Gaze and accessibility in gaming

Lauri Immonen

Not all computer users are able to use conventional control methods. People with physical disabilities use various alternate control methods. One less used control method is gaze control. Entertainment is an important part of computing also for users with disabilities. Games are an essential part of digital entertainment, but they are rarely designed to be played with alternate control methods.

We investigated the characteristics of game genres to assess the suitability of gaze control of the genres. We thoroughly analyzed interactions in racing games, and designed and implemented gaze controls for Super Tux Kart racing. Users with disabilities may find gaze control fatiguing. To get verification that our implementation can be used by the intended target group, we tested the implementation not only with able-bodied participants, but also with participants with muscular dystrophy.

The participants performed a task of driving around a track using gaze control. We measured their performance and asked their opinions about the control method and how fatiguing they found it. We found the implemented versions of gaze control to be intuitive and easy to learn. The participants were able to play the game successfully. The results suggest that people with disabilities benefit of automating selected controls. Automating seems to equalize the difference between able-bodied players and players with disabilities. It is possible that gamers using gaze control may eventually play games equally with gamers using conventional control methods.

Keywords: Eye tracking, gaze interaction, accessible games, gaze controlled games, users with disabilities

Table of contents

1. Introduction

It is often easy to forget that not all computer users are able to use their machines with as little effort as most of us are. There are many users who cannot use traditional control methods for various reasons. Different kind of disabilities present challenges that the users must overcome one way or another to be able to use a computer.

Using a computer is of high importance in the lives of users with disabilities. Gajos et al. (2008) present a study with participants with motor disabilities. Out of eleven participants all but one report using a computer several hours per day, and all reported relying on a computer for some critical aspect of their lives. The answers prove how important it is to be able to use a computer efficiently and satisfactorily. If people are not able to use traditional control methods, alternate methods must be sought.

Do you rely on being able to use a computer for...	# out of 11
Staying in touch with friends, family or members of your community?	10
School or independent learning?	7
Work?	6
Entertainment?	11
Shopping, banking, paying bills or accessing government services?	10

Table 1. Number of participants with motor impairments depending on a computer for different activities (Gajos et al., 2008).

There are, however, ways to gain accessibility. Users with physical disabilities, who are not able to use a mouse, may use alternate pointing devices, such as head tracking systems, joysticks, or different switch input devices. Switches are on-off devices that can be operated with any body part that is able to produce voluntary movement. The act may be for instance puff, sip, pull, push, or squeeze (Yuan et al., 2011). Users with visual impairments may use screen magnification or screen readers (Bergman and Johnson, 1995).

Games are a substantial part of computer entertainment. Games that are specially designed with alternate control methods in mind are rare. Some of the games can be played with these alternate input devices with no need for special modifications. Sometimes playing a game may be difficult for a user, either due to the features of the physical disability or due to the properties of the game itself.

Gaze control is one of the less used alternate control methods. Gaze control is necessary, if the user is not able to use alternate methods, such as switches, at all or using them would be too slow. It has been used for e.g. writing or browsing the internet.

Perhaps some of the games that are hard to play with other alternate control methods could be converted to be played with gaze control?

We divided games into genres and analysed the characteristics of them to assess the suitability of gaze control for each genre. We selected racing games to be thoroughly investigated. Racing games are fast by nature and require continuous control of the car while maintaining awareness of the track. Controlling a racing game with switches or alternate pointing methods would be difficult. Turning a racing game into a gaze controlled game presents a challenge, but it may provide a viable solution, if conventional control methods cannot be used. To achieve a feasible solution, we analysed interaction when playing Super Tux Kart racing, and implemented gaze controls for the game. In this thesis we will describe the analysis and implementation of turning the game into a gaze controlled game.

It has been reported (Istance et al., 2012) that users with physical disabilities can find gaze-only controlled games fatiguing. Thus, we were also interested to experiment, whether using gaze for only part of the required input actions would make the interaction less tiring. Additionally, Istance et al. (2012) argue that to get verification that the techniques can be used by people with disabilities, gaze interaction techniques evaluated by able-bodied users should be also evaluated by the target group population. They present evidence that even though able-bodied participants were able to complete gaze gestures successfully, participants with cerebral palsy and muscular dystrophy had significant difficulties in completing the gestures. In addition, there was a significant difference between the CP and MD group performance.

Therefore testing interaction techniques with only able-bodied participants does not assure that target group people would be able to use the techniques. However, if there are problems with able-bodied participants, the same problems likely exist with the target group participants. This is why we evaluated the implemented gaze-controlled game both at the University of Tampere, Finland and at Ash Field Academy, Leicester, UK. The user trials at Tampere were able-bodied trials, and to get verification that the implementation can be used by the intended gamers, we did user trials in Leicester with disabled gamers.

We can encapsulate the above into the following research questions:

Question 1. Is it feasible to turn a game that is hard to play with other alternate control methods into a gaze controlled game?

Question 2. Gaze control is tiring to the eyes. Is it possible to reduce the tiredness by automating some of the required controls, or providing a possibility to disengage the eye control during racing?

This thesis has nine chapters. Background for the research is presented in Chapters 2, 3 and 4. Chapter 2 describes special user groups, assistive technology and accessible interfaces. Chapter 3 covers how games can be made accessible. We present strategies to make a game playable by people, who are not able to use conventional control methods. In Chapter 4 we present game genres and the characteristics of the genres. We analyse what kind of effect the characteristics have regarding playing games with gaze.

In the next two chapters we analyse the selected game genre in more detailed level, and describe how the gaze interface for the selected game was designed and implemented. Chapter 5 describes analysis of interaction first on a general level when playing a racing game, and then the interaction in Super Tux Kart racing game. In Chapter 6, we report the planning and designing of the gaze interface, and describe turning Super Tux Kart racing into a gaze controlled game.

Chapters 7 and 8 cover evaluating the implementation. We report testing the implementation with able-bodied gamers in Tampere and disabled gamers in Leicester. In Chapter 9 we present conclusions about the experiment. We report how gamers were able to use a new control method to play a game that commonly would be played with conventional control methods.

2. Special user groups

Physiological conditions, such as motor impairments, may cause involuntary movements or may prevent movement completely. Thus the use of traditional control methods, such as keyboard and mouse, is not physically possible and alternate control methods must be used. Möllenbach (2010) states that *"When researching interaction techniques several parameters affect each other and should be taken into consideration when determining the most appropriate input, selection strategy and visualization. The three basic parameters that can be considered are **task**, **user context** and **feedback**. "*

In regard to *tasks*, Möllenbach (2010) explains that different approaches need to be employed when dealing with search tasks in graphic data representation as compared to search tasks in textual data.

She states that the *user context* determines the necessity for an alternative input device and also what type of device is applicable: *"Physical impairment constitutes a context in which the choice of input device can be a life changing necessity."* Thus not all alternate control methods are suitable for all users; individual needs and abilities define the methods that are suitable for each individual.

System feedback for one determines the type on input that can be used. The feedback can be auditory, visual or tactile. There is also a big difference when working with different size displays (Möllenbach, 2010).

Gajos et al. (2008) present a study, in which a participant talks about an everyday problem a user with disabilities may have: the participant tells that many objects have large clickable areas but it is hard to tell that the areas are indeed clickable. There is a lack of clear visual feedback when the mouse pointer enters such an area. Gajos et al. have noticed that many users are "risk-averse" and the users carefully move the pointer to the centre of the object before clicking it. If they would be sure that a click also elsewhere within the object would be clickable, they perhaps would not do so.

There are numerous ways to assist people with using computers: screen readers and tactile screens for people with visual impairments, visual notifications for people with hearing impairments, alternate control devices such as switches, and joysticks for people with motor impairments. *Gaze tracking* is one aid that can assist people with using computers, since it can be used not only to track where the person is looking, but to use the information to actively control a computer.

2.1. Accessible interfaces

Gaze tracking may be one of the solutions to help people with disabilities to use a computer more efficiently. The condition of the user may not be severe enough for gaze tracking to be needed, or it may simply be too expensive to be used. Modifying the user interface is one way to provide a more usable environment for users with impairments.

User interfaces can be modified to better meet the needs of users with impairments, but the problem is that all users are individuals. A modification which suits someone may not be useful to another user. Therefore a personalized user interface that takes into account the individual abilities of the user would be a solution to tackle that problem.

Gajos et al. (2008) evaluate two systems for automatically generating personalized interfaces adapted to the individual motor capabilities of users who have motor impairments. The first system, SUPPLE, adapts indirectly by asking the user's preferences about the user interface. The other system, SUPPLE++, however adapts automatically, based on a set on motor performance tests.

In the study the users' preferences were found out by an active elicitation process, in which the participants were presented with pairs of user interfaces and asked which they preferred. Furthermore the participants were offered a chance to suggest improvements to the interfaces that were generated for them. The automatic process had pointing, dragging, selection and clicking tasks to build a model of the participants' capabilities. The model was used to create the personalized user interface. (Gajos et al., 2008)

In the experiment by Gajos et al. the users had to carry out common tasks with a graphical user interface, such as clicking buttons or setting values. They present evidence that user interfaces can automatically adapt themselves to users' capabilities. According to the study, the participants performed faster with fewer errors and preferred using the adaptive interfaces compared to a baseline interface. Both systems showed improvement in performance and a reduced amount of errors compared to a baseline interface. The results were especially strong with the ability-based interfaces produced by SUPPLE++: they were found faster, preferable, easiest to use and least tiring in the participants' opinion.

Gajos et al. state that one reason for the difference in performance between users with motor impairments and able-bodied users is that user interfaces are designed with inaccurate assumptions about the users with disabilities. They say that instead of requiring users to adapt themselves to software using separate assistive technologies, software can adapt itself to the capabilities of the users. Hence adaptive interfaces

would be an important tool in removing the difference between different user groups, or at least making it smaller.

2.2. Gaze as means of input in a specially designed interface for users with disabilities

Although people with severe motor disabilities may not be able to use computers efficiently with traditional control methods, they may very well be able to use some control devices, such as a switch or joystick. Added to those, gaze control could make the using of a computer less strenuous and more efficient.

Gaze is not often the only modality people can use, but sometimes it is: some people may even not be able to communicate except by using their eyes. Therefore, gaze interaction is extremely important for those people. ALS (Amyotrophic Lateral Sclerosis) patients eventually lose their ability to move their muscles, but the ability to move their eyes is rarely affected and offers a way to communicate with people by gaze (UC San Diego, 2014).

Ware and Mikaelian (1987) write that *"since humans direct their visual attention by means of eye movement, a device which monitors eye movements should be a natural "pick" device for selecting objects visually present on a monitor"*. They notice that there are, however, a number of issues which need to be addressed in order to compare the functionality of eye trackers to other input devices.

Since gaze is always on, there must be a way to distinguish between meaningful gaze interaction and one-way looking that is meant to get information but not to give commands. When using gaze interaction, the eye serves at the same time as an input modality to the user as well as an output modality from the user to the interface (Bates and Istance, 2002). However, gaze interaction has the potential as a means of interaction, since it is a natural and intuitive way of pointing at the screen.

Pointing and selecting objects allows users to write, facilitating communication, which is perhaps the most important utilisation of gaze interaction. When using gaze to point, there are different possibilities how the selection can be made and there may be issues regarding them. Ware and Mikaelian (1987) talk about choosing the method of selection: should the observer stare at the object or use a button? The size of the object must also be considered so that it can be comfortably selected.

Using a standard interface designed for a mouse and keyboard can be very hard and strenuous to use by gaze. Gaze tracking is not as accurate as moving the cursor with a mouse, which can be positioned to a desired place with the accuracy of a few pixels. The calibration of the tracker may be a bit off. It means that the user has to look a bit

off the target, which is irritating and hard. The natural jittering of the eyes and slow drift movements further limits the practical accuracy of eye tracking (Jacob and Karn, 2003). If the selection is made by *dwell clicking*, i.e. looking at the target longer than a threshold time, selecting small targets successfully may be difficult, perhaps even impossible.

Using gaze as an input modality does not necessarily mean dependency of gaze only: gaze can be used either as the sole input or as an addition to existing input modalities. If gaze is used as the sole input, navigation and selections have to be made by gaze whereas if gaze is used as an addition, it enhances navigation (Möllenbach, 2011). Ware and Mikaelian (1987) mention that dwell clicking also has the permanent barrier of the time that is needed to register the dwell fixation. They suggest that if the user with disabilities has the ability of making a button press, it may be the technique of choice over dwell clicking.

To make gaze interaction easier, there are different techniques that may help. Kumar and Winograd (2007) present applications that use gaze as enhancing pointing and selecting, switching between applications and scrolling the screen while reading. They investigate how gaze-based interaction could be made simple, accurate and fast enough to not only allow users with disabilities to use it, but also to make it worthwhile for able-bodied users to prefer to use gaze-based interaction.

The applications, EyePoint, EyeExpose, and EyeScroll presented by Kumar and Winograd (2007) enhance the use of an interface by adding gaze interaction. *EyePoint* allows the user to look at a target on the screen, and by using a hotkey trigger a desired action, such as click, double click etc. When pressing the hotkey, EyePoint displays a magnified view of the area the user is looking at to improve accuracy in the target selection. According to Kumar and Winograd, the performance of EyePoint is similar to the mouse and keyboard, but with slightly higher error rates. However the users strongly preferred using gaze-based pointing over the mouse.

