285 |
| 10 | 1501862125589 | 1559.904 | 712.2333 | 0 Present | 0 Present | 0.2222061 | -3.485 | 0.739625 | 2.285 | 5.174279 | 1.496381 | 5.219244 | -2.657811 | -2.465975 | 2.285 |
| 11 | 1501862125622 | 1551.353 | 698.4601 | 0 Present | 0 Present | 0.1226751 | -3.485 | 0.8400731 | 2.285 | 5.240024 | 1.429485 | 5.143003 | -2.732211 | -2.385527 | 2.285 |
| 12 | 1501862125656 | 1541.316 | 671.2068 | 0 Present | 0 Present | 0.02249987 | -3.485 | 0.9396041 | 2.285 | 5.313827 | 1.35394 | 5.067458 | -2.788013 | -2.265996 | 2.285 |
| 13 | 1501862125689 | 1536.122 | 654.6206 | 0 Present | 0 Present | -0.07827287 | -3.485 | 1.039779 | 2.285 | 5.379049 | 1.277907 | 4.991424 | -2.853235 | -2.165821 | 2.285 |
| 14 | 1501862125722 | 1505.843 | 437.7156 | 0 Present | 0 Present | -0.1779362 | -3.485 | 1.141007 | 2.285 | 5.444957 | 1.201074 | 4.914591 | -2.919143 | -2.064593 | 2.285 |
| 15 | 1501862125756 | 1477.54 | 286.2522 | 0 Present | 0 Present | -0.2776936 | -3.485 | 1.240215 | 2.285 | 5.509549 | 1.125774 | 4.813582 | -2.973212 | -1.965385 | 2.285 |
| 16 | 1501862125789 | 1459.26 | 207.4562 | 0 Present | 0 Present | -0.3775412 | -3.485 | 1.339973 | 2.285 | 5.565731 | 1.048634 | 4.746823 | -3.025818 | -1.865628 | 2.285 |
| 17 | 1501862125822 | 1451.893 | 292.7404 | 0 Present | 0 Present | -0.4787475 | -3.485 | 1.439821 | 2.285 | 5.618385 | 0.9587973 | 4.661986 | -3.078472 | -1.765779 | 2.285 |
| 18 | 1501862125856 | 1430.755 | 291.8029 | 0 Present | 0 Present | -0.5786646 | -3.485 | 1.541027 | 2.285 | 5.671574 | 0.8728076 | 4.575996 | -3.133841 | -1.664574 | 2.285 |
| 19 | 1501862125889 | 1413.239 | 295.1013 | 0 Present | 0 Present | -0.6781057 | -3.485 | 1.640944 | 2.285 | 5.724445 | 0.7879126 | 4.488181 | -3.17889 | -1.564657 | 2.285 |
| 20 | 1501862125923 | 1392.959 | 258.3768 | 0 Present | 0 Present | -0.7779212 | -3.485 | 1.740385 | 2.285 | 5.773244 | 0.701538 | 4.396584 | -3.217601 | -1.465216 | 2.285 |
| 21 | 1501862125956 | 1369.983 | 226.3026 | 0 Present | 0 Present | -0.8773464 | -3.485 | 1.8402 | 2.285 | 5.812101 | 0.6095961 | 4.304642 | -3.26457 | -1.3654 | 2.285 |
| 22 | 1501862125990 | 1353.412 | 222.3565 | 0 Present | 0 Present | -0.9796934 | -3.485 | 1.939626 | 2.285 | 5.850805 | 0.518037 | 4.21306 | -3.295162 | -1.265975 | 2.285 |
| 23 | 1501862126023 | 1314.982 | 227.5051 | 0 Present | 0 Present | -1.079345 | -3.485 | 2.041972 | 2.285 | 5.890647 | 0.4237401 | 4.118766 | -3.335004 | -1.163628 | 2.285 |
| 24 | 1501862126056 | 1302.116 | 240.9453 | 0 Present | 0 Present | -1.177512 | -3.485 | 2.141624 | 2.285 | 5.92944 | 0.3319492 | 4.022399 | -3.359957 | -1.063976 | 2.285 |
| 25 | 1501862126089 | 1288.927 | 236.5615 | 0 Present | 0 Present | -1.277695 | -3.485 | 2.239791 | 2.285 | 5.96485 | 0.2377159 | 3.92708 | -3.38343 | -0.9658089 | 2.285 |
| 26 | 1501862126123 | 1289.851 | 235.607 | 0 Present | 0 Present | -1.379115 | -3.485 | 2.339974 | 2.285 | 5.98014 | 0.1404394 | 3.829803 | -3.407385 | -0.8656262 | 2.285 |
| 27 | 1501862126156 | 1282.374 | 247.6226 | 0 Present | 0 Present | -1.479218 | -3.485 | 2.441394 | 2.285 | 6.004391 | 0.04196116 | 3.731325 | -3.431636 | -0.7642059 | 2.285 |
| 28 | 1501862126189 | 1252.029 | 252.731 | 0 Present | 0 Present | -1.578513 | -3.485 | 2.541497 | 2.284999 | 6.028327 | -0.05523725 | 3.633229 | -3.450043 | -0.6641037 | 2.285 |
| 29 | 1501862126223 | 1275.894 | 268.1286 | 0 Present | 0 Present | -1.679543 | -3.485 | 2.640792 | 2.284999 | 6.048864 | -0.1521724 | 3.534255 | -3.458029 | -0.5648087 | 2.285 |

Figure 4.7: The usage of Tobi Unity SDK for data collection in each level.

As seen from the above pictures, each file collected data about the timestamp, gaze points, blinks, user presence and car coordinate points on the screen in the three levels. As the number of distractor cars were increased from one level to another, the file grew in size. The following pictures will display how the gaze points, blinks and user presence changed depending whether the user was looking inside of the screen or outside of the game view as well as if blinks were detected and if the user wasn't in front of the screen:

| | A | B | C | D | E | F | G | H | I |
|----|---------------|----------|----------|---|---------|----------|----------|----------|----------|
| 79 | 1501867090172 | 510.0208 | 243.43 | 0 | Present | -5.96213 | -1.54924 | 4.951395 | -2.88757 |
| 80 | 1501867090212 | 515.7247 | -110.82 | 0 | Present | -5.99663 | -1.43591 | 4.858821 | -2.95631 |
| 81 | 1501867090251 | 526.2747 | -105.069 | 0 | Present | -6.02454 | -1.32255 | 4.757888 | -3.01895 |
| 82 | 1501867090283 | 538.4484 | -92.156 | 0 | Present | -6.04845 | -1.22548 | 4.658695 | -3.08052 |
| 83 | 1501867090314 | 543.6732 | -78.7638 | 0 | Present | -6.06953 | -1.13987 | 4.573749 | -3.13324 |
| 84 | 1501867090344 | 550.9932 | -156.098 | 0 | Present | -6.07695 | -1.10974 | 4.496569 | -3.17535 |
| 85 | 1501867090375 | 556.4307 | -216.101 | 0 | Present | -6.08414 | -1.08056 | 4.410832 | -3.21158 |
| 86 | 1501867090409 | 587.3772 | -290.955 | 0 | Present | -6.08911 | -1.04479 | 4.327774 | -3.24668 |
| 87 | 1501867090443 | 589.616 | -293.139 | 0 | Present | -6.09185 | -1.01088 | 4.227685 | -3.28898 |
| 88 | 1501867090480 | 592.7775 | -336.242 | 0 | Present | -6.09467 | -0.97592 | 4.133678 | -3.32871 |
| 89 | 1501867090513 | 597.0344 | -329.19 | 0 | Present | -6.09751 | -0.94063 | 4.032679 | -3.35743 |
| 90 | 1501867090544 | 598.4082 | -337.239 | 0 | Present | -6.0999 | -0.91101 | 3.929569 | -3.38282 |
| 91 | 1501867090576 | 596.932 | -348.732 | 0 | Present | -6.10237 | -0.88042 | 3.842988 | -3.40414 |
| 92 | 1501867090611 | 648.9949 | -388.414 | 0 | Present | -6.10517 | -0.84582 | 3.753582 | -3.42616 |
| 93 | 1501867090649 | 675.8269 | -400.323 | 0 | Present | -6.10832 | -0.80666 | 3.652058 | -3.44852 |
| 94 | 1501867090686 | 700.9736 | -411.964 | 0 | Present | -6.11131 | -0.76969 | 3.534581 | -3.458 |
| 95 | 1501867090726 | 705.2336 | -419.948 | 0 | Present | -6.11444 | -0.73092 | 3.423673 | -3.46695 |
| 96 | 1501867090763 | 702.764 | -418.284 | 0 | Present | -6.11743 | -0.69383 | 3.307369 | -3.47634 |
| 97 | 1501867090802 | 693.5341 | -437.945 | 0 | Present | -6.12059 | -0.65471 | 3.196071 | -3.485 |
| 98 | 1501867090835 | 692.5341 | -437.945 | 1 | Present | -6.12377 | -0.61448 | 3.078331 | -3.485 |

Figure 4.8: Data collected when the user looked outside of the game view. Changes in the third column (“y” gaze coordinates).

| | A | B | C | D | E | F | G | H | I |
|----|---------------|----------|----------|---|---------|----------|----------|----------|----------|
| 58 | 1501866836613 | 849.7311 | 384.3998 | 0 | Present | -4.40007 | -3.23303 | 5.929758 | 0.331198 |
| 59 | 1501866836638 | 844.5889 | 384.1805 | 0 | Present | -4.46934 | -3.20376 | 5.952476 | 0.252778 |
| 60 | 1501866836667 | 836.1408 | 381.5108 | 0 | Present | -4.54885 | -3.17016 | 5.970459 | 0.179749 |
| 61 | 1501866836696 | 832.1184 | 383.6606 | 0 | Present | -4.62386 | -3.12696 | 5.991098 | 0.09594 |
| 62 | 1501866836721 | 836.685 | 378.8253 | 0 | Present | -4.68826 | -3.08699 | 6.011837 | 0.011721 |
| 63 | 1501866836747 | 836.685 | 378.8253 | 1 | Present | -4.75459 | -3.04582 | 6.029961 | -0.06188 |
| 64 | 1501866836772 | 836.685 | 378.8253 | 1 | Present | -4.81951 | -3.00553 | 6.047707 | -0.13783 |
| 65 | 1501866836809 | 836.685 | 378.8253 | 1 | Present | -4.90738 | -2.95099 | 6.053853 | -0.21399 |
| 66 | 1501866836849 | 836.685 | 378.8253 | 1 | Present | -4.99687 | -2.88287 | 6.06217 | -0.31708 |
| 67 | 1501866836889 | 836.685 | 378.8253 | 1 | Present | -5.02847 | -2.85577 | 6.071241 | -0.42949 |
| 68 | 1501866836924 | 641.6531 | 394.3045 | 0 | Present | -5.05695 | -2.83134 | 6.081286 | -0.55398 |
| 69 | 1501866836957 | 658.8428 | 391.3867 | 0 | Present | -5.13189 | -2.76705 | 6.079661 | -0.66616 |
| 70 | 1501866836985 | 645.5024 | 425.9256 | 0 | Present | -5.19573 | -2.7123 | 6.071719 | -0.76458 |
| 71 | 1501866837013 | 625.4349 | 498.1971 | 0 | Present | -5.25975 | -2.65738 | 6.064955 | -0.84841 |
| 72 | 1501866837070 | 610.346 | 590.4066 | 0 | Present | -5.35689 | -2.55037 | 6.058171 | -0.93249 |
| 73 | 1501866837154 | 610.4757 | 576.7153 | 0 | Present | -5.52844 | -2.35038 | 6.045118 | -1.07657 |
| 74 | 1501866837175 | 572.6854 | 619.8884 | 0 | Present | -5.57497 | -2.2932 | 5.982116 | -1.33242 |
| 75 | 1501866837198 | 579.6623 | 621.9384 | 0 | Present | -5.61353 | -2.23106 | 5.964459 | -1.40411 |
| 76 | 1501866837227 | 591.6836 | 631.7455 | 0 | Present | -5.65957 | -2.15689 | 5.946973 | -1.47512 |
| 77 | 1501866837255 | 600.2050 | 635.80 | 0 | Present | -5.70345 | -2.08770 | 5.918676 | -1.55743 |

Figure 4.9: Data collected when the eye tracking device encountered a blink. Changes in the second, third and fourth column (value “0” when a blink wasn’t occurred and value “1” when a blink occurred, when value is 1 in the fourth column, the gaze points in the second and third columns are the same).

| | A | B | C | D | E | F | G | H | I |
|-----|---------------|----------|----------|---|-------------|----------|----------|----------|----------|
| 100 | 1501866838062 | 411.9723 | 823.8453 | 1 | Present | -6.01118 | 0.17682 | 4.314644 | -3.25223 |
| 101 | 1501866838093 | 411.9723 | 823.8453 | 1 | Present | -6.00336 | 0.20859 | 4.229655 | -3.28815 |
| 102 | 1501866838114 | 411.9723 | 823.8453 | 1 | Present | -5.99871 | 0.227472 | 4.139239 | -3.32636 |
| 103 | 1501866838138 | 411.9723 | 823.8453 | 1 | Present | -5.9924 | 0.253067 | 4.084076 | -3.34477 |
| 104 | 1501866838162 | 411.9723 | 823.8453 | 1 | Present | -5.98645 | 0.27726 | 4.00729 | -3.36368 |
| 105 | 1501866838187 | 411.9723 | 823.8453 | 1 | Present | -5.9805 | 0.30141 | 3.934711 | -3.38155 |
| 106 | 1501866838214 | 411.9723 | 823.8453 | 1 | Present | -5.97194 | 0.326042 | 3.862263 | -3.39939 |
| 107 | 1501866838240 | 411.9723 | 823.8453 | 1 | Present | -5.96169 | 0.350288 | 3.786065 | -3.41816 |
| 108 | 1501866838295 | 411.9723 | 823.8453 | 1 | Present | -5.9429 | 0.394741 | 3.709389 | -3.43704 |
| 109 | 1501866838373 | 411.9723 | 823.8453 | 1 | Present | -5.91137 | 0.469363 | 3.566177 | -3.45545 |
| 110 | 1501866838402 | 411.9723 | 823.8453 | 1 | Present | -5.89989 | 0.496526 | 3.323927 | -3.475 |
| 111 | 1501866838421 | 411.9723 | 823.8453 | 1 | Present | -5.89116 | 0.51717 | 3.235746 | -3.48212 |
| 112 | 1501866838444 | 411.9723 | 823.8453 | 1 | Present | -5.88213 | 0.538551 | 3.168628 | -3.485 |
| 113 | 1501866838470 | 411.9723 | 823.8453 | 1 | Present | -5.87195 | 0.562624 | 3.098991 | -3.485 |
| 114 | 1501866838497 | 411.9723 | 823.8453 | 1 | Present | -5.86146 | 0.587443 | 3.02059 | -3.485 |
| 115 | 1501866838525 | 411.9723 | 823.8453 | 1 | Present | -5.85062 | 0.613102 | 2.939756 | -3.485 |
| 116 | 1501866838553 | 411.9723 | 823.8453 | 1 | Present | -5.83974 | 0.638842 | 2.856185 | -3.485 |
| 117 | 1501866838582 | 411.9723 | 823.8453 | 1 | Present | -5.82875 | 0.66486 | 2.772354 | -3.485 |
| 118 | 1501866838607 | 411.9723 | 823.8453 | 1 | Present | -5.81864 | 0.688771 | 2.687615 | -3.485 |
| 119 | 1501866838634 | 411.9723 | 823.8453 | 0 | Not Present | -5.80845 | 0.712876 | 2.609738 | -3.485 |
| 120 | 1501866838660 | 411.9723 | 823.8453 | 0 | Not Present | -5.79683 | 0.735732 | 2.531229 | -3.485 |
| 121 | 1501866838690 | 411.9723 | 823.8453 | 0 | Not Present | -5.78072 | 0.761687 | 2.454075 | -3.485 |
| 122 | 1501866838720 | 411.9723 | 823.8453 | 0 | Not Present | -5.76493 | 0.78713 | 2.362434 | -3.485 |
| 123 | 1501866838755 | 411.9723 | 823.8453 | 0 | Not Present | -5.74846 | 0.813664 | 2.272598 | -3.485 |
| 124 | 1501866838794 | 411.9723 | 823.8453 | 0 | Not Present | -5.72645 | 0.849127 | 2.178909 | -3.485 |

Figure 4.10: Data collected when the user wasn't present in front of the screen. Changes in the second, third, fourth and fifth columns (when the gaze coordinates were the same, register value "1" in the fourth column. If the difference between the previous timestamp and the current timestamp was more than 0.7 second, write to the fifth column "Not Present", otherwise write "Present").

For this example, I have used the data collected in the first level. As shown in Figure 4.8, the user was looking outside of the game view particularly down of the screen, therefore the y coordinates of the gaze points were negative. In the second example (see Figure 4.9) the fourth column contained 0 values when a blink wasn't detected and 1 values when the blink occurred. It can be acknowledged that some values were 1 and their gaze points were equal meaning that the user had no current gaze points therefore a blink was registered. From the last picture (see Figure 4.10), it can be noticed that the previous gaze points are identical from the current ones informing us that there were no new gaze points on the screen. From this, two cases could be happening, either there has been a blink, either the user wasn't present. The threshold for this case, was used to determine which of the following options was occurring. If the threshold which was 0.7 seconds, was surpassed, the application would no longer assume that the user was present in front of the Tobii device or that the user had a blink, therefore it returned that the user wasn't present on the screen. The final Excel file that was created, saved the scores for each level as well as the total score which was the sum of the previous three scores (see Figure 4.11):

| | A | B | C | D |
|---|---------------|---------------|---------------|-------------|
| 1 | Score Level 1 | Score Level 2 | Score Level 3 | Total Score |
| 2 | 8720 | 9080 | 9130 | 26930 |
| 3 | | | | |

Figure 4.11: The file displays the scores collected in each level and the total score which was calculated from the software as the sum of all the scores for the three levels.

The following pseudocode explains the data collection process:

```

While (Car Racing Game == Enter Play Mode) {
  If (Scene == "Play Level 1 Scene") {
    Get position of Target Car;
    Get position of Distractor Car1;
    Create file "Level 1 File";
    Create column texts to "Level 1 File": "Timestamp" + "," + "GazePoints (X)" + "," + "GazePoints
      (Y)" + "," + "Blinks" + "," + "User Presence" + "," +
      "Target Car X" + "," + "Target Car Y" + "," + "Distractor
      Car1 X" + "," + "Distractor Car1 Y";
    If (Current Gaze Points == Previous Gaze Points) {
      If (Previous Time – Current Time) > 0.7 {
        Append to column texts of "Level 1 File": gazePoint.Screen.x + "," + gazePoint.Screen.y
          + "," + "0" + "," + userNotPresent + "," +
          targetCar.x + "," + targetCar.y + "," +
          distractorCar1.x + "," + distractorCar1.y);
      } else If (Previous Time – Current Time) < 0.7 {
        Append to column texts of "Level 1 File": gazePoint.Screen.x + "," + gazePoint.Screen.y
          + "," + "1" + "," + userPresent + "," +
          targetCar.x + "," + targetCar.y + "," +
          distractorCar1.x + "," + distractorCar1.y);
      } ENDIF
    } else {
      Append to column texts of "Level 1 File": gazePoint.Screen.x + "," + gazePoint.Screen.y +
        "," + "0" + "," + userPresent + "," + targetCar.x +
        "," + targetCar.y + "," + distractorCar1.x + "," +
        distractorCar1.y);
    } ENDIF
  } else If (Scene == "Play Level 2 Scene") {

```

```

Get position of Target Car;
Get position of Distractor Car1;
Get position of Distractor Car2;
Create file "Level 2 File";
Create column texts to "Level 2 File": "Timestamp" + "," + "GazePoints (X)" + "," + "GazePoints
(Y)" + "," + "Blinks" + "," + "User Presence" + "," +
"Target Car X" + "," + "Target Car Y" + "," + "Distractor
Car1 X" + "," + "Distractor Car1 Y" + "," + "Distractor
Car2 X" + "," + "Distractor Car2 Y";

If (Current Gaze Points == Previous Gaze Points) {
  If (Previous Time – Current Time) > 0.7 {
    Append to column texts of "Level 2 File": gazePoint.Screen.x + "," + gazePoint.Screen.y +
    "," + "0" + "," + userNotPresent + "," +
    targetCar.x + "," + targetCar.y + "," +
    distractorCar1.x + "," + distractorCar1.y + ","
    + distractorCar2.x + "," + distractorCar2.y);
  } else If (Previous Time – Current Time) < 0.7 {
    Append to column texts of "Level 2 File": gazePoint.Screen.x + "," + gazePoint.Screen.y +
    "," + "1" + "," + userPresent + "," + targetCar.x
    + "," + targetCar.y + "," + distractorCar1.x + ","
    + distractorCar1.y + "," + distractorCar2.x + ","
    + distractorCar2.y);
  } ENDIF
} else {
  Append to column texts of "Level 2 File": gazePoint.Screen.x + "," + gazePoint.Screen.y +
  "," + "0" + "," + userPresent + "," + targetCar.x +
  "," + targetCar.y + "," + distractorCar1.x + ","
  + distractorCar1.y + "," + distractorCar2.x + ","
  + distractorCar2.y);
} ENDIF
} else If (Scene == "Play Level 3 Scene") {
  Get position of Target Car;
  Get position of Distractor Car1;
  Get position of Distractor Car2;
  Get position of Distractor Car3;
  Get position of Distractor Car4;
  Create file "Level 3 File";
  Create column texts to "Level 3 File": "Timestamp" + "," + "GazePoints (X)" + "," + "GazePoints
(Y)" + "," + "Blinks" + "," + "User Presence" + "," + "Target
Car X" + "," + "Target Car Y" + "," + "Distractor Car1 X" +
  "," + "Distractor Car1 Y" + "," + "Distractor Car2 X" +
  "," + "Distractor Car2 Y" + "," + "Distractor Car3 X" +
  "," + "Distractor Car3 Y" + "," + "Distractor Car4 X" +
  "," + "Distractor Car4 Y";
}

```

```

If (Current Gaze Points == Previous Gaze Points) {
  If (Previous Time – Current Time) > 0.7 {
    Append to column texts of “Level 3 File”: gazePoint.Screen.x + "," + gazePoint.Screen.y +
      "," + "0" + "," + userNotPresent + "," +
      targetCar.x + "," + targetCar.y + "," +
      distractorCar1.x + "," + distractorCar1.y + "," +
      distractorCar2.x + "," + distractorCar2.y + "," +
      distractorCar3.x + "," + distractorCar3.y + "," +
      distractorCar4.x + "," + distractorCar4.y);
  } else If (Previous Time – Current Time) < 0.7 {
    Append to column texts of “Level 3 File”: gazePoint.Screen.x + "," + gazePoint.Screen.y +
      "," + "1" + "," + userPresent + "," + targetCar.x
      + "," + targetCar.y + "," + distractorCar1.x + ","
      + distractorCar1.y + "," + distractorCar2.x + ","
      + distractorCar2.y + "," + distractorCar3.x + ","
      + distractorCar3.y + "," + distractorCar4.x + ","
      + distractorCar4.y);
  } ENDIF
} else {
  Append to column texts of “Level 3 File”: gazePoint.Screen.x + "," + gazePoint.Screen.y +
    "," + "0" + "," + userPresent + "," + targetCar.x +
    "," + targetCar.y + "," + distractorCar1.x + "," +
    distractorCar1.y + "," + distractorCar2.x + "," +
    distractorCar2.y + "," + distractorCar3.x + "," +
    distractorCar3.y + "," + distractorCar4.x + "," +
    distractorCar4.y);
} ENDIF
} ENDIF
Create file “Scores File”;
Create column texts to “Scores File”: “Score Level 1” + “,” + “Score Level 2” + “,” + “Score Level 3”
  + “,” + “Total Score”;

Get score1;
Get score2;
Get score3;
totalScore = score1 + score2 + score3;
Append to column texts of “Scores File”: score1 + “,” + score2 + “,” + score3 + “,” + totalScore;
} ENDWHILE

```

4.4 Conclusions

In this chapter (accompanied with pictures), it was discussed the concept of the game and a typical session with the software for each scenario in each level. The gaze trace was included to better understand how the target car changed its speed depending whether the user looks. Afterwards, it was explained how the eye tracking device functioned as well as how it detected the gaze points of the user's. Furthermore, a brief introduction on how Tobii EyeX must be placed on the computer followed by the calibration procedure and how the user's must be positioned for achieving an accurate interaction with the game, were presented. The following subsections discussed all the implementation processes of the game in detail along with pseudocode and with a diagram. These details included all the features utilized from Unity engine, the functions used from Tobii API, the programming language applied for achieving the interaction with the game only with the gaze points and the functions utilized from Tobii Unity SDK for the data collection process. The next chapter will go through the evaluation of the game design in a study with healthy users.