EyeExposé allows the users to switch between applications by using gaze interaction. The user presses a hotkey, and EyeExposé shows a view of the applications that are open on the desktop. The user then looks at the desired application and releases the hotkey. Switching between twelve open applications was significantly faster than using the common Alt-Tab keyboard command. (Kumar and Winograd, 2007)

EyeScroll provides the user the possibility to automatically and adaptively scroll the screen. The scrolling mode is toggled with a hotkey. When the user's gaze falls beneath a threshold on the screen, it starts to scroll down. When the user's gaze drifts up on the screen and passes an upper threshold, the scrolling stops. The speed of scrolling is

adaptive to the reading style and speed of the user. Kumar and Winograd have found out in pilot tests that the participants found EyeScroll to be natural and easy to use; they especially liked that the speed of scrolling was adaptive.

Bates and Istance (2002) present a "Zoom Screen" facility, where they added a zooming enhancement to improve the performance of an eye mouse. To reduce the eye jitter effect when selecting objects, the objects can be made "sticky" so that the cursor does not drift away from them. Objects can also be made larger to improve selecting them.

Ware and Mikaelian present a study (1987) where they investigate how target size affects the response speed and the error rates for two selection methods: a button press and dwell clicking. They report that increasing the target size from 0.45 degrees of visual angle on the screen to 0.75 degrees increases the speed of selection dramatically. Increasing the size from 0.75 degrees to 1.5 degrees of visual angle furthermore increased the speed of selection, but above 1.5 degrees there appeared to be only minor changes.

They report that for all sizes and all participants the hardware button was faster than the dwell button. Perhaps a little surprisingly they report that for all target sizes all participants made fewer errors using the dwell selection. They provide a possible explanation to their finding: The experiment involved continuous responding that may have caused the participants to synchronize their button presses with the arrival of eye movement to the target, i.e. they were performing two tasks simultaneously: pressing the button and making the eye movement. During dwell clicking, the task of eye movement must be done before the task of making the selection by dwelling. This accounts for the increased speed of selection with the hardware button.

Means of making computers accessible for special user groups was discussed in this chapter. Next, let us look at ideas underpinning accessibility at games.

3. Games and accessibility

People with disabilities want to play games just as able-bodied people do. However, the vast majority of games are not intended for gamers with disabilities, and cannot be played with other means than traditional game controllers.

Playing games should be fun, entertaining and satisfactory. In order to successfully play a game, the player must be able to carry out several tasks. These tasks may be e.g. controlling an avatar, pointing and clicking, triggering control buttons, or reading text on the screen. There are countless of different tasks which may and often do overlap each other. When a game is designed for able-bodied gamers, it is likely that gamers with disabilities will encounter difficulties that make the game hard or impossible to play. These difficulties may include not being able to provide input using conventional input devices, not being able to receive feedback, and not being able to determine in-game responses (Yuan et al., 2011). Some games, even though not designed to be played with gaze, may yet be playable with suitable middleware that allows the game to be played with a gaze tracker.

3.1. How to make a game accessible?

There are several accessibility features in operating systems, designed for people with disabilities. Examples of these features are screen readers and support for keyboard shortcuts. Games rarely have these features, even though there may be some functions that allow some accessibility. Games with dialogue often have subtitles for people with hearing disabilities or it may be possible to slow down the gaming speed. However, these few options are not always offered, they are not applicable to all games and they may help only a small part of players. (Yuan et al., 2011)

User trials are useful for locating accessibility problems in games. However, it can be possible to estimate, without conducting user trials, where problems may arise. We may analyze the requirements of successful gaming, e.g. the pace of the game and the amount of simultaneous controls required, in order to comprehend whether conventional input methods could be replaced using suitable middleware or changing the game somehow. Based on the analysis, we can create a user interface with appropriate input devices. The modified game environment can be tested with players of the intended target group to make sure if the changes are successful.

Is it worth noting, however, that players are individuals with different skills and capabilities, and there is a danger in generalizing individuals too much into generic player groups. The more we know about the players and their capabilities, the better we can estimate their ability to play a game, but we also end up with narrower player

groups. Categorizing people into groups involves always some level of generalizing; it is always case-specific how much generalizing is acceptable.

In any case, in the game there are some kind of tasks that the player has to be able to perform by using some input device. The device transforms physical actions into signals that the game understands. Problems may arise, if the player is not experienced with the input device, or is physically not able to use it efficiently. Experience can be gained with practice, but physical problems may be impossible to get around by practice. The device must be possible to use; if using a device causes physical or mental tiredness, aching or other discomfort, it is of no use to the player.

A common problem regarding gaze control is the *Midas Touch problem*. It means that the users accidentally triggers or activates something that is not wanted by looking at it. The reason for this is that humans naturally look around and observe things with eyes, and the gaze interface erroneously interprets the observation glances as active gaze control actions. The eyes are constantly moving, some eye movements are voluntary and some are involuntary, natural reactive movements. It is difficult to distinguish, which eye movements are meant to control the software and which are not (Istance et al., 2008).

Dwell clicking is a common way to try to overcome the Midas Touch problem. With the time threshold that is required to activate something, the users can avoid accidentally clicking on objects. Another possible solution is to present different modes to the user; they can have a passive look-around-mode (Istance et al., 2008) that the users can select and then observe the game environment in peace without having to worry that they might accidentally do something that they do not want to.

If problems arise with traditional control methods, alternative options must be explored. To find out which alternative methods could be suitable for successful gaming, we must have a look to the characteristics of the game and the tasks that players have to carry out, and work out the input commands in those tasks. The player's experience and skills may affect the decisions; novice players may be satisfied simply being able to play a game whereas more experienced players may want more challenge.

3.2. Strategies to make a game accessible

There are as many physical limitations as there are people with limitations; they may include e.g. weakness of muscles, limited trajectory of hands, inaccuracy when triggering a button timely, involuntary movements. How can we make a game playable when the player is not able to use conventional control methods?

3.2.1. Middleware

Middleware is hardware or software that is being used between the player and a game. *Hardware* middleware can be used to make a game accessible to players who are not able to use traditional control devices. Yuan et al. (2011) list a number of alternative input devices that allow people with disabilities to interact with games. These devices include switches, mouth controllers, one-handed controllers, head trackers, eye trackers, and brain wave controllers.

Different kinds of middleware allow different types of interaction, but have disadvantages, too. An example could be using dwell clicking for gaze interaction. It facilitates using the cursor and clicking for some who are unable to use a mouse, but makes achieving high timing accuracy difficult.

Another example is a switch, which is a useful tool for lots of people even with severe motor disabilities, allowing people to e.g. write text or browse the internet, but it does slow down the interaction. A switch can be used to select a desired option by scanning, which means browsing a selection of options one by one until the desired option is reached. The more there are interaction options, the slower it is to perform the selection.

However, some traditional control methods cannot be replaced by middleware. A traditional game pad supports numerous simultaneous commands, since the player can press several buttons at the same time and thus create numerous button combinations. This would be difficult to handle with middleware. For example a gaze tracker does not allow looking around and dwell clicking objects at the same time, nor does a binary switch support analogue control or simultaneous button presses.

Software middleware is used between a device and an application. It may allow easier configurations and help users to use several devices with one software. An example is the Eye-Tracking Universal Driver implemented by Špakov that provides device-independent data access and control and can be used with several eye trackers (ETU-Driver, 2014).

Snap Clutch is a tool that can be used to switch gaze control quickly on and off. Furthermore it can be used to select additional pre-defined modes that allow the users to e.g. dwell click or click and drag on the screen (Istance et al., 2008). Snap clutch can also be used to make gaze gestures, which can be used to activate commands instead of dwell clicking objects on the screen. This method has been used with the World of Warcraft online role playing game (Istance et al., 2010).

It is important to understand what the users want to do, what they can do, and cannot do, and then find ways to allow the users to use middleware successfully to achieve the

original goal. If it is not possible to achieve, alternative and acceptable goals must be explored.

3.2.2. *Changing the game*

Not only middleware can be used to make a game accessible, but also the game itself may be changed to achieve more accessibility. Some features that are causing problems may be changed or even totally removed from the game. Many commercial games have some options to make the game easier to play, e.g. the gaming speed may be slowed down. Unfortunately the options are usually limited, and cannot be expanded since the games are not open source and cannot be modified.

Open source games can be freely modified. It is possible to add or leave out features, and change the game a lot if needed. For example in a racing game with obstacles on the track, it is possible to completely remove the obstacles or change the game parameters so that hitting the objects does not hinder gameplay.

However, when changes are made to the game, the playing experience changes. Whether it is a positive, negative or a neutral change, depends of the players and the goals they have. For players who have difficulties in controlling the car, it may be a good idea to remove the objects and allow the player to concentrate on driving the track only. When the player gathers experience and wants a more challenging racing experience, the objects can be put on the track to make the game more difficult and thus create more challenge and enjoyment.

In the next chapter we will have a look at games from the gaze control point of view. We will consider what kind of characteristics of a game have an impact on whether the game could be controlled by gaze only. We will also divide games into eight genres and contemplate using gaze control in each of the genres.

4.   Computer games and playing games with gaze

There is a wide selection of computer games at the market. To help getting an idea about what the game is about, games can be divided into different game genres. Some games can be classified more easily than others. Examples of some popular genres are sports games, first person shooters (FPS), racing games or strategy games. However, some games cross genres and are hard to or cannot be classified in one game genre. As an example of genre crossing, the popular football game FIFA 14 from EA Sports has a game mode (FIFA 14 Career mode, 2013) in which the players can manage their teams, playing a strategy game besides a football game.

The game genres have characteristics that are typical for the games in that specific genre. For example in strategy games (Jönsson, 2005) the players have to think, plan and create a strategy for their actions to accomplish a goal in the game. To be able to play an FPS game successfully, planning may be less important than fast and accurate reactions.

4.1.   Parameters which affect using gaze in games

In games there are several different parameters and features that can have either positive or negative effect into how feasible it is to play the game with gaze.

General pace of game

The pace of the game can have a significant effect on the possibility to play the game with gaze. If the pace is fast and there are lots of commands to give, and especially if the players have no chance to try again or correct a false command they have given, it can be very difficult to play the game with gaze.

The most common solution to overcome the Midas Touch problem is dwell clicking (Istance et al., 2008). However, it is slow compared to traditional control methods and it is hard to give more than one command at a time. During dwell clicking the user cannot look away from the object, or the selection is canceled. This makes observing the game environment at the same time very hard, since peripheral vision must be used to make observations.

Gaze control can be physically and mentally tiring to users. They should have the possibility to either pause the game whenever they want to, or at least the game should provide calm moments where the user does not have to be in control and can relax for a moment. It is important to provide users in some way or another a possibility to rest their eyes and take a break.

One solution to overcome the problem of having to give several fast paced commands after another is to create combinations of commands, i.e. macros, and give those as a single command to the game. An example could be a fighting game, in which the player could create a macro that would mean "block", "attack" and "move back". However, if the game had several different possibilities of command combinations, this kind of solution would only lessen but not get rid of the problem. If the game is designed in such a way that the gaming pace in general is fast but there is not a possibility to create customized control combinations, the game is likely not suitable for gaze control.

Timing accuracy of giving commands

Dwell clicking accurately at a certain time is challenging, and while the user is gazing at an object, it is not possible to look anywhere else on the screen; otherwise the intended dwell click is canceled.

Games often require players to click or activate things at a certain time, which makes using gaze difficult. For example, the movements of the game character or shooting at an enemy require precise control. If the player is not successful with timing, the gaming experience can be very frustrating or even impossible. Some challenges with timing can be reduced with automating the timing: the player only has to select the element and the game takes care of giving the command at a correct time. However, this can reduce the playing satisfaction and gaming experience especially with games where timing is an essential part of playing, e.g. with music and beat matching games.

Style of gameplay

Somewhat similar to the general pace of game, the style of gameplay has effects on using gaze. The game can be turn based, which means that the players can think of their actions in more or less peace and then give the command when they are ready, or the game can require constant control.

The more the players have time to look around and plan their actions, the easier it is to use the game with gaze. An example of a turn based game, which would be easy to play with gaze, is a chess game. The player can look at the game board in peace, then activate a mode for making a move, then select the piece to be moved and select the target square. The final selection can even be verified or canceled to avoid errors when selecting the pieces and squares.

Short time limits make the game more challenging for playing with gaze. If there are time limits that still allow enough time for gaze control, they will not affect the game considering gaze playing, but just make the game more challenging. A reasonable

amount of challenge is desired, since players lose easily interest in a game that is too easy to play.

Amount of human players in the game

It is fun to play games online with other human players, which is proved by the success of multiplayer online games. Human players are often unpredictable whereas computer controlled players may lack a proper artificial intelligence and are rather predictable in their actions. It is often more enjoyable to beat other people than to beat a computer game. The knowledge that the player is not the only one playing the game can also cause additional stress to be successful in the game. Losing to other human players can be more annoying than to lose to an artificial opponent.

When playing with other people, there can be fear of standing out among the players in a negative way; there is a fear of not being equal with other players. In a virtual environment, all players regardless of their background should be equal to start with. If the game is harder to some players because of their physical abilities, the game does not provide equal possibilities for all. Since online multiplayer games are hugely popular it is important to try to develop gaming possibilities also for players with disabilities, which would allow a full and equal gaming experience.