5.Evaluating the Game Design

This chapter starts by presenting the research questions established for this study followed by the user evaluation procedure. Next, it discusses the data collected from the online form and from the eye tracking device. Based on the participants feedbacks from the online form, statistical analyses will be displayed to test the software functionality to show whether it has achieved its aim of being an interactive application. The following subsection will explain all the statistical analyses conducted from the data collected on the user evaluation online form, from the eye tracking device and from the overall performance of the participants based on their scores achieved on the game. These analyses will be used to build conclusions, answer the research questions as well as to test the user's ability to keep their focus on the target object.

5.1 Research Questions

The study aims at answering the following research questions:

- In an eye tracking game application, are users able to keep their attention to the intended target object and successfully complete the game while various distractors are being displayed on the screen?
- Is the game challenging for the users and do they feel that its difficulty increases as they progress from one level to another?
- Does increasing the number of distractors effect the user's ability to keep their eyes on the target object?
- Did the user get distracted due to other objects displayed on the screen excluding the ones intended to be the distractors?
- Do the users lose their attention from the blue car due to the designed distractor objects presented throughout the game or they just lost their interest in playing the game and had random distractions?
- Does the disappearance of the car under the cloud in the third level, have negative effects on the user's level of attention and their ability to keep tracing the car?
- Does the idea of being followed from another car make subjects more distracted or increase their level of attention on the target car?

- Does the idea of being nearly touched by another car make individuals more distracted or increase their level of attention on the target car?
- Do users become more focused on the task or lose their interest on the game after their car crashes with another car?

5.2 User Evaluation Procedure

Each participant was met randomly in person by me and was asked to be part of the research study. The experiments were conducted in the quiet group room in the library located at the Lancaster University and lasted approximately 15 minutes where the user was first required to read the participant information sheet and sign the consent form. The ethics approval process is a critical phase that comes before the actual experiment. The approval criteria included the following information:

- Research methods used for collecting the data.
- The right to withdraw from the study at any time.
- The right to not take part to the study.
- The right to being anonymous.
- Risks to being part of the study.
- Benefits to being part of the study.

From the beginning, no criteria was set for a target demographic in age whereas for gender the criteria was set to include an equal number in genders. In total, 30 healthy (non-ADHD) participants accepted to volunteer in the study in which 15 were females and the other 15 were males as shown in Figure 5.1(a). From all the participants, 60% of them didn't required for vision correction, 30% required to normal vision with glasses, 7% required vision correction whereas 3% required vision correction with contact lenses (see Figure 5.1(b)). The average mean of the user's age was 24 which varied from 21 years old to 34 years old as shown in Figure 5.2. From all the participants, only one student had problems in finishing the game, therefore wasn't included in the study and was replaced with another student.

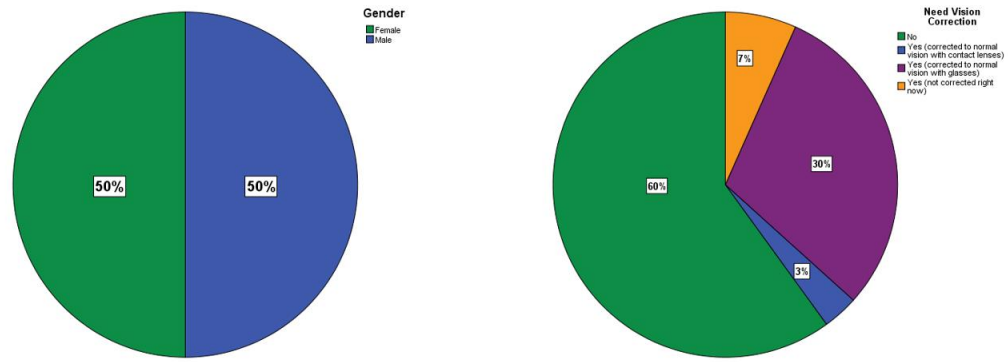


Figure 5.1: (a) The pie chart shows gender equality between the participants. (b) The pie chart displays the percentage of the participants that required for vision correction.

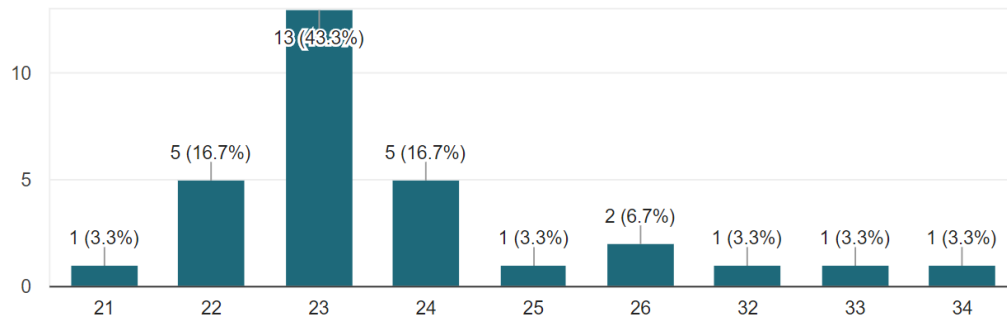


Figure 5.2: The range of age across all the 30 participants.

Before commencing the game, each participant played a small trial of the application which lasted 30 seconds and throughout this time further instructions were provided to better explain how the users would interact with it. The ‘Car Racing’ application consisted of three levels where each of them lasted 1 minute. The task that the users were required to execute was to keep their gaze on the target car while distractor objects such as other cars, moving clouds, unmoving clouds, sounds and objects outside the path were displayed and played during the game.

5.3 Data Collected

Data was partially collected from the Tobii EyeX device and partially from an online form that the users were required to complete after finishing the game. The questionnaire consisted of 35 questions in total where the first 7 questions were related to user's demographics and included: user's ID, name, age, gender, if they needed vision correction and if they had previously interacted with applications that relied on gaze. The second section of the questionnaire was the most important part of the data process as it was used to build statistical analyses and answer the research questions. This section consisted of 28 questions in which 25 of them were in a scale form whereas the last 3 questions required from the user to click one or more checkboxes based on their opinions.

Likert Scale is the most common measurement way to validate the user's opinions, their perceptions and their attitudes on the application or the device tested. This measurement is comprised with several statements known as Likert items that asks the individual to show the level of their agreement by selecting one of the ordered options. For this study, the Likert scale consisted of 25 statements each of which offered the participants the choice to select one of five ranked options. The subjects were required to rate each statement starting from 1 score for 'strongly disagree' to 5 score for 'strongly agree' with the middle option 'neither/nor agree'. The following 25 statements were included:

- 1- Interacting with the game was easy to learn.
- 2- Interacting with the game was natural.
- 3- Interacting with the game was fast.
- 4- Interacting with the game worked reliably.
- 5- Interacting with the game was tiring for my eyes.
- 6- Interacting with the game was mentally tiring.
- 7- I was able to keep my eyes on my car and successfully finish the game without any problems.
- 8- Playing the game was challenging.
- 9- As the number of cars increased from one level to another, I got more distracted.
- 10- It was hard to keep attention at the blue car in the first level.
- 11- It was hard to keep attention at the blue car in the second level.
- 12- It was hard to keep attention at the blue car in the third level.
- 13- The other cars distracted me.
- 14- I got distracted from other objects on the screen and not the cars.
- 15- I got distracted as I lost interest playing the game and not from the objects on the screen.
- 16- I think that the disappearance of my car under the cloud in the third level, made it difficult for me to follow it.
- 17- I think that the idea of being followed from other cars, distracted me.
- 18- I think that the idea that the other cars were on the opposite side of the road, distracted me.
- 19- When another car approached mine, I got distracted.
- 20- When another car approached mine, I was more focused on the task.

- 21- I think adding more distracting objects and more levels would make this game more challenging and entertaining.
- 22- I think the score is a good feature of the game as it motivates me to play it again.
- 23- I think ending the game if my car gets touched by another car, is a good penalty to impose my attention.
- 24- I think interacting only with my eyes is more entertaining than using a keyboard.
- 25- I think interacting only with my eyes is more entertaining than using a mouse.

The last three questions of the online form asked participants which were the most distracting objects for each level. Participants were required to click one or more options listed in the form and they also had the chance to include one of their own opinions.

As previously mentioned in the “Implementation” chapter, by utilizing Tobii Unity SDK features, we were able to retrieve data from the Tobii device. By including Tobii API functions in my scripts, it was possible to capture the user’s gaze points on the screen, the user’s blinks, the user’s presence in front of the Tobii device as well as the x and y coordinates of the cars. Such data was collected to understand the levels of ADHD and particularly the levels of attention of the participants while they were playing the game.

5.4 Software Functionality

The most appropriate way to test if the software functioned correctly was to retrieve and display feedbacks from the participants. Therefore, generating some statistical analysis on the first 4 statements of the online form, it was possible to gain insights whether the application was easy to learn, if the interaction felt natural for the users as well as if it worked fast and reliably. From the first 4 statements of the scale chart, the following bar charts built with SPSS statistical package display the participants opinions on the software functionality.

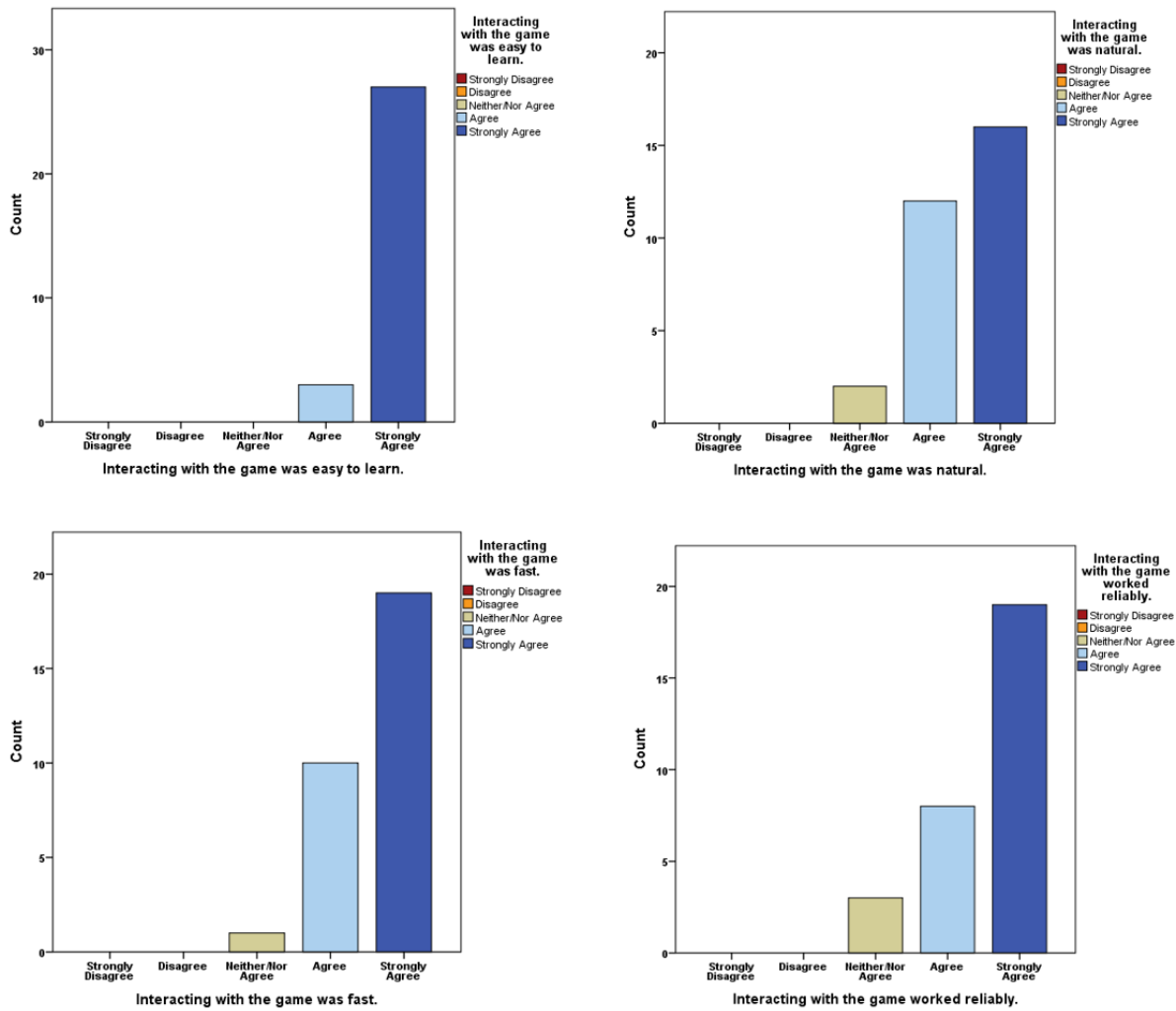


Figure 5.3: Participants feedback on the functionality of the application (a) Feedback on “Interacting with the game was easy to learn”, (b) Feedback on “Interacting with the game was natural”, (c) Feedback on “Interacting with the game was fast”, (d) Feedback on “Interacting with the game worked reliably”.