Location accuracy

Gaze control is not as accurate as mouse control, and it never will achieve the same accuracy (Hyrskykari et al., 2003). If a game presents several small objects for the player to interact with, it will be challenging to efficiently operate those objects. The risk of accidentally selecting an object that is not wanted will increase. This problem can be corrected with e.g. creating "sticky" objects that make drifting from an object to another less likely. The difficulty with sticky objects is that the user experience may feel less smooth, the users feel that they are not in total control of the interface but the interface is deciding things for them. Hyrskykari et al. (2003) state that if an application is poorly designed, an automatically triggered action very easily becomes irritating.

A rather simple answer to the small objects problem is to make them larger on the screen. This is not always possible, but quite often essential elements for gameplay could be made slightly larger without blocking the playing screen from the players. Even a small difference in the size of objects that are used with gaze can make a big difference. Another solution may be a zooming interface, in which the target area is enlarged and thus it is easier to select the objects.

Amount of same time input

In many games, the players have to do several things at the same time, e.g. in First Person Shooter games, the player is required to move and shoot at the same time. In FPS games, the players often have to reload or change the weapon to be used while moving and shooting, or they have to interact quickly with maps, doors, health pack etc. things in the game.

It is hard to create a gaze-based interface in which the users could interact with several objects at a time. However, gaze could be used along other control methods to make it possible. In addition automating commands, like automatic reload, can lessen the burden the player has. Commands could also be combined; the player could activate one command to execute a pre-defined combination of commands.

Dispersed attention during gameplay

If there are lots of things requiring the players' attention during gameplay, it becomes hard to try to separate active gaze commands and observation glances. The players have to gaze constantly upon things on the screen and perhaps react to them depending on the game event, and at the same time they would have to give commands. Giving a gaze command may take the attention off the gameplay. Dwell clicking focuses the attention on the object to be dwelled on and changing action modes, like in Snap Clutch tool, also takes the eyes off the screen for a little while.

If there are lots of objects of interest on the screen, the players probably have to react to them, which means a lot of interaction and commands to the game. In e.g. shoot'em up games, objects on the screen mean the need to move quickly and accurately, to shoot, and perhaps change weapons and select other commands. However this is not always the case, as with turn based strategy games: there are lots of things to observe but the players can think for their moves in peace and perform the actions whenever they are ready.

4.2.   Game genres

Games can be classified into genres, based on characteristics that are typical for the games in the same genre. Isokoski et al. (2009), Jönsson (2005) and Bardzell (2008) present lists of game genres. The following game genre classification, based on their listings, presents common game genres and features of the genres that could affect suitability for gaze interaction.

4.2.1. Puzzle, board and card games

Puzzle, board and card games are usually slow paced, turn-based games in which the players play a game with their own desired pace. Some examples of these games are solitaire, mine sweeper or a chess game. The players may take their time while considering the move, and then make it when they are ready.

These kinds of games can very well be modified to be played with gaze, since there is no demand for fast paced and time-accurate commands. Dwell clicking could be enough to select the objects in the game, but a truly enjoyable gaming experience would be achieved with a possibility to switch gaze control totally off, i.e. a safe mode. This would allow the player to look at the objects in peace without having to worry about erroneous selections.

4.2.2. Strategy and role-playing games

Strategy and role-playing games are usually slower paced games than e.g. fighting games, but there can be action sequences which require fast and accurate commands for successful playing. An example is the popular multiplayer online game World of Warcraft that has calm locomotion parts but also fighting with other players. Some strategy games are turn-based, which could make a game playable with gaze only. However some modifications would be required, especially if the objects on the screen were small and hard to select with gaze.

For example, locomotion to a place from another can be done efficiently by gaze but fast action and fighting sequences can be troublesome for the players. Istance et al. (2010) have used gaze gestures for locomotion and fighting in the World of Warcraft game. The players found locomotion with gestures while fighting time consuming and effortful, but spell casting was found very effective.

4.2.3. Platform jumping games

Platform jumping games are games in which the players move in a world usually seen from the side of the character. The character is moving through the game world mostly in horizontal way, avoiding obstacles and collecting items. The basic control requirements are moving around and using a button to jump.

Even though the control requirements are less demanding than e.g. in racing or FPS games, controlling a platform jumping game with gaze could be challenging. Often very precise movement of the character is required, in addition to exact timing of jumping. If high location and timing precision cannot be achieved, platform games quickly become frustrating to play, instead of being enjoyable. Isokoski et al. (2009) suggest that even though gaze control would be inefficient, a rewarding gaming experience may be

possible since platform jumping games are usually single player games, and the player's goals are to explore new strategies and beat their own records.

4.2.4. Simulation games

Simulator games try to simulate a real world experience accurately. There are various simulation games on the market, e.g. car, flight, truck or train simulation games. A flight simulator, for example, presents the player an accurate cockpit of an aeroplane to be operated, realistic weather conditions and physical effects during flying and even haptic feedback by a force feedback controller.

Successful simulation playing by gaze would require a fairly slow pace of game and a limited amount of time-accurate controls. A passenger plane simulation with partial flight automation could be playable. On the other hand, the same game in a stressful emergency situation requiring observing the meters and gauges and giving many simultaneous commands, would be impossible to play with gaze. Therefore some simulation games could be at least somewhat playable and rewarding to play, but since the nature of simulation games is to imitate real world environments, high performance and playability is desired and that is hard to achieve with gaze control.

4.2.5. Racing games

In racing games, the players control a vehicle driving around a track or course and try to get to the finish line as soon as possible. The selection of racing games varies a lot; there are all kind of games from demanding simulators to very straight forward arcade style (games with simple controls) games.

Some racing games are purely about being as fast as possible whereas others have more features. In simpler games the player must only steer the car and control speed, but a game may also require e.g. collecting items on the track, shifting gears, changing the point of view, even shooting at other players while driving. The viewpoint is usually from behind or from inside the vehicle. Sometimes it can also be directly from above the car. It is often possible to change the viewpoint, even during racing.

Since racing games require at least steering and adjusting speed at the same time while staying on a defined track, there is lots of controlling going on simultaneously. If other controls, such as selecting gears or changing the point of view, are needed, the requirements for successful and enjoyable gaming get even more demanding.

The player must constantly look at the screen while playing, since there are rarely natural pauses in racing games. The player has to focus from the beginning of the race to the end. There may be a pause option in the game, but using it takes away the immersion of the game. In addition to the controls, there often is useful information on

the screen while racing. There may be a map of the track, information about lap times and the player's position in the race, and about e.g. the selected gear. The amount of dispersed information makes it more difficult to focus just on the track and the vehicle. This presents a challenge for gaze control; how to allow the player to look at the track and possibly other things at the same time while controlling the vehicle successfully? A solution is required in order to reach a satisfying gaming experience.

4.2.6. Action games

The large number of different action games can be divided into categories depending on the viewpoint or the role of the player in the game.

3rd person action games are games where the players can see the character. The player's viewpoint is often behind the character, but the position of the camera can be changed if desired. Usually the game pace is quick and there are complex controls required. The action could be shooting at objects or manipulating them otherwise, casting spells or using objects from the player's inventory. The players have to move constantly to avoid getting hit by enemies or getting into dangerous situations.

Playing these games with gaze only could be difficult, since there are so many commands that have to be given in a quick pace. Playing partially with gaze, e.g. aiming by gaze but otherwise controlling the game with a traditional controller could work quite well.

First person shooter games are games, in which the player sees the game world from the game character's point of view. The view is from the character's eyes. The players move freely in an area where there are enemies and other targets to find and to shoot at. Many FPS games have a single player campaign and an online multiplayer mode that allows several players to play, usually against each other, simultaneously via internet.

In FPS games, aiming with gaze could be possible since the target needs usually to be in the centre of the screen to be shot at. If the target is at the edge of the screen, just by looking at it the character would turn towards the target until the target is in the centre of the screen.

Isokoski and Martin (2006) have experimented with a FPS game using gaze for aiming. They used mouse and keyboard for moving, adjusting the camera angle and shooting, and gaze tracking for aiming the weapon. The empirical study revealed no improvement in player performance, but they did find the results promising. They believe it is possible to design a gaze based setup that allows players with disabilities to have a satisfying gaming experience.

Shoot'em up games require the players to shoot at targets and move the player's character or vehicle sideways and possibly up or down at the same time. The screen normally scrolls automatically downwards. The goals of the game are to destroy as many enemies or objects as possible and to avoid getting hit from hostile hits.

Shoot'em up games would be hard to play with gaze, because of the fast paced nature of the games. The players would have to detect enemies, shoot at them, detect possible attacks and move the character at the same time. There are too many elements in parallel to be controlled by gaze only. At least some of the required actions would have to be automated on behalf of the player, or controlled with another modality. Isokoski et al. (2009) suggest that with changes to the control requirements rewarding eye control could be achieved, even though it would change the nature of the game. They present an auto-fire function as an example of changing the game.

Fighting games require the players to battle against another player or a computer controlled character. The playing arena usually is two-dimensional and the player must perform combinations of movements and hits to successfully fight the enemy. The combinations are usually button presses and direction movements at the same time. Accurate timing is needed for both attacking and blocking attacks in the game. Since fighting games require several commands simultaneously or in quick sequences, gaze control can be very challenging to implement. However, if the game could be changed to a tactical turn-based game, where the players would in turns select combinations of movement, gaze control could be achieved by e.g. gaze gestures. This on the other hand would change the nature of the game more towards a strategy game.

A shared characteristic for these action games is that they all are relatively fast paced game genres requiring lots of simultaneous actions. There is lots of movement and controls used at the same time, which makes it hard to create a gaze interface for games in these genres. Removing elements of the gameplay could make gaze control possible, but that would change the nature of the game. Full gaze control for these game genres may prove impossible to implement, but an enjoyable gaming experience may be achieved by automating some functions.

4.2.7. Sports games

Sports games are popular games. There are several successful sports game series on the market, like EA Sports FIFA football (FIFA Soccer, 2014) and NHL ice hockey (NHL Hockey, 2014) games. In the team sport games, the player usually controls either one specific character, e.g. a defence player, in the team, or always the character that currently is active, i.e. is in the control of the ball or the puck.

Sports games are fast paced requiring lots of looking around and observing the other characters on the screen, so it is hard to imagine that a sports game could be successfully played by gaze only. A problem with team sports games is that the players must observe what is happening on the screen and move and react according to that information.

If there was some automation of the controls and the player could focus on for example just moving the character and giving some simple commands, a simpler sports game could be enjoyable enough to be played by gaze. A tennis game, for example, could be simplified to the point where the player would just move the player to a certain place on the playing field, and hitting would be automated. However this kind of simplifying may take away the fun of playing because it would be too easy to play. The game would be eventually reduced to be a nice looking paddle game. Dorr et al. (2007) present results of a gaze controlled pong game; gaze players beat players with mouse by far.

4.2.8. Rhythm action games

The idea of rhythm action games is to successfully "play" the controller, which usually is a plastic guitar or drums, and press buttons on the controller to hit matching scrolling notes on the screen accurately in rhythm. An example is the Guitar Hero series with several games. The goal is to play songs as well as possible and collect points. The points can be used to buy accessories for the game character, e.g. a new guitar, or to unlock new songs, bonus videos, or harder levels.

It is difficult to create a gaze based game where the player would hit a note at an exact time. The gaze tracking location accuracy would not be a major problem, since the notes could either be large enough to hit or made "sticky" to help selecting the correct note, but accurate timing is very difficult to achieve with gaze tracking.

Vickers, Istance and Smalley (2010) have designed a guitar rhythm game, in which the note is played automatically, but the player selects the note to be played with gaze. However simultaneous selection of two or more notes was not possible, nor was playing notes that were very close together. The gaming performance was better than with keyboard, but an essential element, the rhythm, was automated. Playing the game was still fun, even though it was not like playing a guitar simulator. Vickers et al. say that it is possible for gamers with severe physical disabilities to play rhythm games, but there still is work to be done on improving the interaction technique.

4.2.9. Exercise games

Exercise games are games that require the players to do physical movements to successfully play the game. Modern technology has allowed game developers to utilize

built-in acceleration sensors to create games, where the movements of the game controller can be tracked and used to control the movements of the game characters.

Microsoft Kinect for Xbox 360 does not require the players to have a controller at all. All that is needed is the player to be situated in front of the screen and the tracking device of the game console. The device can track the player's body, their hands and legs (Kinect for Windows, 2014), and use that information to display the player's movements on the screen. The goal is to play a game imitating the movements that a person would do when playing a similar game in the real world.

Some exercise games are meant to improve the player's physical health. The users can set up an exercise program and follow it during the coming weeks and months. It can be debatable if this kind of exercise programs are games at all since there are not necessary lots of game like elements such as collecting scores or beating the game. On the other hand, there are clear goals that the players try to achieve: they try to improve their health and gain stamina and successfully complete the personal training programs. This point of view allows exercise programs to be called games.

Exercise programs cannot be modified to be played by gaze only, since the essential element of these games is the physical participation of the player.

After this general analysis of games we chose to take racing games under more detailed investigation. Is it possible to modify a racing game so that it could be played by gaze only, or at least use gaze in a significant role when controlling the game? In the next chapter we first analyse interaction when playing a racing game, and describe more closely one specific racing game.