As shown in Figure 5.3, feedbacks from the participants on the software functionality were positive. Most of the subjects strongly agreed that the game was easy to learn (see Figure 5.3(a)), felt natural (see Figure 5.3(b)), was fast (see Figure 5.3(c)) and worked reliably (see Figure 5.3(d)). These results indicate that the application functioned correctly and achieved its aim on being an interactive vision based game application.

5.5 Comments from the Participants

To reach more conclusions on how the user's perceived the application and if it functioned correctly, an additional section was included in the online form in which they were required to give their comments on the game. The following comments were submitted:

- The most interesting eye tracking experiment.
- I really enjoyed playing this game.
- Fun and easy to play. Really liked it.
- Change the path for different levels, it would be more challenging. However, it was an interesting game.
- Never interacted with a game only with my eyes. This was a great experience.
- It was really fun to play. The siren lights distracted me.
- The game was interesting.
- Cool game and cool technology.
- I was very impressed with this game.
- Happy to be part of this study, the game was interesting.
- Really entertaining.
- Interesting idea. I like how smooth the interaction was.

5.6 Data Analysis Process

A critical part of the study is the data analyses process as it is conducted to answer the research questions as well as build conclusions. By generating comparative statistical analyses, we can test whether an application developed with an eye tracker can efficiently test the user's ability to follow a specific task and pay attention to the target object. Such analyses were generated based on the user's responses from the online form. Likert scale chart, bar plots and histograms were conducted to visualize participants average answers for each statement in order to reach conclusions from the participants opinions.

By using the data collected from Tobii EyeX device, more statistical analysis can be conducted to show whether the user is looking at the target car or at the distractor cars by plotting the distance between the gaze points and the target car positions or between the gaze points and the distractor cars positions for each level. As the gaze points become negative when the user looks outside of the game view, the data on the gaze coordinates can be used to comprehend whether the participants were focused on the game or if they weren't paying attention. As blinks are linked with the level of attention, calculating the number of blinks can exhibit the user's level of arousal and therefore we can gain insights on their level of attention. Furthermore, data analyses can be

generated on the user's levels of hyperactivity based on whether the user was in front of the Tobii device or not. In addition to the histogram presentation, other data plots such as linear model fit can be generated to give information on the position of the gaze points and the position of the objects in the screen. However, as such analyses will give more significant insights between an ADHD group and a control group, the data from the eye tracking device wasn't fully utilized but it will be taken in consideration in the future as such data is mostly used to determine the levels of inattention and hyperactivity for subjects with ADHD.

Furthermore, to make a complete validation of the application developed, the experimental process will make two additional analyses based on gender and age where each of them will include one independent variable (IV) and one dependent variable (DV). Independent variable in an experiment is used to retrieve changes in the user's responses and must have at least two levels whereas the dependent variable is the outcome registered and is used only for evaluating the human behaviour. To measure the dependent variable, the task of the experiment must bring a difference as well as must be representative. As the experiment is developed to manipulate the independent variable to understand how this effects on the dependent variable, conclusions will be established if there is any difference on the level of attention between two genders and if there is any significant difference between the ages of the participants. The statistical programs required for all the types of analyses mentioned above are SPSS and Matlab as they are very powerful programs for establishing accurate results and conclusions.

5.6.1 Results from the Online Form

This subsection presents with a Likert Scale Chart the average scores for each statement registered from the user evaluation process. Additional analyses with bar charts and histograms are presented with the aim to reach accurate conclusions and answer the research questions correctly:

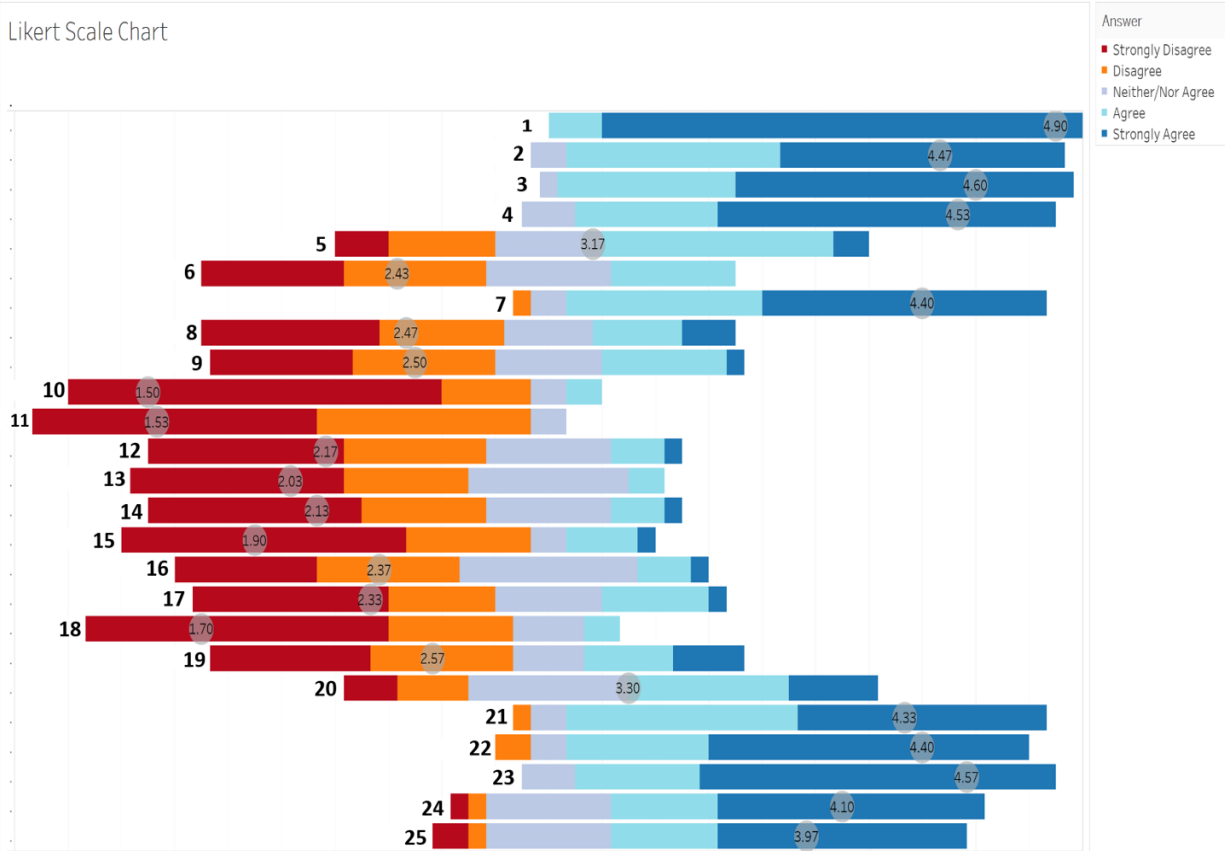


Figure 5.4: Likert Scale Chart based on the user’s feedbacks on the 25 statements.

The Likert scale chart displays the participant answers and the average scores for each item. As shown in Figure 5.4, most of the users ranked the first 4 items with the average scores of 4.90, 4.47, 4.60, 4.53 respectively, indicating that the interaction with the game was easy to learn, was natural, was fast and worked reliably. The average score on the fifth question was 3.17 displaying that the users had a neutral opinion and slightly agreed that the game was tiring for their eyes. However, they didn’t consider the game to be mentally demanding as they disagreed to the sixth statement (average score 2.43). The next Likert item was included to answer the first research question with the aim to understand whether the players were able to keep their attention to the intended target object and successfully complete the game while various distractors were displayed on the screen. With an average score of 4.40, the results displayed that most of the users strongly agreed to this statement. Furthermore, more females rated this statement with 5 score compared to males as shown in Figure 5.5 (a). To answer the second and the third research questions, participants were first asked to give their opinions whether they believed that the game was challenging for them. In another statement, they were asked if moving from one level to another becomes more difficult for them to follow the task and the next 3 questions were included to

determine whether it was difficult for the participants to keep their attention at the blue car in the first, second and the third level. The results from the Likert scale display that the users disagreed in the first two statements with the average scores of 2.47, 2.50 respectively whereas for the other 3 Likert items, the average scores of 1.50, 1.53, 2.17 were registered. Furthermore, for the last 3 statements, another histogram plot was generated to display how challenging was for the participants to follow the blue car in the three levels (see Figure 5.5 (b)). These answers suggest that users didn't find the game too difficult as they moved from one level to another and an increase of the distractor objects made the game more challenging but it didn't have a big effect on their level of attention. These results were as expected as all the participants weren't diagnosed with ADHD and all of them managed to finish the game successfully.

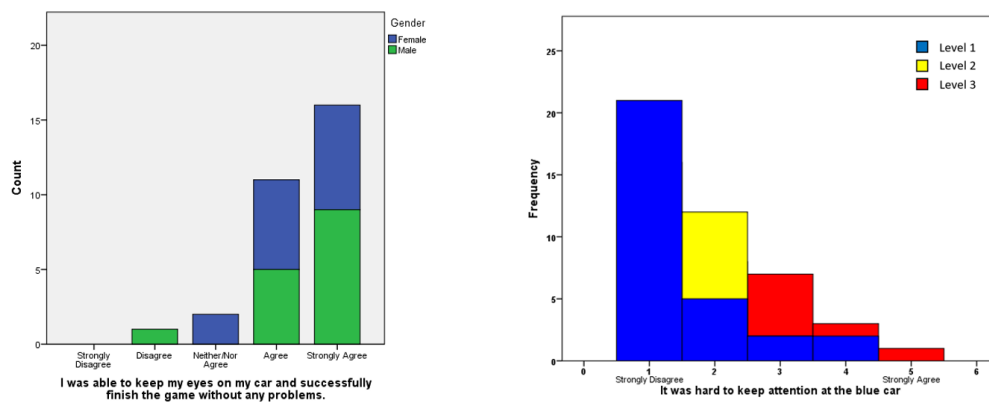


Figure 5.5: (a) Feedback on being able to finish the game successfully. (b) Feedback on how challenging was for the participants to follow the blue car in the three levels.

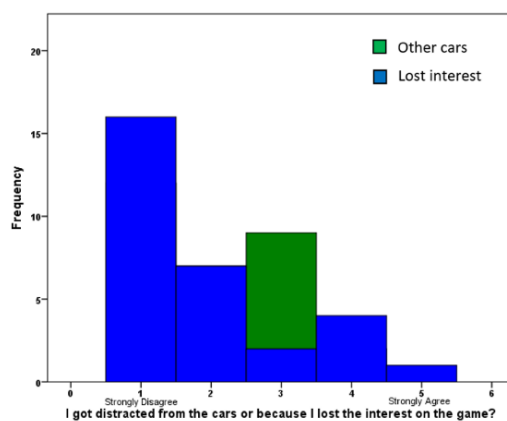


Figure 5.6: Histogram displaying feedbacks on being distracted from other cars or losing interest on the game.