5. Racing games and gaze based gaming

Racing games and gaze interaction present a challenge, since there usually is constant action on the screen and the player needs to continuously control the racing vehicle. While racing, there may be other vehicles, obstacles, collectible items and such on the track. In addition to that, there may be lots of information about the race, which the player should pay attention to. This presents a challenge to the planning and designing of the gaze interface — how to maintain attention and focus on the game while controlling the car? Is successful racing possible by gaze control?

We have previous experience about gaze based gaming from the multiplayer online game World of Warcraft, where gaze gestures were used for locomotion tasks (Istance et al., 2010). While locomotion in a virtual world environment and racing on a track are basically similar tasks as both include moving along a somewhat pre-defined track, racing games do differ from an online virtual world. There is usually a strictly defined track, on which the player must stay on, or the racing car will either crash or slow down speed. A virtual world is more forgiving, there rarely is a narrow path and usually the players can stop and look at the environment to plan their next moving direction. There often is also either a time limit or timekeeping in a racing game, which do not exist when running around in a virtual world.

5.1. Analysis of playing a racing game

People play computer and video games for different reasons. Sometimes games are used for educational purposes, but the most common reason for playing a game is entertainment. The lack of suitable games for people with disabilities is a situation that should be corrected, as people with disabilities want to play games and have enjoy gaming just as able-bodied gamers do. In order to plan a gaze interface for the racing game, an analysis of the game should be done; what happens when people play it and what kind of things are there that could affect playing with gaze?

In the next sections we will analyse interaction in racing game playing first on a general level, and then more closely in the racing game Super Tux Kart racing, which we will instrument for gaze interaction.

5.2. Game interaction cycle

Yuan et al. present (2011) a game interaction model that has three stages in it:

1. Receive stimuli
2. Determine response
3. Provide input

The interaction model describes the gaming process from the beginning of a game until the end of it. The players receive stimuli, react to it by determining their response, and provide input to the game. This cycle goes on as long as they are playing the game. The model is simplified, since there can be several cycles going on at the same time with different stimuli, such as visual and audio at the same time. It is also possible that new stimuli cause the response to change before the player has executed a previous response. The pace of the game has an effect on the cycle; the slower the game, the steadier the cycle since the players have more time to execute their responses without receiving new, overriding stimuli.

The disability of a player may cause problems in any stage of the model. They may have difficulties in receiving stimuli from the game, e.g. visually impaired people cannot see what happens on the screen or people with hearing problems cannot receive auditory output from the game. Determining a response to an observed stimuli can be challenging, e.g. with people with cognitive disabilities. It is also possible to have difficulties in the third stage of the model, since for example people with motor disabilities may have problems using regular game controllers.

The interaction model provided by Yuan et al. (2011) describes the gameplay process on a quite high and general level. To better understand the parts where players may have problems when playing a racing game, and to understand the reasons for those problems, we present a more detailed model of gameplay. The three stages presented by Yuan et al. have been expanded to cover the playing of a racing game more thoroughly considering the playing process.
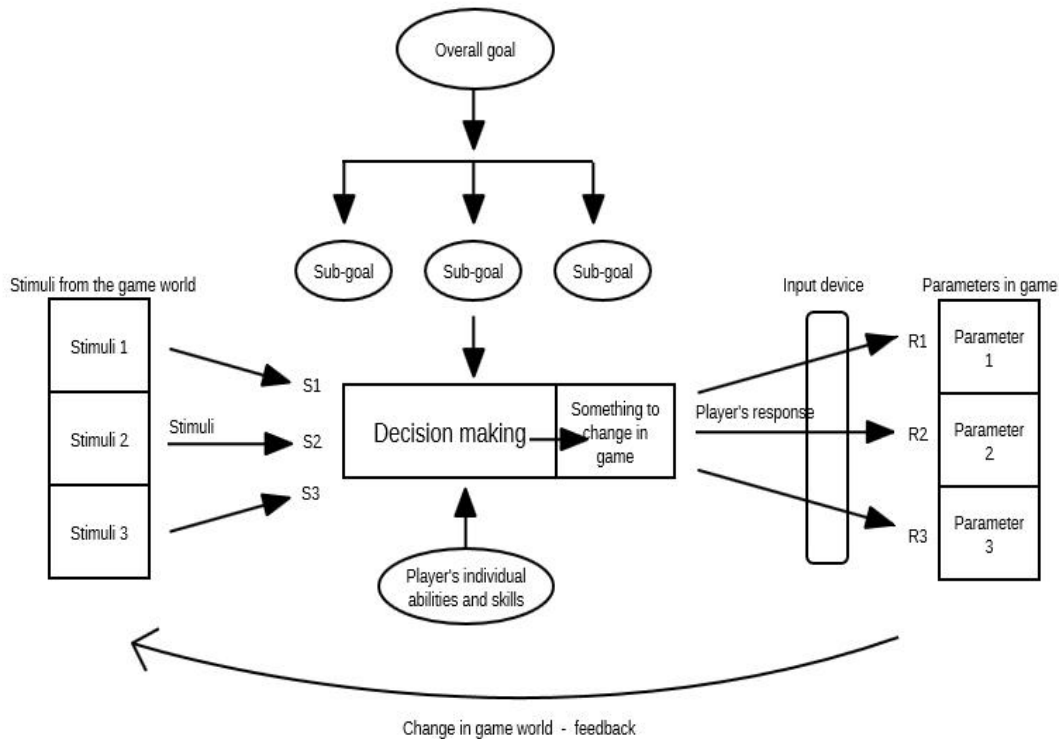
Figure 1. Interaction model of a racing game.

5.2.1. Goals and sub-goals

The players have goals when playing a game. The goal can be a vague one, "to have fun" which in turn can be specified into sub-goals, like "win a race against competitors".

The goals can be defined by the game or by the player. The game provides overall goals for the player, but often the players define new goals for themselves. When playing a game, the player wants to do things, like "move an avatar from a place to another" and has to figure out what to do to get it done. Thus, the overall goal consists of several sub-goals, each of which brings the player closer to achieving the overall goal.

In a racing game, the overall goal often is "to race as fast as possible", i.e. "win the race". There can be other goals too, like setting up a new lap record, collecting points or money to get upgrades or new cars. Whatever the overall goal may be, the players aim to reach it by completing several sub-goals, such as "overtake the competitor" or "collect a turbo boost" to ultimately "win the race". The goals can also change or cease to exist, if the game environment changes or the player decides to pursue a different goal in the game.

5.2.2. Decision making

In order to reach a goal or sub-goal, the players have to make decisions regarding the gameplay. A decision is based on stimuli received from the game. It usually is visual or

auditory; something the player sees or hears when playing the game. The objective of decision making is to change something in the game world and thus reach the desired goal.

Depending on the game genre, the decisions can be of different nature. The player makes decisions about locomotion of an avatar or vehicle, firing a weapon or communicating with other game characters. The decisions have an effect on gameplay. Some effects are instant like when the player hits an enemy but some decisions can have an effect later on in the game; for example the game plot can change based on the player's previous decision in the game.

There are different factors affecting the decision making. Experience with the game is a factor, since novices may be insecure or simply lack knowledge of the consequences of the decisions they are about to make. Experts may make decisions very fast, based on previous gameplay knowledge.

Players gather experience not only with games, but also game genres. If players have lots of experience with a certain game genre, it is likely that they perform rather well with a new game of the same genre. However, even an experienced player may encounter difficulties, if the game differs from the expectations the players has. Also individual abilities may have an effect on the decision making; e.g. players with limited cognitive skills have difficulties with their ability to determine an in-game response based on the feedback provided by the game (Yuan et al., 2011) .

5.2.3. Input devices

An input device is hardware that is used to receive input from the players and translate it into electronic messages, which are interpreted by the game software (Zagal et al., 2007). Common input devices in gaming are mouse and keyboard, and different joysticks and other game controllers. People with disabilities may use special input devices designed for their needs, if they are not able to use conventional input devices or using them would cause discomfort. Special input devices include for example switches, gaze trackers and voice recognizers.

In racing games, the most common input devices are either keyboard, game controllers and steering wheels. The wheels may also have pedals and even a gear stick attached to them. Sometimes also a mouse can be used to control the vehicle.

5.2.4. Parameters

In order to reach the desired goals, the players make decisions and use input devices to response, thus affecting the game world by adjusting game parameters. These parameters are elements that the players can manipulate in the game, such as speed and

direction of movement of a vehicle or an avatar attacking an enemy by sword. The adjustable amount of parameters vary greatly by game and game genre; at the simplest the player can manipulate only a few parameters but in some games there are tens or hundreds of parameters to manipulate.

For example in racing games, the most common parameters to be adjusted are the velocity and the direction of movement of the car. Other parameters in racing games are e.g. turbo boosts which give more speed for a little while, and perhaps other extra items to be used.

5.2.5. Feedback and stimuli

Whatever changes the players do to the gameworld by adjusting game parameters, they receive feedback of the changes by noticing changes in the gameworld. They interpret these changes and decide whether they are desired, and make new decisions based on the interpretation of the previous changes. In e.g. FPS games, the players may see that they hit the enemy and decide to pursue a new goal, and they may hear noise from outside the screen and decide to turn that way to find out, what is causing the noise.

The feedback is usually presented to the players visually on the display and by sound through speakers. There may also be other channels of communication; e.g. force feedback by haptic devices. Especially with racing and flying simulators, force feedback controllers are common input devices that are also capable to deliver physical feedback to the players.

5.2.6. Errors in racing games

Each stage in the decision cycle has possibilities of players making errors while playing a game. The errors may be small and easily corrected, but they could also be serious and hinder or even prevent the player from reaching the goal she is pursuing. Errors relating to playing experience and skills are easier to sort out, but errors arising from disabilities may require alternative control methods to overcome.

Errors with goals and sub-goals. If players are not familiar with a game genre or a specific game, if is possible that they make errors when setting goals for playing, because they do not know what the purpose of the game is. Even if the main goal is clear, there may be individual features in the game, which are not known for the players beforehand. When they get familiar with the game, gain skills and e.g. complete a gameplay tutorial, they understand what the game is about and are able to set suitable goals for playing.

Racing games are usually rather similar between each other, so the overall goal is clear if the racing genre is familiar. However, some features may present problems with sub-

goals, such as gathering items on track. Arcade racing games often display items on the track for the player to collect. The purpose of the items may not be clear and the player has either to read instructions to find out the meaning of the items, or figure it out by trial and error.

Errors with decision making. A common area of mistakes is decision making. Players make constantly wrong or poor decisions when playing. This, on the other hand, is a factor in making gaming enjoyable and exciting. An enjoyable game must present a suitable amount of challenge to the players; it should not be too difficult but not too easy either.

As players gather more experience and skills, they make less wrong decisions. The players learn the consequences of different decisions and are able to quickly decide their actions in gameplay. However, if players have high experience of games similar as the one played, they may make lots of wrong decisions in the beginning while assuming that things work equally in the game being played.

Players with cognitive disabilities may have difficulties in making decisions in the game. If this is the case, the game should be simplified, slowed down, hints given or some another method provided to assist the player to make right decisions.

Errors with input devices and parameters. Players adjust different game parameters in order to cause desired changes in the game world. Many racing games require precise control to be played successfully. "Precise control" consists of accurate timing and accurate spatial resolution of control. Accurate timing requires that the player is able to trigger commands with the input device fast enough to achieve the desired change in game environment. The adjusting of steering, speed and other commands such as activating speed boosts have to happen fast enough, before it is too late for that specific command in gameplay. The spatial resolution required for successful gaming varies between racing games; racing simulations require high spatial resolution whereas arcade style racing games are more forgiving. Arcade racing games often have binary controls; the input is either on or off, whereas the spatial resolution of controls in simulation games aims to be as realistic as possible.

People with disabilities may not be able to use normal mice or keyboards, and much less state-of-the-art steering wheel and pedal combinations that require a high level of accuracy to be used. This may give rise to errors with either accuracy or spatial resolution. For example limits with control of hands or fingers cause great problems when trying to use mouse and keyboard accurately. However it may be possible to create alternative ways to give commands to the game, by allocating some input to different input devices.

5.3. Super Tux Kart Racing game

To be able to convert a racing game into a gaze controlled game, we wanted to find an open source racing game, in case modifications to the game itself were needed. A suitable racing game, Super Tux Kart Racing (later referred to STK), was found. It is a versatile game with lots of game modes and options, and it seemed feasible to be used with gaze control. The game is suitable for children, which was important; the racing avatars are e.g. animals and the game environment is colourful and cartoon-like.

5.3.1. Gameplay in Super Tux Kart Racing

There are several game modes in the game, such as racing with several other players or racing alone. One game mode was chosen to be considered thoroughly. The game mode was time trial, where the player's goal is to drive a lap as fast as possible. This mode was chosen, since new players often want to get familiar with the game before starting to play more challenging modes against other racers. Some challenge in gaming is still desired, so a time trial is a good way for the players to get to know the game and to monitor and improve their performance. There can also be other racers on the track in the time trial mode, if so selected.

The gamers have to decide what they want to do in order to fulfill the overall goal. The goal is to "drive a lap as fast as possible". The first task would be staying on the track in general. Besides this task, the players want to avoid or collect items on the track and possibly use them. If there are other racers on the track, the players may want to overtake them or follow their line on the track to learn a fast driving line.

Figure 2. Screenshot of Super Tux Kart Racing

There are several items on the screen providing information about the race to the players, but they may also draw the player's attention while racing. At the bottom of the screen there are a map of the circuit and a speedometer. At the right, there is a nitro boost meter that fills as the player collects nitro boost bottles while racing.

At the top left corner, there are icons of the participating racers. In case of single player race, there is only the icon of the player. In case of multi-player race, the order of icons tells the racing order. At the top of the screen, the red arrows tell the amount of pre-set speed boosts the player has left. At the top right corner, there is information about the lap time, position in race and the amount of laps to be driven.

5.3.2. *Vocabulary in Super Tux Kart Racing*

Throttle. Throttle is used to maintain speed. In STK Racing throttle is used by keeping the throttle button (arrow up by default) pressed. When throttle is activated and the car starts to move, there is a brief acceleration process, until the car has reached its maximum speed. The acceleration time can be ignored; simplified the speed is immediately on full speed.

Idle. Idle means a state of the car when neither throttle or braking is activated. No speed related control is applied to the car. If the car had speed before idling, the car slows down slowly until it stops completely. Idling can be used as a means of reducing speed, in cases where only minor reducing of speed is required.

Brake. Braking means actively reducing the speed of the car. In STK racing braking is activated by pressing down a brake button or key (arrow down by default). When braking is activated, the car will quickly slow down and then stop completely. Braking can be used to reduce speed more efficiently than by idling. Since the effect of braking is strong and slows down the car quickly, precise slowing down requires a high timing precision of pressing the control for a short amount of time.

Reverse. The same control as for braking is also used for reversing the car. If the car is stopped, and the brake control is still activated, the car will start reversing and will continue reversing until the brake control is released. As with the throttle, the reverse acceleration lasts for a very short time until the reverse speed reaches the top reverse speed.

Steering. The car can be steered to either left or right by pressing a steering button or key (arrows left and right by default). In this setup, the steering is binary, i.e. the steering is either on or off. Since there is no analogue steering, which would allow more precise steering, the steering control must be pressed until the car has turned enough, which requires a moderate level of timing accuracy. Small steering movements must be done by very short presses of the steering controls.

Speed boost. A speed boost brings temporarily extra speed to the car, increasing the top speed of the car for a moment. When the effect of the boost wears off, the maximum speed returns to the original speed. There are three kind of speed boosts in STK racing: set boost, nitro boost and area boost. The set boost and nitro boost can be triggered wherever on the track with a boost control, the area boost is activated by steering over a specific area on the track. The set and nitro boosts are activated by a key or button press. The difference between them is that the set boost lasts a set time, whereas the nitro boost lasts as long as there is nitro in the nitro meter. The amount of the set boosts is limited to a set number, and cannot be collected during racing, unlike the nitro boost.

Nitro. There are nitro bottles on the track, which raise the nitro meter bar on the screen when driven over. By collecting bottles, the player gathers nitro speed boost that raises the speed of the car when activated with a speed boost control. The nitro runs out when used, but can be collected more during racing.

Bananas. On the track there are bananas that slow down the car if driven over. There are three kind of slowing effects; a parachute, an anchor and a bomb. The parachute and anchor attach themselves to the car for a brief period slowing down the car. The bomb also attaches itself to the car, and explodes in a while sending the car up in the air and down again on the track.

A summary of the different concepts of STK racing is presented in table 2.

Concept	Explanation	Control / Trigger
Throttle	Maintain the speed of the car	Press throttle button or key
Idle	Slow down slowly, stop braking or stay still	Release throttle or brake button or key
Brake	Slow down speed quickly	Press brake button or key briefly
Reverse	Reverse the car	Keep brake button or key pressed
Steer left or right	Turn the car to desired direction	Keep steering button pressed until desired degree of turning is reached
Speed boost – set boost	Add extra speed to car for a set time	Press speed boost button or key
Speed boost – nitro boost	Add extra speed to car for a desired time	Press speed boost button or key for a desired time or until nitro meter runs out
Speed boost – area boost	Add extra speed to car for a set time	Drive over a specific area on the track
Nitro	Collect nitro, which can be used for a speed boost	Drive over a nitro bottle on the track
Banana	Slow down the car for a brief time	Drive over a banana on the track

Table 2. Summary of concepts in Super Tux Kart racing.

5.3.3. Tasks in Super Tux Kart Racing

Task: Staying on the track. Staying on the track requires the players to follow the direction where the track is going, be aware of the car's position on the track and to control the speed and direction of the racing car. If the player steers out of the track, the speed of the car reduces significantly and the goal, to be as fast as possible, cannot be reached.

On straight parts of the track, the players need to use the throttle or the brake, but they do not need to steer. When approaching a corner and while cornering, the position of the car needs to be adjusted and steering is required. Along with steering, the players may need to adjust the speed of the car to avoid drifting out of the track.

Steering and speed adjusting requires the use of four buttons; throttle, break, steer left and steer right. Of those buttons one or two are used at the same time. The rate of using the buttons varies, on a long straight the players do not have to do anything but keep the throttle button pressed. During corners more action may be required.

Sub-task: Collect or avoid collecting items on track. While completing the task of staying on the track, the players may want to collect or avoid items on the track. When collecting items, the speed must be adjusted and steering is required. The decision cycle

rolls fast, the player must quickly make a decision of the direction of the vehicle while completing the task.

Sub-task: Use a speed boost. The players have the option of using speed boosts while driving. The two speed boosts for the player to use whenever they want to are the set boost and nitro boost. Nitro boosts can be collected during racing, and the nitro meter on the screen tells the player the amount of nitro boost available. The players must pay attention on the meter during the race, if they want to use the nitro boost. The amount of set boost is shown on the top of the screen. The area boost is activated by an area on the track, which speeds up the car for a while when driven over.

The nitro and set boosts are used by pressing a button or key. This means that the player has to press a second or even third button or key at the same time, depending on the speed and steering situation at that time.

Sub-task: Overtake an opponent. In case there are opponents on the track, the player has to pay attention to them while racing. This presents a challenge, since the opponents are not stationary as the items are, but are moving around the track at a fast pace. If the player is faster than an opponent, he must overtake. Like collecting an item, overtaking requires quick decisions about the speed and direction of the car, but perhaps also the decision of using a speed boost at the same time.

Since the opponent is driving on the track, the overtaking is not a simple decision like "steer left". A change of direction in the track causes the opponent to change his speed accordingly, and forces the player to very quickly adjust speed and direction to either follow the opponent and wait for a better overtaking chance, or to make the decision of overtaking.

The overtaking process requires fast using of speed, direction and possibly speed boost buttons. It is possible to hit the opponent's car, which has an effect on the speed and direction of the player's car.

Next we will describe how STK racing game was turned to a gaze controlled game.

6.   Planning and designing a gaze interface

Our goal was to implement a gaze-assisted interface for Super Tux Kart racing game that would be suitable for children with physical disabilities. It could be that the expectations for a satisfactory gaming experience are lesser, since players with disabilities have not been used to a wide range of different games. It is possible that some players have not been able to play any games at all, so even a mere change to play a simple game with little goals could deliver a highly satisfying gaming experience.

The interface should be intuitive and easy to learn, and able to provide a satisfying gaming experience. Even though the participants in the gaze point recording were able-bodied, we decided that the data could be used to help planning an interface for gamers with disabilities.

6.1.   The game and middleware

Snap Clutch was selected as the gaze tracking software. It has proved to be useful with locomotion tasks in environments like Second Life (Istance et al., 2008). Therefore it could also be used with a racing game, since there are similarities with the goals of a racing game and locomotion in virtual environments: "stay on the road while driving" and "guide the avatar on a path from a location to another".

Snap Clutch would have made possible using e.g. different gaze modes which could have been selected by gaze gestures, but eventually it was used just to track the gaze. To convert the gaze into commands to the game, a software called Alt Controller was chosen. It allows defining areas on the screen and launching keyboard and game controller commands when the player looks at the defined areas (Alt Controller, 2013). STK racing was decided to be kept as it was, with no modifications.

6.2.   Planning a gaze interface

Since eyes will be used not only to control the game, but also for observing the game environment, we should know where players look at when playing the STK racing game. In order to estimate where the players look, a racing session with STK racing was recorded and analyzed. Two players raced three rounds on two different tracks and the gaze point data was recorded. The video material was analyzed to distinguish where the gaze is focused during normal gameplay with keyboard. Even if playing with keyboard is not the same as playing with gaze control, it gives good indication of the player's points of interest when racing and therefore it will provide a starting point for creating a gaze control interface.

To analyze the falling of gaze points while playing, we chose a simple set-up in which the player drives the car around a track as fast as possible, but without competing with

other players. There were collectable objects on the road, but the purpose was not to collect or avoid the objects.

The different elements that we were looking into are presented in table 3.

Element of gameplay	Area of interest
The track: straights and corners	Location of gaze points
The track: tight corners and gentle corners	Difference between tight and gentle corners
Speedometer	Amount of gaze points
Map of the track	Amount of gaze points
Time and position information	Amount of gaze points
Objects on the track	Amount of gaze points

Table 3. Elements under observation during keyboard gameplay

In order to create a gaze control interface, we wanted to know where the players would be normally looking at when playing the game with traditional input methods. This allows to avoid conflict in using those screen areas for unsuitable controls.

To avoid the Midas Touch problem, it is important to estimate where the players will probably look during gameplay. In a racing game this is particularly important, since constant control of the vehicle is required. If other vehicles and objects on the track or screen draw much attention to them, they will cause problems during gaze racing if control of the car is disturbed.

Regarding the track, we assumed that on a straight part of the track the player would be looking in the horizon to find out when the next corner will come. This would make the upper center of the screen a suitable place for the area which controls the throttle. We had to, though, analyze the different parts of the track to find out if we can define where the players are looking in different parts of the track. If we could find those locations, we could use that information to decide the parts of the screen that control the throttle, brake and turning left or right.

6.2.1. Data recording

Two tracks were raced on, and gaze points were recorded while the participants played the game. The other track was simple, while the other was harder with more turns and less straight parts (figure 3). Two participants played the game with keyboard commands. The other participant was a novice with racing games while the other was experienced with racing games. A novice and an expert player were chosen in case there would be differences in the falling of gaze points between the players. Both participants completed a training session so they were comfortable with the game. After training, they raced both tracks for three consecutive laps.
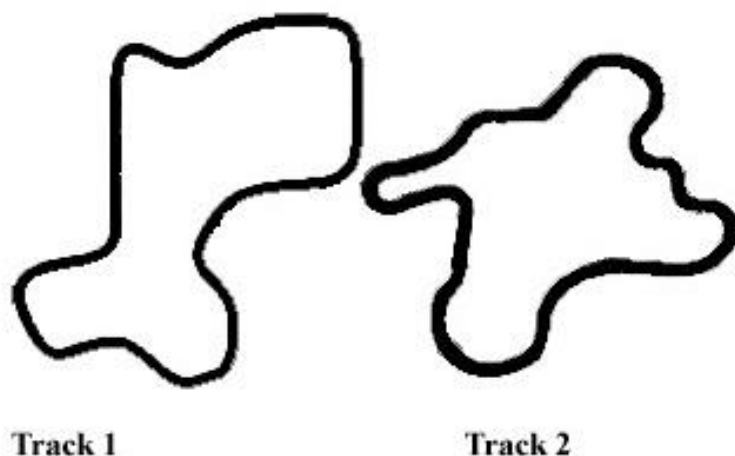
Figure 3. The tracks.

6.2.2.   Results of gaze point tracking

Both tracks were classified into different parts; straights and turns. The turns were classified into being either sharp of gentle. Both tracks were raced in a clockwise direction. Heat maps of the gaze points were created, with a screen capture of the game as background to present the falling of gaze points during different parts of the tracks (figure 4).

The heat maps demonstrate a strong similarity between the two players' eye behavior. However, there were some differences, too. The expert player kept his eyes focused on the horizon and not much elsewhere. The red color in the heat map indicates this. The expert glanced also more to the map of the track, while the novice player looked at the map just a little bit. This could be because the expert player wanted to know beforehand where the track was going to turn and plan the racing, while the novice player focused more on the track and just steered as the track was turning.

Both players paid little or no attention to the speedometer. This was likely because of the nature of the game, STK racing is an arcade style game and most parts can be raced with full or almost full speed. The car engine noise audio may be sufficient in this game to indicate the speed to the player. If no audio is available, the players learn quickly by trial and error if they have to reduce speed in certain parts of the track. Therefore no speedometer is needed even in tight corners.

Regarding the track, both players had similar patterns of gaze points. On straight parts, most of the gaze points fell on a rather small area above the racing car, straight ahead, on the horizon. The heat maps presented in figure 4 show that the experienced player was looking ahead to the coming corner, with gaze points also on the following corner

side even when driving on the straight. However, the points were still very close to the center.

Figure 4. Heat maps – expert on the left and novice player the right. Gaze points shown were recorded on a straight section of the track.

The tight concentration of gaze points created a challenge to the planning of the gaze control interface, since the player's focus keeps in the middle parts of the screen very often. The gaze points are concentrated on a relatively small area in the center of the screen, and the majority of the screen is looked at not at all during playing.

6.2.3. *Controls needed during gameplay*

The very basic controls that are required to play the game are controls for throttle, brake, and steering left and right. For gaze only control one solution would be to map areas on the screen with the required controls, as e.g. has been done with locomotion tasks in virtual environments (Istance et al., 2008).