The following statements asked the participants if they were distracted from the other cars, from the other objects on the screen excluding the cars or if they were distracted because of losing their interest on the game. The average scores for the three statements were 2.03, 2.13, 1.90 indicating that the participants strongly disagreed with the questions. Another histogram was built to display if the users were distracted from other cars or because they lost interest on the game. The results show that the players mostly disagreed on being distracted from losing interest on the game (see Figure 5.6). This indicates that they found the game interesting and entertaining. Furthermore, to gain more insights on which were the most distracting objects on the screen for each level, participants were asked to tick one or more options from the objects listed in the form or to write another option based on their opinions. The results are shown below:

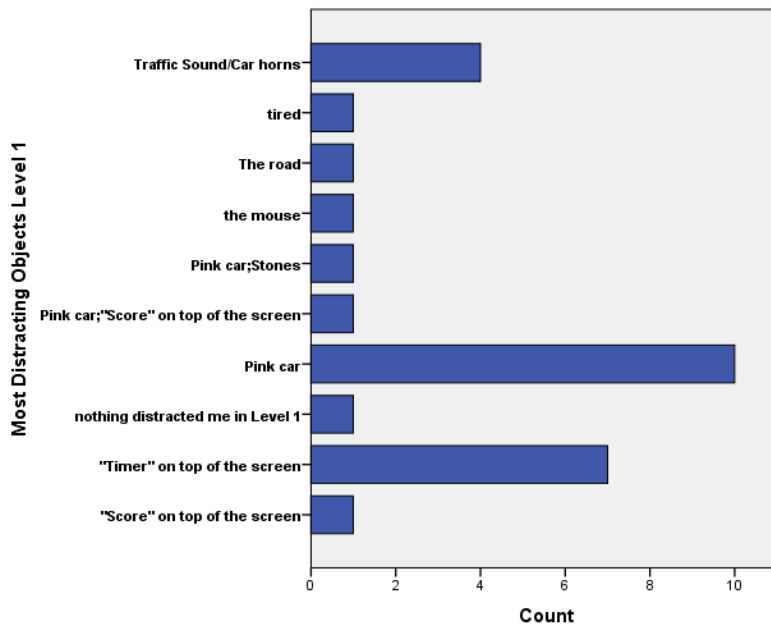


Figure 5.7: Most distracting objects in level 1

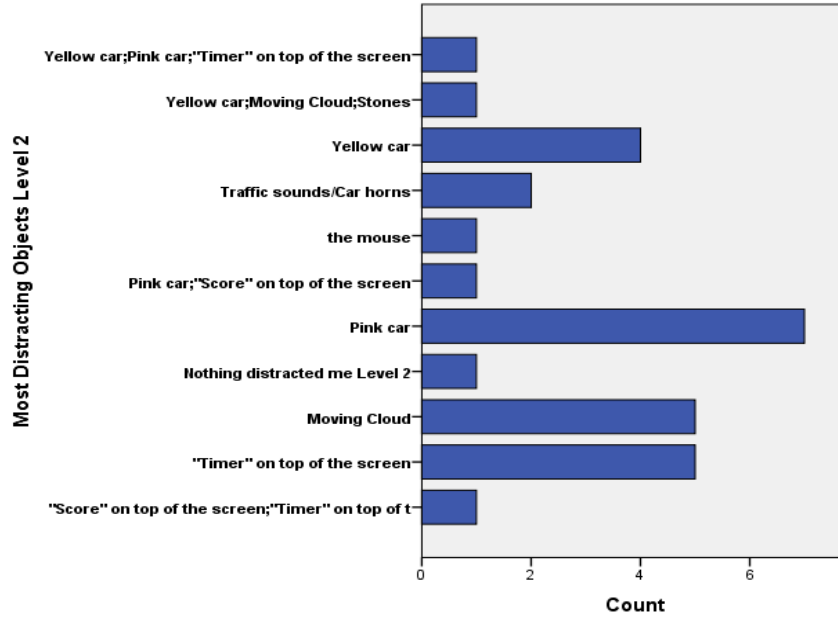


Figure 5.8: Most distracting objects in level 2

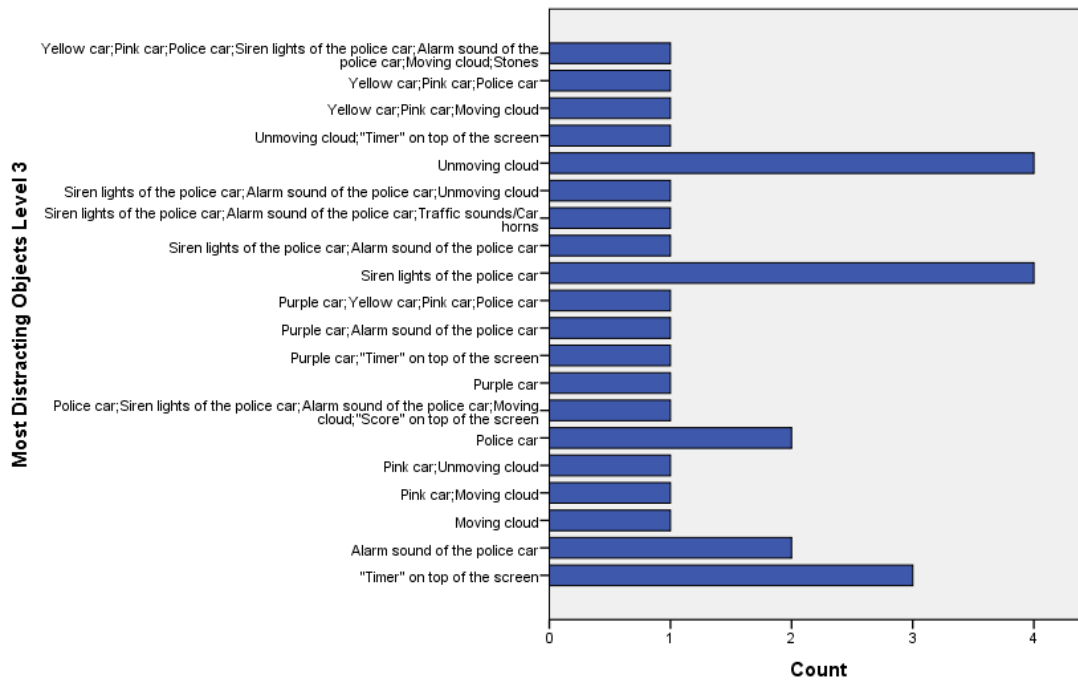


Figure 5.9: Most distracting objects in level 3

In the first level (see Figure 5.7), the users rated the pink car as the most distracting object, followed by the timer on top of the screen which was the second most distracting object and the traffic sounds was rated as the third most distracting feature included in the game. In the second level (see Figure 5.8), pink car is again the most rated object, followed by the timer and the moving cloud which have the same ratings and lastly the yellow car was ranked as the third most distracting object. As shown in Figure 5.9, unmoving cloud and the siren lights of the police car are displayed to be the objects that draw most of the attention, followed again by the timer which is rated as the second most distracting object and by the police car and its alarm sound which are ranked in the third place. Overall, these results suggest that the objects intended to be included as distractors, indeed had an effect on drawing the user's attention. Surprisingly, the timer was distractive for the users in every level. This indicates that either the users weren't that much interested on the game and were hoping to finish it soon or either they were feeling that it was challenging for them to keep their eyes only at the blue car and were hoping to finish it successfully. As from the previous histogram, it was concluded that the users didn't lose their interest on the game, the first option drops therefore the second assumption might be the most appropriate reason for this question. However, this topic might be explored in the future to gain insights on how the user's will behave if the timer gets increased and how much it will distract them from the task.

The unmoving cloud which was placed on the road was included as another distractor to reveal if subjects would have difficulties to follow the target car even if it was hidden for a moment. The next statement asked participants if it was difficult for them to keep their attention at the blue car when it disappeared under the cloud. Participants disagreed that they had difficulties to follow the blue car and for this case it was registered an average score of 2.37. This indicates that even though the unmoving cloud was distracting for them as seen in the previous bar chart of the most distracting objects, they didn't face much difficulties to keep their eyes on their car. In the next statement, participants were required to give their opinion on whether they got distracted because of the idea of being followed from the other cars and the results show that the participants strongly disagreed. From the bar chart below (see Figure 5.10), we can further conclude that females disagreed the most in this question.

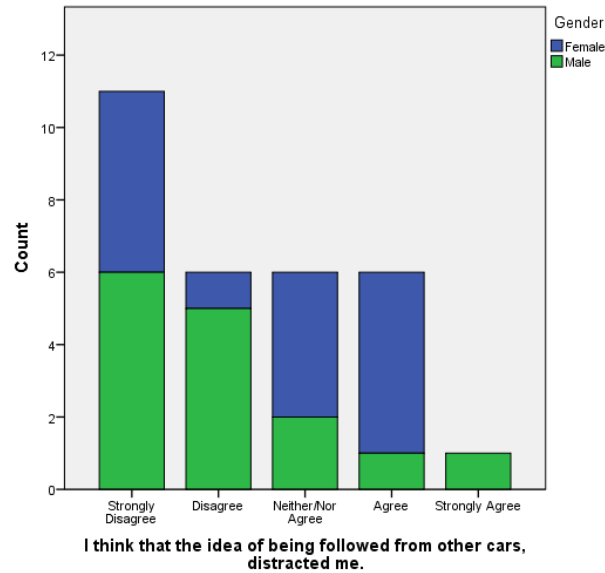


Figure 5.10: Feedback on being distracted because of being followed from other cars.

To answer the next research question, the participants were asked whether being approached by another car makes them more distracted or more focused on the task and the average scores for the two statements were 2.57, 3.30 respectively. These results show that the subjects disagreed in the first statement and slightly agreed in the second statement. Such results suggest that the idea of displaying distracting objects on the screen and the pressure that comes from being approached by another distractor, is a good way to impose attention.

The average score for the next statement was 4.33 displaying that the users strongly agreed that adding more distracting objects and more levels would make the game more challenging and entertaining. Furthermore, females rated this question with more points than males (see Figure 5.11 (a)). For the 22 and 23 questions, the Likert scale chart shows that the participants strongly agreed that the score and the penalty of ending the game if were touched by another car, were good features as motivated them to play the game again. The results are displayed also in the histogram below (see Figure 5.11 (b)) and the score is shown to be a more motivational feature of the game as it was rated with slightly more points compared to the penalty feature.

The last two statements asked the participants if interacting with games only with their eyes based on the interaction with this application, was more entertaining than using a keyboard or a mouse and the average scores for these questions were 4.10 and 3.97 respectively. As displayed also in Figure 5.12 participants strongly agreed with both statements.

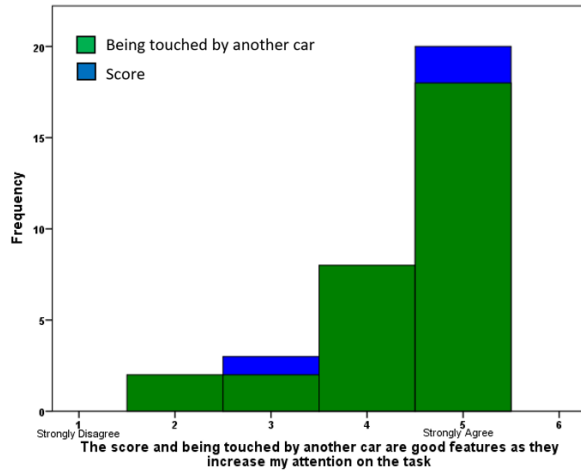
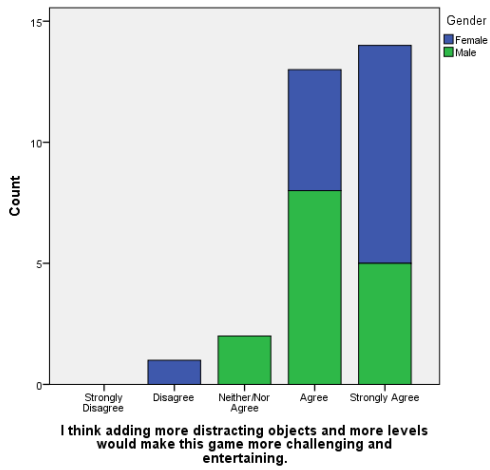


Figure 5.11: (a) Feedback on adding more distracting objects and more levels. (b) Feedback on reward and penalty.

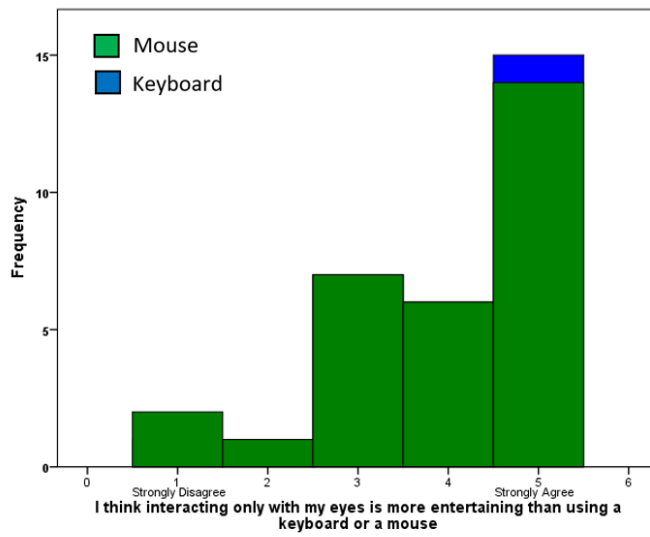


Figure 5.12: Feedback on interacting only with eyes.

Overall, these results suggest that the game worked very well and interacted fast even with users who were wearing glasses or contact lenses. The participants found the game somehow challenging as they moved from one level to another and as the number of distractors increased. Even though some of the participants had to restart the game because they were touched by another car, as they weren't diagnosed with ADHD, they managed to finish the game successfully. Participants thought of the game of being well developed because the purpose of the intended distractors effected the participants. Furthermore, they liked the way it worked and the way it was designed and they thought that it was very interesting and even more entertaining than using a mouse or a keyboard. The purpose of the game in long term is not only to test inattention but also to train it and this game accomplished both purposes as first it tested whether the users would follow the task or not and secondly the users agreed on the 20, 21, 22, 23 statements which indicate that in long term, this game would impose attention and decrease levels of inattention and hyperactivity in ADHD users.

5.6.2 Results from Tobii EyeX

As previously mentioned, by utilizing the data collected from the eye tracking device, more statistical analyses can be generated to show the participants levels of attention. The most appropriate way to determine if the users were paying attention to the game is to plot the distance between the gaze points and the target car as well as the distance between the gaze points and the nearest distractor car. To achieve the following histograms, each data collected from the participants were first joined together for every level. To calculate the distance between the gaze points and the target car as well between the gaze points and the nearest distractor car, the following function was applied for every participant and was stored in the three Excel files:

$$\text{Distance} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

As each gaze point had two coordinates and each of the cars had also two coordinates (x, y), by applying this formula, it was possible to generate plots with Matlab and retrieve the distances for all participants in each level:

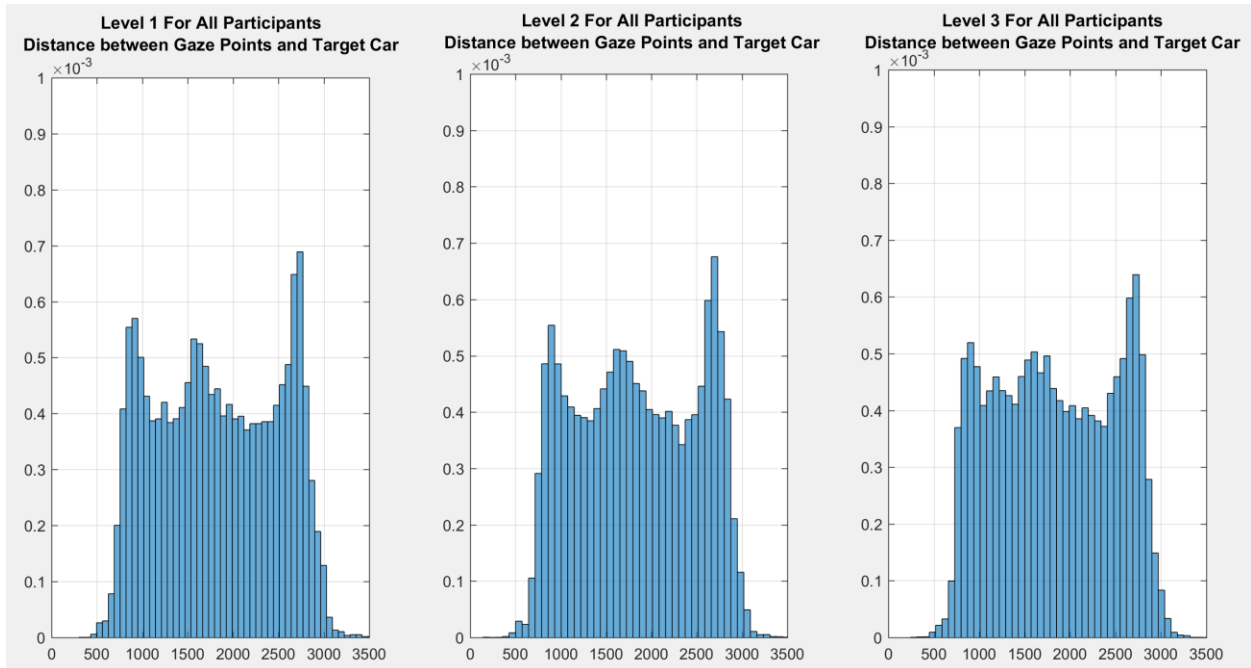


Figure 5.13: Distances between the gaze points and Target car for all participants in each level.

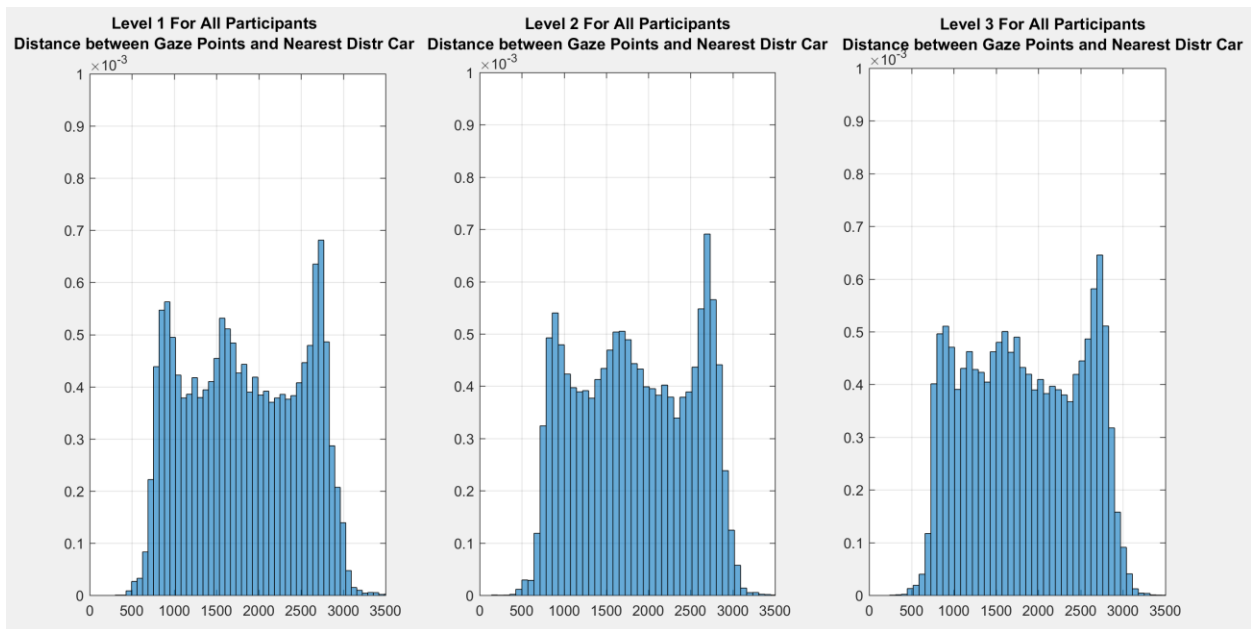


Figure 5.14: Distances between the gaze points and nearest Distractor car for all participants in each level.

As shown in Figure 5.13 and in Figure 5.14, there are no significant differences in distances between the gaze points and target car as well as between the gaze points and the nearest distractor car between the three levels. These results indicate that participants didn't lose their attention from the task. They managed to keep their focus at the target car throughout the game and finish it successfully. Such outcomes were as expected from the conclusions reached on the online form and from the overall performance of the users on the game. Further statistical analyses can be generated by comparing the number of blinks or evaluating the user presence in front of the game view. However, such analyses demand for two groups (ADHD and non-ADHD groups), in order to retrieve significant results.

5.6.3 Results from the Application

By utilizing SPSS statistical package, two additional statistical analyses were conducted to determine if there is a gender and an age impact on the participants performance based on their scores achieved from the game.

To compare the performance between the two genders with the aim to understand if there is a significant difference between females and males based on their performance and to reach conclusions on their levels of attention, an independent samples t-test was conducted to test two assumptions. In order to conduct the independent samples t-test, one independent variable with two or more levels and one dependent variable are required. The independent variable (IV) is a binomial group variable whereas the dependent variable (DV) is the continuous variable which is used to calculate the mean between the two independent variables. In our example, 30 students participated in the study, where 50% of them were females and the other 50% were males. All the students undertook the same task and successfully managed to finish the game. The application was developed to save the scores of the participants for each level as well as to save their total score in the end of the game. Therefore, having their performance based on their total scores as well as having two groups to compare, the independent samples t-test was the most appropriate test to draw accurate conclusions for this case. The categorical independent variable for our study is gender which has two levels: females and males whereas the continuous dependent variable is the performance achieved from the students based on their scores.

A “descriptive statistics” of all the scores for all the students was performed to retrieve the minimum, the maximum as well as the mean score achieved. As shown in Table 5.1, the minimum score reached from the participants was 25750, the maximum score was 33110 whereas the average score was 28246.50.

| | N | Minimum | Maximum | Mean |
|--------------------|----|---------|---------|----------|
| Total Score | 30 | 25750 | 33110 | 28246.50 |
| Valid N (listwise) | 30 | | | |

Table 5.1: Descriptive statistics on the minimum, maximum and mean score achieved from participants.

| Gender | | |
|--------|---------|----|
| N | Valid | 30 |
| | Missing | 0 |

Table 5.2: Number of the students that participated in the study.

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------|--------|-----------|---------|---------------|--------------------|
| Valid | Female | 15 | 50.0 | 50.0 | 50.0 |
| | Male | 15 | 50.0 | 50.0 | 100.0 |
| Total | | 30 | 100.0 | 100.0 | |

Table 5.3: Statistical summary between genders.

As the data was categorical, the frequencies procedure was used to display the amount of times each value was presented in the data. A statistical summary between genders was retrieved with tables. From the tables, we can acknowledge that the total number of students that participated in the study was 30 where all the students were included and none of them were missing (see Table 5.2). Furthermore, 15 of them were females whereas the other 15 were males, displaying that the group was separated in two equal subgroups (see Table 5.3).

As we want to test if there is a gender impact on the level of attention based on the scores gained from the game, the following hypotheses are established:

Two-tailed significance test:

$H_0: \mu_0 = \mu_1$ (means of the two groups are equal). It suggests that there is not a significant difference between the two genders.

$H_a: \mu_0 \neq \mu_1$ (means of the two groups are not equal). It suggests that there is a significant difference between the two genders.

| | Gender | N | Mean | Std. Deviation | Std. Error Mean |
|-------------|--------|----|----------|----------------|-----------------|
| Total Score | Female | 15 | 28490.67 | 2405.779 | 621.169 |
| | Male | 15 | 28002.33 | 2039.247 | 526.531 |

Table 5.4: Differences between the group means based on their scores.

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | |
|-------------|-----------------------------|---|------|------------------------------|--------|-----------------|-----------------|-----------------------|---|----------|
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | | | | Lower | Upper |
| Total Score | Equal variances assumed | 3.239 | .083 | .600 | 28 | .554 | 488.333 | 814.301 | -1179.687 | 2156.354 |
| | Equal variances not assumed | | | .600 | 27.268 | .554 | 488.333 | 814.301 | -1181.706 | 2158.373 |

Table 5.5: Independent Samples Test for determining the equality of means.

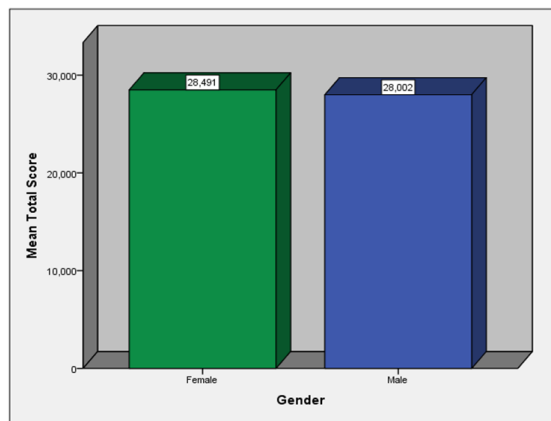


Figure 5.15: Mean scores of females and males.