For more versatile gameplay, some other controls are required. These controls are of the nature of triggering events or actions and require either a simple key press or a brief holding of a key pressed. An example is the speed boost that gives more speed, and can be kept on for as long as the boost is available. The time for this is short, maximum of a few seconds.

6.2.4. *Timing and accuracy of controls and suitability for gaze control*

STK racing is a rather fast paced game and corners come quickly when racing. Steering left and right requires at least moderately accurate timing for successful gaming without too many errors.

There are different kinds of tracks and the ones with more corners are more challenging, since the players have to adjust the direction often. In addition, on the track

there are objects that affect racing and present a steering challenge for the player. The players have to decide with each object whether to drive over it or avoid it.

6.2.5. *Gaze gestures*

Gaze gestures were considered as one gaze control method, but were discarded. Gestures have been successfully used in World of Warcraft for casting spells and other explicit commands, but were considered harder to control locomotion (Istance et al., 2010). It seemed likely that gestures would not work well with a racing game that requires continuous control of the car.

6.3. Deciding the gaze interface layout style

Mapping dedicated areas of the screen for controlling the game was selected as a basis for designing the gaze interface. The player could activate controls by just looking at an area on the screen. The possibility of showing the areas while playing was considered; a screen overlay could help the player to recognize the gaze areas, and the game would still be visible through the partially transparent overlay.

The idea of the transparent overlay was nonetheless dropped early in the design process. Preliminary pilot testing revealed that the overlay was found disturbing. While it did help with learning and recognizing the gaze areas, the pilot testers reported that it was distracting and took attention away from the game into the overlay itself. The pilot testers focused not on playing the game, but on keeping gaze on the gaze areas, and immersion and enjoyment of the game was reduced.

6.4. Optional gaze control methods

Although there are not too many controls in the Super Tux Kart racing game, there are lots of different possibilities for controls with gaze only or gaze and some other modality combined together. The different control possibilities have strengths and weaknesses, and those may vary regarding the player's personal abilities.

There are different methods for allocating controls for modalities. There cannot be too many gaze areas, since learning them would be too hard, resulting to erroneous commands. The aim was to design the gaze areas so that the player intuitively would activate the desired control.

Besides gaze control, some controls can be allocated to a switch. The switch operates just as a button or any binary control method; it is either on or off. For example, the speed boost could be activated by pressing the switch. Some functions of the game can also be automated by middleware. If a control is on most of the time of gameplay, it may be worth automating. Throttle could be automated, and if the player wants to slow down, the player can brake by gaze or a switch.

6.4.1.   Controls with gaze only

Playing with gaze only presents a challenge. How to allow the player to look at the game and give gaze commands at the same time? The designer of the gaze interface most likely has to make some compromises in the design process, depending on the amount of controls needed.

Option 1: Simple WASD control with gaze only. A simple solution for gaze only controls would be to allocate areas on the screen to match a common WASD-configuration (the same as arrows up, down, left and right). When the player looks on a certain area, the game receives the allocated key command. This solution is too simple for successful playing of a racing game, since only one key can be used at a time, and successful gaming requires one or two key presses at a time — acceleration and steering for example.

Option 2: Advanced WASD control with gaze only. A more sophisticated solution for gaze only control would be to allocate some areas of the screen to trigger two or more key presses at a time. This allows the player more precise control, and has worked well in certain locomotion experiments (Istance et al., 2008). This indicates that a similar control setup could work with a racing game, in which the player's controls are somewhat similar to locomotion controls. The player has control of a WASD setup, while being able to use throttle or brake with steering at the same time. When the player looks at a corner of the screen, the game receives simultaneous key presses; e.g. to look at the top left corner equates to the W and A keys to be pressed down at the same time (figure 5). This adds a considerable amount of precision of control to the player compared to the simple WASD control.

Figure 5. Gaze control areas.

6.4.2. *Controls with gaze, switch and automation*

If players are able to use another modality besides gaze, the possibilities of different control setups extend. Some kind of a switch is commonly used to activate or select things by people with motor disabilities. A switch can be used in a racing game in several different ways, e.g. to switch between gaze control and no gaze control modes or to control acceleration or braking. Some controls could also be automated to be always on, like maintaining speed with throttle.

Option 3: Automated throttle with a switch for braking. The player controls the steering with gaze, by looking at the sides of the car on the screen (figure 6). The throttle is always on, but can be overridden with a switch. The use of braking requires a press of the switch. This requires moderate timing precision. A negative issue is that the player cannot idle the car – either the throttle or the brake is always on. This reduces the level of precision with the controls.
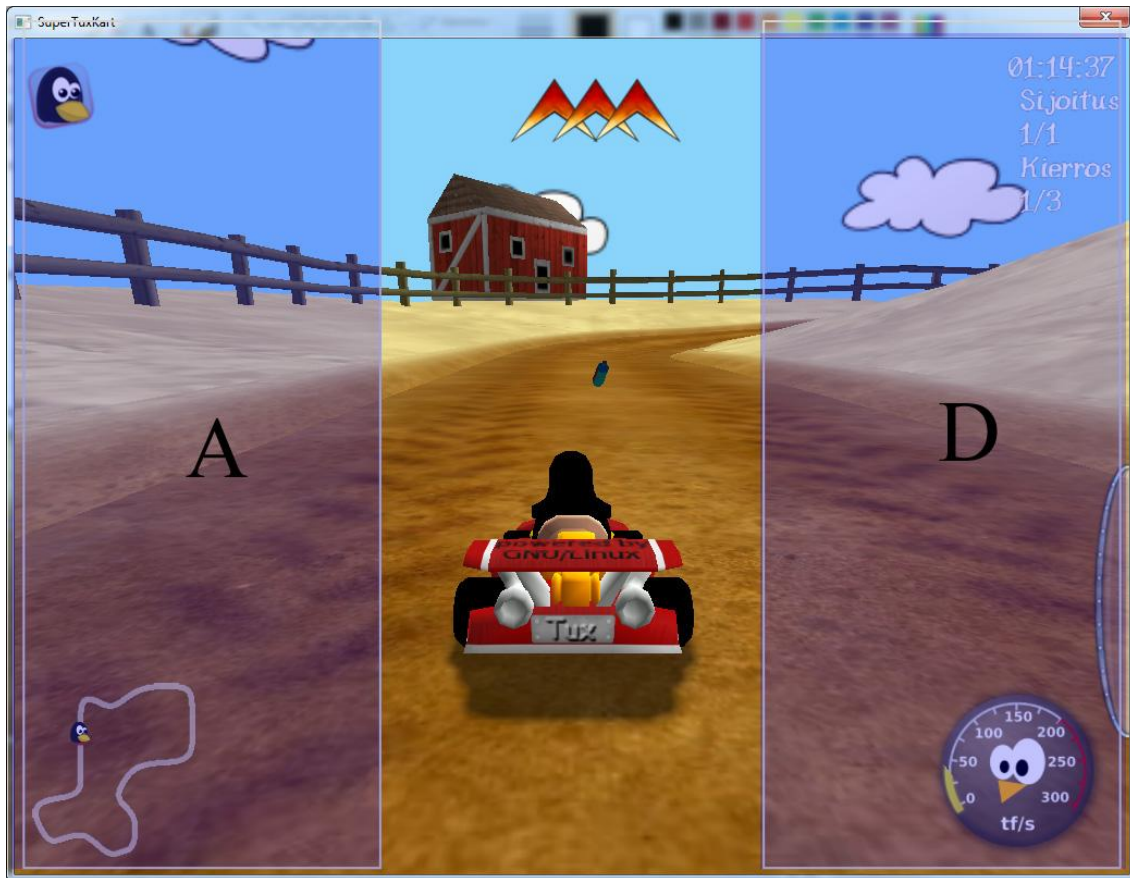
Figure 6. Gaze control areas.

Option 4: Automated braking with a switch for throttle. This control method is similar to auto throttle with a switch for braking, but is vice versa. The player must keep the switch pressed on to maintain speed, and release it for just brief moments for braking. This requires moderate precision with timing. This method could be suitable for a player who rather keeps a switch pressed for a long time, and releases it only for short moments. The idling of the car is not possible with this setup either.

Option 5: Advanced WASD control with a switch for extra speed. This control setup is otherwise the same as advanced WASD, but a switch is used to activate a short speed burst. This allows more access to the game's versatile controls, which includes a speed burst. A speed burst is commonly used in the beginning of a straight section, where high precision of timing to the activation is not necessarily required. This setup could be suitable for someone who is able to press a switch, even if not very accurately. However, the speed burst causes the car to gain more speed rapidly and maintaining a high speed for a brief while, thus making the car more difficult to steer, especially in curves.

Option 6: Automated throttle or braking with a switch for throttle or brake, with a speed boost feature used by gaze. This setup is otherwise similar to the automated throttle and automated braking setups, but the player can activate a speed boost by

glancing at an area on the top of the screen. As the gaze point analysis illustrated, the players did look little at the very top of the screen while playing. Thus that area could be used to activate a speed burst, since it takes little effort to quickly glance there, but the players probably would not glance at the area by accident when playing. Since the boost is usually activated in the beginning of a straight section where no steering is needed, the player has time to activate the boost by gaze.

Option 7: A switch to switch between gaze control on and gaze control off. Constant gaze control is tiring for eyes, but can also be mentally wearing. People look constantly around, and gaze control limits that natural behavior. Using a switch to select between gaze control and a safe mode gives the player the chance to freely look around and rest their eyes. If the player is able to press the switch quickly and with good timing precision, it is possible to look around the track and plan the coming steering and actions, while maintaining a fast pace in the game. Using a switch to turn gaze control on and off requires a high level of timing precision. On straights, where steering is not needed, this kind of setup would allow the player to rest their eyes or to look around.

6.4.3. Controls with gaze and a joystick

If the player is able to use a two axis joystick, gaze control is not necessary needed, since the player is able to use the basic controls, i.e. acceleration, braking and steering. However, if only a one axis joystick is possible to use, some controls can be allocated to the joystick and some to gaze.

Option 8: Steering with gaze, speed with joystick. The player controls steering with gaze, and uses throttle and braking with a two axis joystick. The benefit of this is that the player is able to do also idle driving, besides activating throttle and braking. The area for steering could be as shown in figure 6.

Option 9: Steering with joystick, speed with gaze. This method allows the player to control speed with gaze and steering with a joystick. If the player is able to use the joystick precisely, the steering of the car can be quite accurate. The benefit with this setup is that the throttle area can be quite large, covering the upper part of the screen, since in STK racing, many tracks allow the throttle to be on most of the time.

6.5. Designing the gaze interface

Previous experience has shown that locomotion tasks in virtual environments can be accomplished by using gaze as a control method. STK racing is much faster, but otherwise there are similar elements between the two. We wanted to experiment whether it is possible to play STK racing game by using gaze and to reach a satisfying gaming experience.

Constant gaze control is tiring, which can lead to errors and bad performance, which in turn in a game would lead to poorer performance and thus less satisfaction with the game experience. Is it possible to create methods that would reduce the problems caused by constant gaze control? Perhaps automating an often used control, or allocating one or more controls to a different modality would lessen the burden of gaze control and lead to better performance and thereby to more player satisfaction.

The question arises, if the use of automation and/or another modality brings less tiredness and more enjoyment. Tiredness can be measured by asking subjective opinions, but it is possible that it also can be seen in decreased performance. Possible means to measure performance are measuring lap times and counting points while driving. Lap times measure how well the player manages staying on the track, which tells if the player stays overall in control of the racing car. Counting points measures how accurately the player is able to steer the car, since to gather a point the player must drive over a certain spot on the track.

Of the several different control method possibilities, three methods, i.e. conditions were selected to be studied with participant players. The conditions were driving with gaze only, and two conditions with driving with gaze and using a switch. The other condition of these two included automation too.

Condition name	Explanation of condition
Gaze only	Traditional keyboard controls (WASD) were mapped as layers on the screen. The player activates the controls by looking at an area on the screen. (See figure 5).
Gaze on / off	Similar as gaze only condition, but a switch control was added. The player could switch gaze control off by pressing a switch. As long as the switch was pressed, the player could freely look around the screen avoiding the Midas touch effect.
Autothrottle	The throttle was automated; it was on all the time during racing. Steering was done with gaze, there were two large areas on the sides of the screen which activated the keyboard A and D controls. The player had a button switch that could be used to brake and furthermore reverse, if kept pressed for a longer time. The player could use the switch by pressing it with the thumb. Braking and reversing would override the automated throttle, which would take over as soon as the switch was released.

Table 4. Summary of the conditions.

7. Experiment: Evaluation using able-bodied participants

Two player groups were identified for testing the implementation. One group was able-bodied players and the other the target group for gaze controlled gaming: gamers with disabilities. Able-bodied players were chosen, because even though they do not represent the real target players, they can help identifying successful and problematic solutions in the implementation. If a design solution seems to be working badly, it may be assumed that the solution would cause problems with the intended target group too. Comparing the conditions against each other is also something that could be done by the help of able-bodied players.

The conditions were also tested with the help of players with physical disabilities. The conditions were tested in "real life" situation, which gave a valuable view into how the conditions worked with the intended target players. However, because of a small number of participant players with disabilities and limited time, one must be careful when drawing conclusions about the functioning of the conditions, because the possibility of chance affecting the results is greater than with a large participant group.

7.1. Experiment setup

7.1.1. Participants

The participants in the experiment were all students at the University of Tampere, Finland. There were 12 participants, their ages varying between 19 to 35 years. 8 participants were male and 4 were female.