From the above tables, we can conclude that the assumption of homogeneity of variances is satisfied ($p > .05$). It suggests homogeneity of variance on the scores achieved by users in playing the “Car Racing” game as assessed by Levene’s test for equality of variances ($p = .083$) (see Table 5.5). The t-test for equality of means as shown in the independent sample t-test table (see Table 5.5), displays the difference between the genders from the centre of the distribution. From our results, we can determine that there isn’t a statistically significant difference between the means of the genders on their total scores ($t(28) = .6, p > .05$) and therefore we accept the null hypotheses and reject the alternative hypotheses.

An independent samples t-test was conducted to compare the impact of genders on their performance (total score) in the “Car Racing” game with the aim to display if there is a difference on their level of attention. Findings reveal that female participants achieved slightly more scores in the game ($M = 28490.67, SD = 2405.779$) compared to male participants ($M = 28002.33, SD = 2039.247$). However, there isn’t a significant difference between the means of the two groups ($t(28) = .6, p > .05$). These results suggest that there is no gender impact on the level of attention.

To test whether there was a statistical significant difference between the ages of the subjects based on their performance, another independent samples t-test was conducted in SPSS. The participants ages varied in an interval from 21 years old to 34 years old. To generate the t-test one independent variable with two levels and one dependent variable is required. The independent variable (IV) in this case had two levels: age less or equal to 23 and age more than 23 years old. These levels were calculated based on the median age of all the participants data which was 23 years old. The dependent variable for this case is again the total score that each participant achieved.

As we want to test if there is an age impact on the level of attention based on the scores gained from the game, the following hypotheses are established:

Two-tailed significance test:

$H_0: \mu_0 = \mu_1$ (means of the two groups are equal). It suggests that there is not a significant difference between the ages.

$H_a: \mu_0 \neq \mu_1$ (means of the two groups are not equal). It suggests that there is a significant difference between the ages.

| Group Statistics | | | | | |
|------------------|-------------------------|----|----------|----------------|-----------------|
| | Age | N | Mean | Std. Deviation | Std. Error Mean |
| Score | Age Less Or Equal to 23 | 19 | 28311.84 | 2425.821 | 556.521 |
| | Age More Than 23 | 11 | 28133.64 | 1867.955 | 563.210 |

Table 5.6: Differences between the group means based on their scores.

| Independent Samples Test | | | | | | | | | | |
|--------------------------|-----------------------------|---|------|------------------------------|--------|-----------------|-----------------|-----------------------|---|----------|
| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | 95% Confidence Interval of the Difference | |
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| Score | Equal variances assumed | 1.812 | .189 | .210 | 28 | .835 | 178.206 | 849.637 | -1562.198 | 1918.609 |
| | Equal variances not assumed | | | .225 | 25.536 | .824 | 178.206 | 791.784 | -1450.768 | 1807.180 |

Table 5.7: Independent Samples Test for determining the equality of means.

From the above tables, we can conclude that the assumption of homogeneity of variances is satisfied ($p > .05$). It suggests homogeneity of variance on the scores achieved by users in playing the “Car Racing” game as assessed by Levene’s test for equality of variances ($p = .189$) (see Table 5.7). The t-test for equality of means as shown in the independent sample t-test table (see Table 5.7), displays the difference between the ages from the centre of the distribution. From our results, we can determine that there isn’t a statistically significant difference between the means of the ages on their total scores ($t(28) = .210$, $p > .05$) and therefore we accept the null hypotheses and reject the alternative hypotheses.

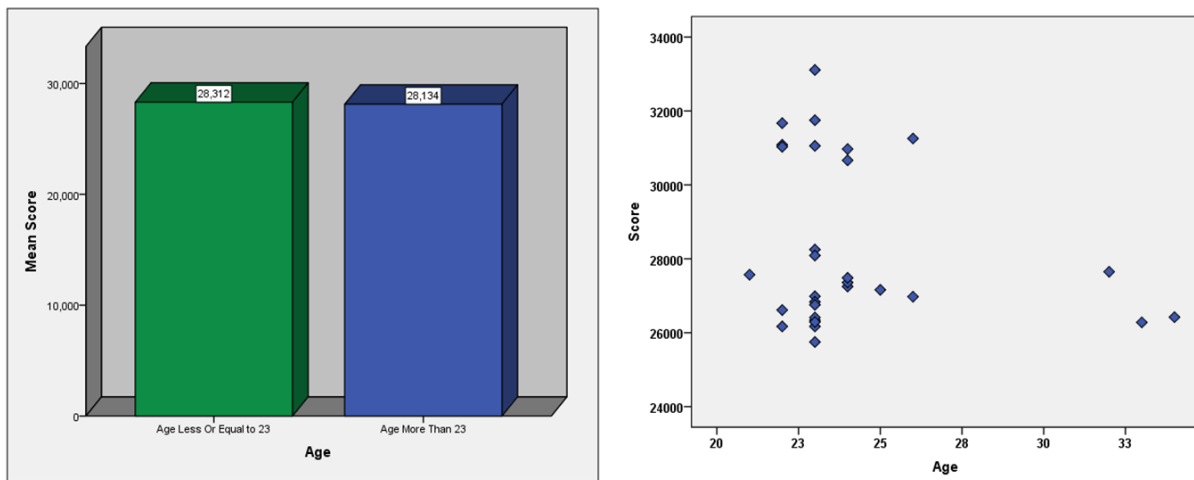


Figure 5.16: (a) Mean scores achieved in the game between participants less or equal to 23 years old and participants more than 23 years old. (b) All scores achieved from each participant.

As shown Figure 5.16 (a), participants younger or equal to 23 years old achieved slightly more scores than participants older than 23 years old but there isn't a significant age impact on the user's performance and subsequently on their level of attention. However, to understand whether there was a correlation between the user's ages and their level of attention, the bivariate Pearson Correlation test was conducted and the following hypotheses were established:

One-tailed significance test:

H₀: $\rho = 0$ (the population correlation coefficient is 0, there is no association)

H_a: $\rho > 0$ (the population correlation coefficient is greater than 0, a positive correlation could exist)

OR

H_a: $\rho < 0$ (the population correlation coefficient is less than 0, a negative correlation could exist)

As shown in Table 5.8, there is a negative weak correlation between the ages and the scores, meaning that the variables tend to change irrespectively from each other. An increase in age is associated with a decrease in performance and therefore a decrease in the level of attention. Therefore, we reject the null hypotheses and accept the alternative hypotheses that a negative correlation between the ages and the performances could exist.

Another independent samples t-test was conducted to compare the impact of the user's age on their performance (total score) in the "Car Racing" game with the aim to display if there is a difference on their level of attention. Findings reveal that participants with the age 23 or less than 23 years old, achieved slightly more scores in the game ($M = 28311.84$, $SD = 2425.821$) compared to participants older than 23 years old ($M = 28133.64$, $SD = 1867.955$). Even that the results suggest that there isn't a significant difference between the means of the two groups ($t(28) = .210$, $p > .05$), there is a negative weak correlation between them, with more scores achieved in a younger age.

| | | Score | Age |
|-------|---------------------|-------|-------|
| Score | Pearson Correlation | 1 | -.214 |
| | Sig. (1-tailed) | | .128 |
| | N | 30 | 30 |
| Age | Pearson Correlation | -.214 | 1 |
| | Sig. (1-tailed) | .128 | |
| | N | 30 | 30 |

Table 5.8: Bivariate Pearson Correlation test displays the correlation between the participants age and their scores.

5.7 Conclusions

This chapter displayed the user evaluation procedure and the data collected from the online form as well as from the eye tracking device. Next, it presented bar charts that were created from the subject feedbacks to test the application developed and reach some conclusions on its functionality. The results achieved, indicate that the “Car Racing” game, was easy to learn, felt natural, was fast and worked reliably. Based on the user’s feedbacks from the first 4 statements and from their comments, it can be concluded that the game worked correctly, participants found it interesting and entertaining and no problems were encountered from the users while they were interacting with it. Afterwards, statistical analyses were built from the online form, eye tracking device and the overall performance of the participants on the game. These analyses were conducted to answer the research questions and to determine whether the vision based game application that utilizes an eye tracking device as input and being developed on the idea of having a target object besides non-target objects can test the user’s ability on keeping their attention on the target object. Furthermore, additional analyses were built to test if there is a gender and age impact on the user’s attention based on their performance from the game. The results obtained indicate that the users were able to keep their attention at the target object and successfully complete the game and they didn’t find the game too difficult as they moved from one level to another. Moreover, an increase of the distractor objects made the game more challenging but it didn’t have a big effect on their level of attention. It was also observed that participants didn’t lose their attention due to the designed distractor objects, due to other objects displayed on the screen or because they lost interest on the game. However, the most distracting objects rated from the users were: the nearest distractor object, timer, moving/unmoving cloud, traffic sounds, police car siren lights and its alarm sound. Subjects felt that the unmoving cloud was distracting for them but they didn’t face much difficulties to keep their eyes on the target car and the idea of being followed by another car didn’t distracted them as much but being nearly touched or touched by another car was more challenging and at the same time made them more focused on the task. Furthermore, it was concluded that there is no gender and age impact on the user levels of attention. However, there is a negative weak correlation between age and the users scores indicating that an increase in age is followed by a decrease in performance and subsequently a decrease in the level of attention. Finally, based on the participants feedbacks on the game and the results obtained from the statistical analyses, we can conclude that the “Car Racing” game which used only an eye tracker for capturing the user’s eyes to interact with it, was able to test the user’s ability in following a specific task and was more entertaining than traditional point and click applications. The final chapter will outline the overall conclusions of this study.

6. Conclusions

6.1 Review of Aims

To properly evaluate this project, it is important to go through the aims established in the “Introduction” chapter. The aim of this study was to investigate how the problem explored can be addressed with computerized sensing game. Furthermore, this study aimed to develop a vision based game application that used only the user’s eyes as input to correctly interact with it and being based on the idea of having a target object besides non-target objects, can test the subject’s ability to keep their attention at the target object. It can be concluded that the main aim of exploring and developing games that respond to attention as input, was successfully achieved. The first VBI application utilized only a webcam to interact with the users with their head pose / blinks / mouth movements and collected data from their head pose, positions of the cars as well as from webcam images in order to generate statistical analyses and gain insights on ADHD levels. It was concluded that the webcam is a powerful, reliable tool and inexpensive to implement which could be potentially used for capturing ADHD features. The second computerized sensing application which utilized an eye tracker and took the user’s eyes as input to interact with it, showed to be a very powerful, accurate way for achieving efficient interactions and collecting significant data from the user’s eyes as seen from the participant’s positive feedbacks about the game. The interaction functioned correctly as none of the user’s faced difficulties to play the game even though some of them required for visual correction and no calibration procedure was included. From the data collected on the online form, from the eye tracking device and from the participants performance based on their scores achieved on the game, it can be concluded that this study accomplished to test the user’s ability to maintain their focus at the target object. From the statistical analysis built on the online form, it was reached to the conclusions that all the 30 participants managed to finish their game successfully and kept their eyes at the blue car even though they felt that moving from one level to another and as the number of the distractors raised, the game became more challenging. The intended distractor objects included in this game and the idea of being followed or nearly touched by them, were rated by the subjects as being more challenging for them. However, as they had good performances on the game, it was observed that this idea is very effective to impose attention as it required from them to keep their focus at the target object in order to not lose the game. Additional analyses from their scores achieved on the game were built to determine if there is a gender and an age impact on their performances and their level of attention. The findings suggest that there isn’t a significant difference between the genders or the ages on the level of attention. However, there is a weak correlation between the score and age, indicating that the attentional capacity might get decreased as people get older. Moreover, results obtained indicate that the users are more enthusiastic to interact with a game only with human gestures rather than with a mouse or a keyboard.