Half of the participants classified themselves as "experienced" racing game players as the other half was classified as "novice" players. Even though the control method was new to all participants, one could expect that experienced players would perform better, since they were familiar with the concept of racing and thus presumably could focus fully on the control method.

Before the actual tests, several preliminary pilot tests were performed to help to choose the eventual control methods, i.e. conditions. Two pilot tests were performed to test the final experiment setup. The tests were run in the gaze laboratory at the University of Tampere.

7.1.2. Stimulus

The participants were presented with three different conditions. The conditions were tested separately in an identical manner. The order of the conditions for both participant groups was defined by using a Latin square, to eliminate the learning effect.

The participants' lap times were recorded, as was the amount of points gathered during racing. There were objects to be collected as well as objects to be avoided on the track. Before and after each condition, the participant's overall tiredness and tiredness of the eyes were asked with a questionnaire.

The lap time measures the overall control of the car; fast racing means that the controls are suitable for successful racing, whereas slow lap times indicate problems in controlling the car. The accuracy of the controls can be measured with the amount of points gathered, since gathering plus points and avoiding minus points requires accurate control of steering left and right. The participants' tiredness was asked to find out whether there was difference in the fatigue that the conditions caused in participants.

The participants were instructed to collect as many points, i.e. bottles, as possible during racing and to avoid collecting minus points, i.e. bananas. They were not allowed to stop and reverse to collect a missed point.

Pilot trials with keyboard control showed that it was easy to steer over a bottle with a traditional steering method. The maximum possible amount of points collected was 8 per lap, altogether 40 points. The maximum possible amount of minus points was 6 per lap. There were actually more bottles and bananas than that on the track, but the location of many of them was so that the player could only drive over one of several possibilities, as seen in figure 7.

Figure 7. Only one bottle out of two can be collected.

7.1.3. Procedure

The procedure of the test situation was the same through all tests with all participants. When the participants arrived to the gaze tracking laboratory, they were welcomed, asked to sit comfortably and explained the purpose and length of the test. After explaining what will happen during the test, the participants were asked if they had any questions.

The participants were asked to fill a participant information form. After filling the form, the first control method was introduced to the participants. They were explained how the controls work, and asked to practice until they felt comfortable with the controls, but for a maximum time of completing three full laps. Many participants announced that they were comfortable with the controls even before completing three laps, and decided to stop the practice run.

Before each trial, after practicing the condition, the participants were asked to fill a questionnaire about their overall tiredness and tiredness of their eyes. The participants then were asked to drive five laps as fast as possible, to collect points at the same time and to avoid driving over bananas (minus points) on the track.

After each trial, the participants first were asked to fill the same tiredness form as before racing. They also were asked to fill a questionnaire about the control method. The form included statements on a Likert scale along open questions about the control method.

After completing the trials, there was a brief interview about the conditions. Comments about the conditions were asked and the participants had the possibility to ask questions about the test situation and the implementation.

During racing, a video of the screen was recorded. To help analyze the recording, a black dot shows the gaze point of the participant in the video. The participant did not see the gaze point while playing the game, because it would´ve been distractive while racing, as was noticed during preliminary pilot testing.

7.2. Results

7.2.1. Total lap times

Each participant drove 5 laps with each condition. Lap times presented in Figure 8 are the single lap times added together, i.e. the total lap time. Participant N1 reported serious difficulties in keeping gaze in the throttle zone. N1 frequently looked at the car while driving, which caused the car to stop, since the speed area started just above the car (see figure 5). This explains the big difference between the N1 autothrottle and the

two other conditions. With the autothrottle condition, the participant did not have to maintain speed by looking at the speed zones. Otherwise there are no clearly distinguishable differences between the player groups or individual players.
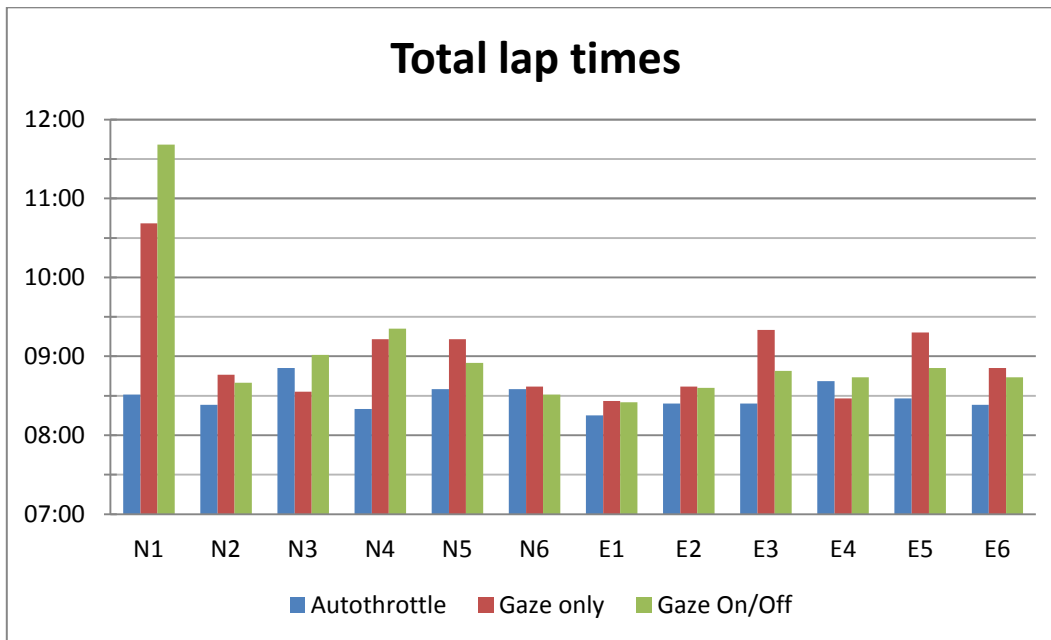

Figure 8. Total lap times (N*n* = novice player, E*n* = Experienced player).

Since N1 lap times with the gaze only and gaze on/off conditions differ so pronounced from the other participants' lap times, it is justified to classify them as outliers and leave them out of further data analysis.

7.2.2. Lap times between novice and experienced players

The average total and single lap times (N1 excluded) are listed in table 6:

	Single lap time			Novices		Experts		All players	
	Average	Novices	Experts	total lap time	SD	total lap time	SD	total lap time	SD
Autothrottle	1:42	1:42	1:41	8:32	0:11	8:26	0:09	8:29	0:10
Gaze only	1:46	1:46	1:46	8:52	0:19	8:50	0:24	8:51	0:21
Gaze On/Off	1:45	1:47	1:44	8:54	0:19	8:41	0:10	8:47	0:15

Table 5. Average total and single lap times and their standard deviation (in minutes and seconds).

The average single lap times are the total lap time divided by five. For comparison, a fast single lap time with keyboard with the test setup is approximately 1:37. This estimate is based on several keyboard races by an expert player. The slowest average single lap time of 1:47 (Novice player, Gaze On/Off condition) is about 10 percent slower than the comparison time. Experienced players were slightly faster than novice players; however the difference is only a few seconds per lap.

Two sample t-tests were performed to see, whether the small difference in lap times between the player groups could be explained with the participant's racing game experience. In all cases, there was *no significant difference* in the lap times. There is no conclusive evidence of experienced players being faster than novice players when using the same control method.

The autothrottle condition. The total lap times are rather close to each other; the fastest being 8:15 (E1) and the slowest 8:51 (N3). The time of participant E1 averages to a lap time of 1:39, which is close to the comparison time with keyboard. The slowest time averages to a lap time of 1:46.

The gaze only condition. There's more difference in lap times between participants in the gaze only condition than in the autothrottle condition, but not much. The fastest total time is 8:26 (E1) and slowest (N1 excluded) is 9:20 (E3). The fastest time averages to a lap time of 1:41. The slowest time averages to a lap time of 1:52.

The gaze on/off condition. The lap times with the gaze on/off condition are very similar to the gaze only condition. The fastest total time is 8:25 (E1) and slowest (N1 excluded) is 9:21 (N4). The fastest time averages to a lap time of 1:41, and the slowest time averages to 1:52. Even though the fastest and slowest time averages are similar to the times of the gaze only condition, the standard deviation is noticeably smaller with the gaze on/off condition. That suggests that the experienced players could achieve a more constant racing performance.

Learning effect. The average lap times for each lap number were examined to find out, if the learning effect was noticed during racing of five laps. As figure 9 presents, there is some difference between the average lap times, but no learning effect can be detected. Even though many participants reported that they learned the controls quickly, improving the lap times distinctively would require more practice and experience.
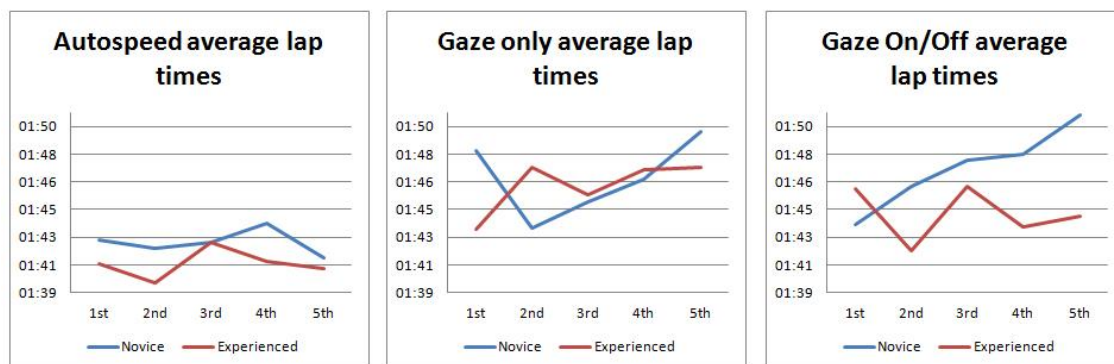

Figure 9. Average lap times for each lap number.

7.2.3.   Lap times between different conditions (N1excluded)

The total lap times are presented in table 5. Autothrottle was the fastest condition. The gaze only and gaze on/off conditions were slower, with little difference between them. Paired two sample t-tests were conducted to compare the lap times between the conditions. The differences between the conditions are further viewed in the following paragraphs.

Gaze only and gaze on/off conditions. The average total lap times of the players were 8min 51sec (gaze only) and 8min 47sec (gaze on/off). The lap times were very close to each other and there was *no significant difference* in the lap times between the gaze only (M=8:51, SD=0:21) and the gaze on/off (M=8:47, SD=0:15) conditions; t(10)=-0.78, p=0.46 (two-way).

Gaze on/off and autothrottle conditions. The average total lap times were 8min 47sec (gaze on/off) and 8min 29sec (autothrottle). There is *a significant difference* in the lap times between the gaze on/off (M=8:47, SD=0:15) and the autothrottle (M=8:29, SD=0:10) conditions; t(10)=3.56, p=0.005 (two-way).

Gaze only and autothrottle conditions. The average total lap times were 8min 51sec (gaze only) and 8min 29sec (autothrottle). There *is a significant difference* in the lap times between the gaze only (M=8:51, SD=0:21) and the autothrottle (M=8:29, SD=0:10) conditions; t(10)=2,85, p=0.02 (two-way).

7.2.4.   Gathering points (N1 excluded)

When considering the collecting of points during racing, two questions arise: Does one condition allow more precision, i.e. the possibility to collect more points than another condition? Are experienced players better in collecting points than novice players, even though the control methods were new to both player groups and there was no evidence of experienced players being significantly faster than novice players? Table 6 presents the points collected in average by all participants for each condition, and the player groups for each condition.

	All participants	Novice	Experienced
Autothrottle	21,8	18,8	24,3
Gaze only	19,3	17,4	20,8
On/Off	19,5	16	22,5

Table 6. The averages of points collected during racing.

Gaze only and gaze on/off conditions. Looking at all players and the points they collected, there is *no significant difference* in points collected between the gaze only

(M=19.3,SD=3.6) and gaze on/off (M=19.5,SD=4.5) conditions; t(10)=-0.25, p=0.81 (two-way).

Gaze only and autothrottle conditions. With the autothrottle condition the participants were able to collect a bit more points during racing than with the other conditions. Since the autothrottle condition lets the player to focus on steering, we could assume that the players would be able to collect more points with the autothrottle condition. However, the difference between the gaze only (M=19.3,SD=3.6) and autothrottle (M=21.8, SD=5.4) conditions is *not significant*; t(10)=-1.61, p=0.07 (one-way).

Gaze on/off and autothrottle conditions. Even though there is little difference in the averages in points collected between the gaze only and gaze on/off conditions and there is no significant difference between the gaze only and autothrottle conditions, there is *a significant difference* between the gaze on/off (M=19.5,SD=4.5) and autothrottle (M=21.8, SD=5.4) conditions; t(10)=-1.84, p=0.05 (one-way). This result suggests that the condition does have an effect on the performance in collecting points: the autothrottle condition allows the player to be more effective than the Gaze on/off condition when collecting points.

Gathering points between player groups. The experienced players collected more points than novice players with all conditions. The expectation was that experienced players would collect more points during racing, since they would be familiar with the concept of gathering points whereas novice players would focus more on just staying on the track. Two-sample t-tests were conducted to compare the points between the player groups and the one-way p value was examined.