6.2 Lessons Learned

As a whole, the project achieved its aim and answered the research questions. All the aspects required for this project such as the design, implementation, testing and evaluation have been accomplished, therefore we can define the study being successful. There were no problems encountered throughout this study. However, there is always space for improvements. As computer vision is becoming highly desired and as it is a wide field, much more input methods can be exploited for achieving accurate and entertaining interactions between the applications and the users. Games based on vision, on the other hand, are becoming highly desired and are started to be taken into consideration for medical trainings. Furthermore, the idea of including target object besides non-target objects can be used to efficiently test and train attentional capacity. By utilizing such findings even further, more interesting and challenging games can be developed. Based on the findings obtained from this study, we can conclude that by comparing ADHD users with non-ADHD users, more significant results can be obtained by building statistical analyses to show differences on their levels of attention. Furthermore, a younger age of participants can be more appropriate for this study as it was less difficult for adults to follow the task required. However, finding participants and especially in a range of age is always challenging as it requires a lot of time, therefore the range of age wasn't taken into consideration for this study. Another lesson learned is that gender doesn't have an impact on the level of attention. However, exploring and analyzing this topic gave additional contributions. Lastly, as the literature review was focused on gaining insights on testing ADHD as well as training this disorder, additional sessions might have been included to observe whether the performance of the participants in long-term would increase by checking their total score achieved from the game as well as by making statistical analysis and comparing their level of attention from the data collected through Tobii device on their gaze points. This way, conclusions could have been generated on whether the game application is an effective tool to train ADHD in a way that the level of inattention as well the level of hyperactivity decreases. However, a repeated measure study requires many sessions and wasn't applied due to time limitations.

6.3 Future Work

This project has accomplished the aims set at the beginning of the document. However, there are ways in which this study can be further explored in the future. A topic of interest is to retrieve findings on levels of attention and hyperactivity between an ADHD group and a control group. In the future, it would be preferred to be included a wide number in age between the participants to better understand what is the correlation between age and the levels of attention. However, for this, there might be a need to develop two or more than two applications where each of them will be used for a specific range of age. Furthermore, by utilizing the data collected on user's such as head/mouth movements as well as their gaze points, their blinks, and the user's presence, insights can be retrieved on what is the difference between the two groups based on these indices. Moreover, by including microsaccades, pupil diameter and other indicators of facial expressions on the data,

more findings can be revealed on aspects of ADHD. Lastly, the games developed in the future will be even nearer to a real game application, by including much more interaction with the user, more distracting objects as well as more levels.

Attention Deficit Hyperactivity Disorder is a very common condition that is becoming a societal concern and the need to treat this disorder has elevated. The most used methods to lessen the levels of ADHD are medications and medical trainings with no game elements. However, medications carry the risk of side effects and do not normalize all the aspects of ADHD whereas traditional therapies with no game elements do not have big effects on training this disorder. On the other hand, differently from medications and traditional therapies, computerized sensing games that aid on learning do not have side effects and are becoming highly desired as they are acknowledged to be more entertaining for individuals. Through this project, a contribution was given to tackle this topic in a way that would be innovative and fun for participants to be part of this study as well as to introduce the ways of what data we can generate to properly diagnose this disorder. In the future, much more funny, innovative and entertaining vision based games will be considered for monitoring and training ADHD.

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Appendices



PARTICIPANT INFORMATION SHEET

A Vision Based User Interface for Monitoring and Training Attention: User Evaluation on a Car Racing Game Application

My name is Fjorda Kazazi and I am conducting this research as a student of the School of Computing and Communications as part of the Computer Science programme at Lancaster University.

What is this research about?

You will participate in this study by playing a vision based game application where interaction with the game will involve only your eyes except when you will be required to click with the mouse the "Play", "Quit" or "Replay" buttons. The aim of this research is test the user's ability to keep their focus on a specific object on the screen while different distractors are being displayed. The game will not only test your attention but will also impose you to keep your focus on the target by providing you with a good feedback on your score as well as penalties when the focus is not on the target object.

Why have I been asked to participate?

In this research, no criteria have been set for a target demographic. You have been asked to participate simply due to convenience: the researcher has met you in person.

Do I have to take part?

No. It is up to you to decide whether you would like to take part. If you do decide to take part, you will be given this information sheet and be asked to sign a consent form. If you do decide to take part, you are free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision to not take part will not affect your rights in any way.

What will I be asked to do if I take part?

The application will be a "Car Racing" game and will include three levels where each of them will last 60 seconds. In the first level, two cars will be driving across a path and you will have to keep your eyes on the blue car in order to move the car in a constant speed same as the other car. Each time you look at the blue car, your score will increase 10 times faster compared to if you don't look at it. The main purpose of the game is to not be touched by another car, otherwise the game will end and you will lose. In the second level, three cars will drive across the path and same as the first level, your task is to look at the blue car. In this level, a cloud will be moving around the scene but you should keep your eyes at your car to get more points and not be touched by another car. The last level will involve more cars including a police car and more clouds but the rules are the same. Always keep your focus on your car.

Will my data be identifiable?

Information collected will be anonymised to the greatest extent reasonably possible, without damaging the materials used in the production of this research. Collected data will

not be confidential as it will be shared with my supervisor and possibly used in the production of an academic report.

What will happen to the results?

The results will be summarised, reported and included as part of an assignment to Lancaster University. They may also be submitted for publication in an academic or professional journal, either wholly or partially.

Are there any risks?

There are no risks anticipated with participating in this study. If you experience any distress following participation you are encouraged to inform the researcher and make use of the contacts provided at the end of this information sheet.

Are there any benefits to taking part?

By taking part, you will have the potential to contribute to the advancement of the research process. In addition to this, your participation will make a valuable contribution to the project being conducted by me undertaking my final dissertation project for my MSc qualification.

Further information, concerns or complaints

If you have any questions, you wish to make a complaint or you wish to raise a concern about any aspect of this study and would prefer not to speak to the researcher, you can instead contact:

Hans Gellersen
hwg@comp.lancs.ac.uk
School of Computing and Communications
InfoLab21
Lancaster University
Lancaster
United Kingdom
LA1 4WA

Thank you for your time in reading this information sheet.

PARTICIPANT CONSENT FORM

***A Vision Based User Interface for Monitoring and Training Attention:
User Evaluation on a Car Racing Game Application***

PLEASE TICK

I confirm I have read all attached information for the above study and have had the opportunity to ask questions.

I fully understand all the information provided.

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

I understand that any data collected about myself will be anonymised.

I understand that any information collected in this study could be potentially displayed in academic writing.

I agree to take part in the above study.

OR

I decline to take part in the above study.

MINGHAO XIAO
Name of participant

MINGHAO XIAO
Signature

10/08/2017
Date

Firdo KAZAZI
Name of researcher


Signature

10/08/2017
Date

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I agree to take part in the above study.

OR

I decline to take part in the above study.

MONICA GIRALDI
Name of participant

Monica Giraldi
Signature

10/08/17
Date

Ferdie Kazazi
Name of researcher

Ferdie
Signature

10/08/17
Date

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I agree to take part in the above study.

OR

I decline to take part in the above study.

Samreen Humayun
Name of participant


Signature

10/8/2017
Date

Fjorda Kazazi
Name of researcher


Signature

10/08/2017
Date

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OR

I decline to take part in the above study.

Pallavi Ganesh
Name of participant

P. Pallavi
Signature

10-08-2017
Date

Forde Korazi
Name of researcher

F. Korazi
Signature

10/08/2017
Date

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OR

I decline to take part in the above study.

Marsya
Name of participant

Marsya
Signature

10-08-2017
Date

Firda Kazazi
Name of researcher

Firda
Signature

10/08/2017
Date

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I agree to take part in the above study.

OR

I decline to take part in the above study.

YEWEN LIN
Name of participant

YEWEN LIN
Signature

10/08/2017
Date

Fjorda Kozarzi
Name of researcher


Signature

10/08/2017
Date

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OR

I decline to take part in the above study.

Dera Hechnum
Name of participant


Signature

10/8/2017
Date

Fiorda Kazazi
Name of researcher


Signature

10/08/2017
Date

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OR

I decline to take part in the above study.

Xiaopu Hu
Name of participant


Signature

10/08/2017
Date

Fjardo Kaszi
Name of researcher


Signature

10/08/2017
Date

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OR

I decline to take part in the above study.

MAFAZA
Name of participant


Signature

10/08/2014
Date

Fjordo Kozqzi
Name of researcher


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10/08/2014
Date

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OR


I decline to take part in the above study.

Anna Garmova
Name of participant


Signature

10.08.17
Date

Fiorda Kazazi
Name of researcher


Signature

10/08/2017
Date

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OR

I decline to take part in the above study.

ZAHABIA CHITALWALA
Name of participant

Zahabia
Signature

10/8/17
Date

Fjords Kazazi
Name of researcher

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10/08/2017
Date

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I decline to take part in the above study.

DHEA
Name of participant


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10/08/2017
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Fjords 492921
Name of researcher


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OR

I decline to take part in the above study.

ADOLRAH
Name of participant


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10/08/17
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Name of researcher


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OR

I decline to take part in the above study.

Victoria Okwar
Name of participant


Signature

11/08/2017
Date

Floode Kazazi
Name of researcher


Signature

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OR

I decline to take part in the above study.

KIRSTY LEE
Name of participant


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Foad Kazazi
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OR

I decline to take part in the above study.

Ali Nawaz Ranjha
Name of participant


Signature

11-8-17
Date

Fjords Kozgeli
Name of researcher


Signature

11/8/2014
Date

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I agree to take part in the above study.

OR

I decline to take part in the above study.

Anthony Muzeli
Name of participant


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Fjorods Kazazi
Name of researcher


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I decline to take part in the above study.

Jack Caffelle
Name of participant

Hassene
Signature

11/08/17
Date

Fjodor Kozari
Name of researcher

(Signature)
Signature

11/08/2014
Date

PARTICIPANT CONSENT FORM

***A Vision Based User Interface for Monitoring and Training Attention:
User Evaluation on a Car Racing Game Application***

PLEASE TICK

I confirm I have read all attached information for the above study and have had the opportunity to ask questions.

I fully understand all the information provided.

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

I understand that any data collected about myself will be anonymised.

I understand that any information collected in this study could be potentially displayed in academic writing.

I agree to take part in the above study.

OR

I decline to take part in the above study.

JACOB FULLER
Name of participant


Signature

11/08/17
Date

Fiora Kazazi
Name of researcher


Signature

11/08/2017
Date

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OR

I decline to take part in the above study.

Dimitrios
Name of participant

D. Alexiou
Signature

11/08/2017
Date

Ferdia Kazazi
Name of researcher

[Signature]
Signature

11/08/2017
Date

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OR

I decline to take part in the above study.

Yulca: Giom
Name of participant

铁雨筑
Signature

11/08/2017
Date

Fjarda Kazazi
Name of researcher

Fjarda
Signature

11/03/2014
Date

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OR


I decline to take part in the above study.

Pierre Walltemin
Name of participant


Signature

11/08/2014
Date

Fjordis Kazazi
Name of researcher


Signature

11/08/2014
Date

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I decline to take part in the above study.

ABDUL HAQI
Name of participant

A. Hali
Signature

11/08/17
Date

Foad Kazaizi
Name of researcher

[Signature]
Signature

11/08/17
Date

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I decline to take part in the above study.

Allen Jiang
Name of participant

Allen
Signature

11/08/2017
Date

Fjerdas Kazazi
Name of researcher

Fjerdas
Signature

11/8/2014
Date

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I decline to take part in the above study.

Eric
Name of participant

[Signature]
Signature

11/08/2017
Date

Foad Kozqi
Name of researcher

[Signature]
Signature

11/08/2017
Date

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Josh Wilcox
Name of participant

Abhinav
Signature

11/8/17
Date

Frodo Kazazi
Name of researcher

FEU
Signature

11/08/2017
Date

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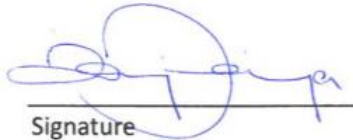
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ANUJ TARAIYA
Name of participant


Signature

11/08/17
Date

Fiora Kazzi
Name of researcher


Signature

11/08/2017
Date

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OR

I decline to take part in the above study.

Raymond
Name of participant

Raymond W
Signature

11/08/2017
Date

Frodo Kozaki
Name of researcher

FKM
Signature

11/08/2017
Date

PARTICIPANT CONSENT FORM

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I decline to take part in the above study.

RITHVIC EMMILA
Name of participant


Signature

11/08/2017
Date

Fjorda Kazazi
Name of researcher


Signature

11/08/2017
Date

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Asim A. Mohiuddin
Name of participant


Signature

11/08/2017
Date

Firda Kazazi
Name of researcher


Signature

11/08/2017
Date