Autothrottle. There is *a significant difference* in points collected between the novice (M=18.8, SD=3.1) and experienced (M=24.3, SD=5.8) players; t(8)=-2.03, p=0.04 (one-way).

Gaze only. There is *a significant difference* in points collected between the novice (M=17.4, SD=2.6) and experienced (M=20.8, SD=3.7) players; t(9)=-1.80, p=0.05 (one-way).

Gaze on/off. There is *a significant difference* in points collected between the novice (M=16, SD=1.9) and experienced (M=,22.5 SD=3.8) players; t(7)=-3.67, p=0.004 (one-way).

The differences in all conditions between the player groups are of significant difference. The results suggest that if players are introduced to a new control method to play a racing game, players with previous experience of the game genre will perform more efficiently than novice players.

There were differences between novice and experienced players in collecting points, as table 6 and figure 10 show. With all conditions, the experienced players were able to collect more plus points than the novice players. As collecting points requires accurate steering, the experienced players were better at controlling the car. However, a factor that could affect the collecting of points, could be that the experienced players focused more on collecting points whereas the novice players simply chose to focus on staying on the track and ignored some points to be collected. The difference in points collected may not exist only because the experienced players simply were better at controlling the car, but because of the combination of wanting to collect points and being more able to do so.

Rather interesting is the amount of minus points, as shown in Figure 10. The figure shows the average amount of minus points collected for each condition. With the autothrottle and gaze only conditions there is little difference between the player groups but with gaze on/off condition there is a noticeable difference in the minus points collected.
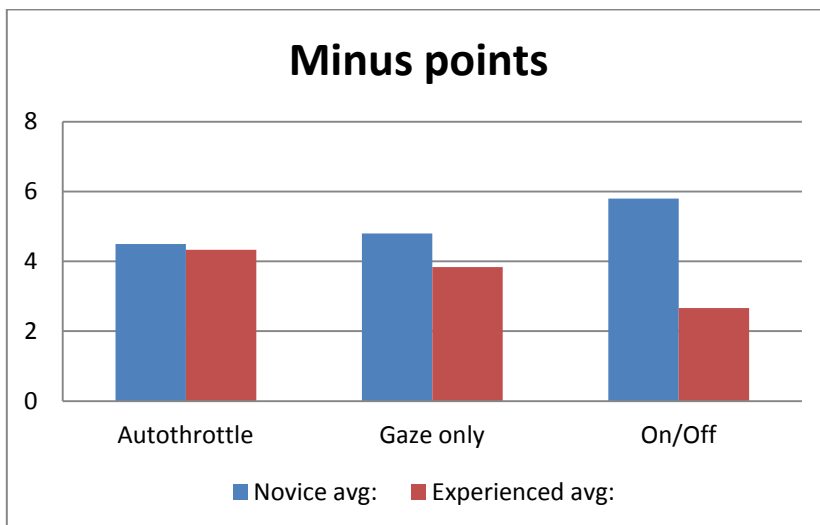
Figure 10. Collected minus points during racing.

The difference between collected minus points in gaze on/off condition *is of significant difference* (Experienced players (M=5.8, SD=1.3), novice players (M=2.7, SD=1.4); t(9)=3.89, p=0.002).

The observation is interesting, since if we look at collecting plus points, the autothrottle condition was better than the gaze on/off condition, as it was with novice players regarding minus points. The explanation for gaze on/off being better with experienced players regarding minus points is that it is possible that the idea of collecting plus points was easier to understand than the idea of avoiding minus points, especially for novice players. When playing games, they may have been experiencing collecting some items,

but not *avoiding* collecting items. Experienced players may have been more familiar with the idea of not collecting something while playing a game.

One explanation could be that experienced players were able to, and wanted to use a more complex control method more efficiently than the novice players, even though it does not show in the lap times. Noteworthy is that when collecting plus points, the participants were able to collect more points with the autothrottle condition than with the other conditions. It is possible that this difference is merely caused by chance.

Racing game experience may contribute to the ability to immediately put new control methods to good use. Experienced players may be immediately able to perform better and thus a more challenging game may be provided to them to keep the playing experience satisfying.

7.2.5. *Questionnare, subjective opinions*

It is essential for a game to be enjoyable to play. Quantitative data is indicative of how playable a game is, but qualitative data is required to find out if the players actually enjoy playing a game. We asked questions regarding the controls of the game, learning them, getting tired while playing, and about enjoyment of playing. The questions about each condition were asked after completing the trial run. The questions were both Likert scale questions and open questions. The Likert scale questions and the scales are presented in table 7.

Question	Scale from 1 to 7
A. Was it easy or hard to learn the controls required for controlling the car?	1 = extremely easy, 4 = not easy nor difficult, 7 = extremely hard
B. How did you feel about the speed of the car?	1 = far too slow, 4 = suitable speed, 7 = far too fast
C. How difficult did it feel to control the car?	1 = not at all difficult, 4 = moderately difficult, 7 = extremely difficult
D. How precisely were you able to control the car?	1 = not at all precisely, 4 = moderately precisely, 7 = extremely precisely
E. Was it enjoyable to play the game using this control method?	1 = not at all enjoyable, 4 = moderately enjoyable, 7 = extremely enjoyable
F. How tiring did playing the game using this control method feel to your eyes?	1 = not at all tiring, 4 = moderately tiring, 7 = extremely tiring

Table 7. Likert scale questions.

A. *Easiness of learning the controls.* The participants evaluated all conditions to be not difficult to learn. There was very little difference between the gaze only and gaze on/off conditions. The autothrottle condition was rated noticeably easier to learn then the two other conditions. Especially experienced players thought that the autothrottle condition was very easy to learn. Since the number of controls was smaller than in the other conditions, it is not surprising that the autothrottle condition was rated as the easiest to learn.
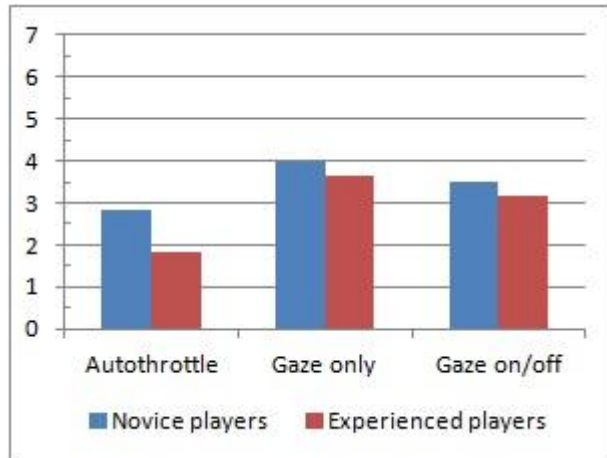
Figure 11. Easiness of learning the controls.

Even though the gaze on/off condition has the option to switch gaze control off with a switch, it was found a little bit easier to learn than the gaze only condition, which does not have a switch function. However the difference between the gaze on/off and the gaze only conditions is small.

B. *Gaming speed.* The speed of the car was pre-set and the players could not change it. The speed of the car was slowed down significantly from the normal game speed, because the pilot testing showed that the normal speed was too fast for gaze racing. The participants found the speed of the car to be suitable for racing with gaze, which furthermore presents evidence that the normal speed would have been too fast for gaze control.

Figure 12. Gaming speed.

There was little difference between the conditions. The experienced players thought that the speed was a bit too slow, whereas novice players thought it to be just right. When the players gain racing experience, the speed of the car can be gradually adjusted towards the normal game speed, thus maintaining a challenging and enjoyable gaming experience.

C. Difficulty of controlling the car. The participants were asked how difficult it felt to control the car. Again, there is very little difference between the gaze only and 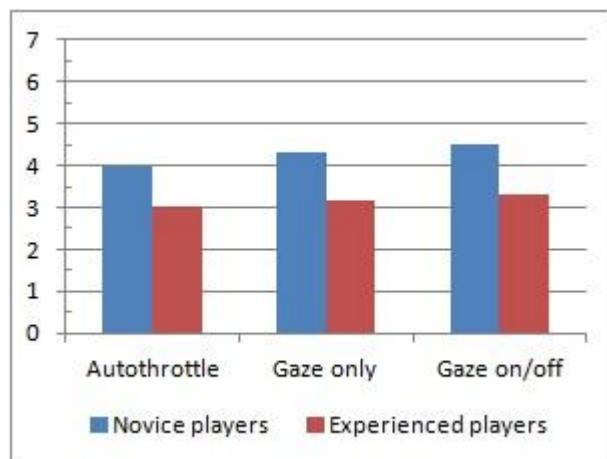gaze on/off conditions. Novice players found controlling the car with the autothrottle condition easier than with the other conditions. So did experienced players, but the difference is smaller.
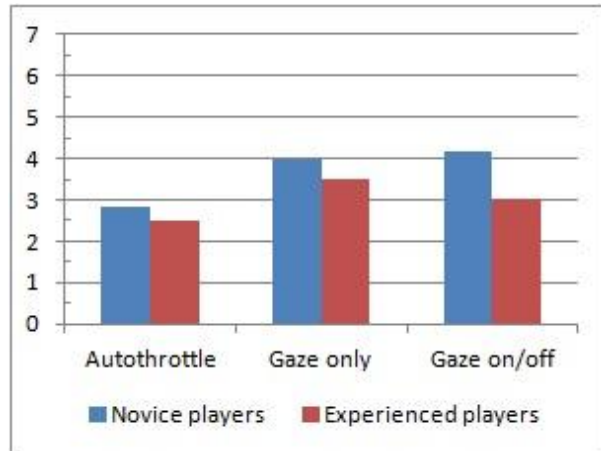
Figure 13. Difficulty of controlling the car.

The results correlate with the question about the easiness of learning the controls; the autothrottle condition was found again the easiest. No condition was found to be exceptionally difficult; all were thought to be on the easier side.

It seems that the gaze areas are quite intuitive and suitable for racing. A failure in the design of gaze areas would have resulted in the opinion of the controlling being difficult and learning the controls to be harder.

D. Precision of the controls. An important and interesting question is how precisely it is possible to control the car. The test setup was rather forgiving and high precision was not required for successful playing, but if the controls were to be used with a more challenging racing game, the controls must provide at least a reasonable level of precision. Imprecise controls will lead to frustration and an unsatisfying racing experience.
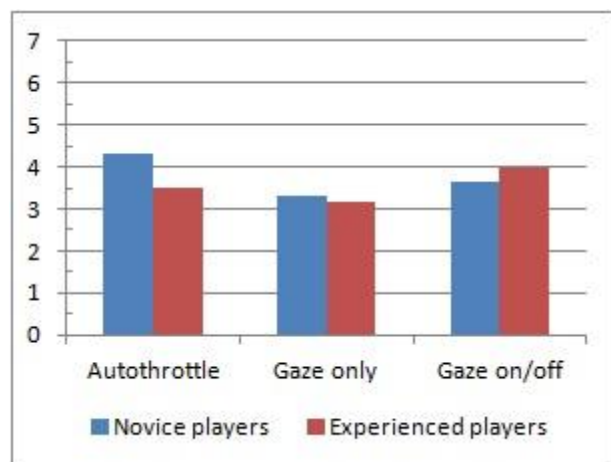
Figure 14. Precision of the controls.

There was little difference in the opinion of preciseness of the controls in all conditions. No condition was found to be very precise, but neither not at all precise. Novice players estimated the autothrottle to be most precise whereas experienced players rated gaze on/off as the most precise, the difference being however small. An experienced player commented: *"[used it] to rest eyes, aim at objects and to avoid errors on straights."*

E. Gaming enjoyability. The question of enjoyment is also important; if a control method is unpleasant, it may ruin the whole gaming experience, regardless how

enjoyable the game itself may be. There was little difference in the enjoyment estimation: All conditions were rated as more or less somewhat enjoyable. There is no large difference between the conditions.

Since a control method, whatever it may be, is just a way to reach the gaming experience, it is important to notice that the conditions are not unenjoyable. Even though they are not remarkably enjoyable, they are at least somewhat enjoyable. This is acceptable, as long as the game is otherwise playable with the control methods. The control method is eventually just a tool to reach an immersive and satisfying gaming experience.
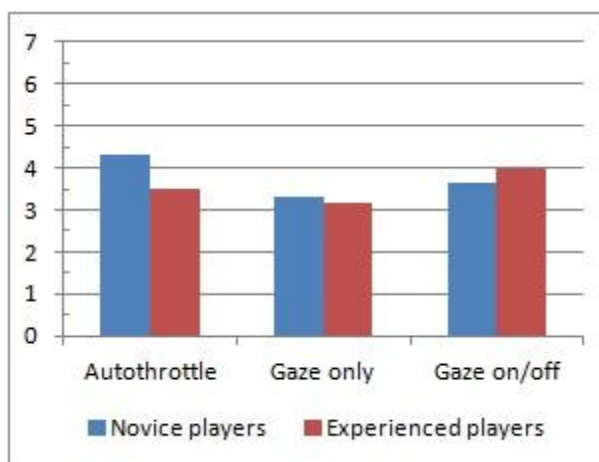
Figure 15. Gaming enjoyability.

F. Tiredness of eyes. A game that requires continuous gaze control should be as little tiring as possible to make an enjoyable gaming session possible. There was little difference between the conditions in the tiredness of eyes after racing. All conditions were considered to be a little tiring, but no condition was estimated as very tiring. It is interesting that the experienced players thought all conditions to be a bit less tiring than the novice players, even though all participants were novices regarding gaze control.
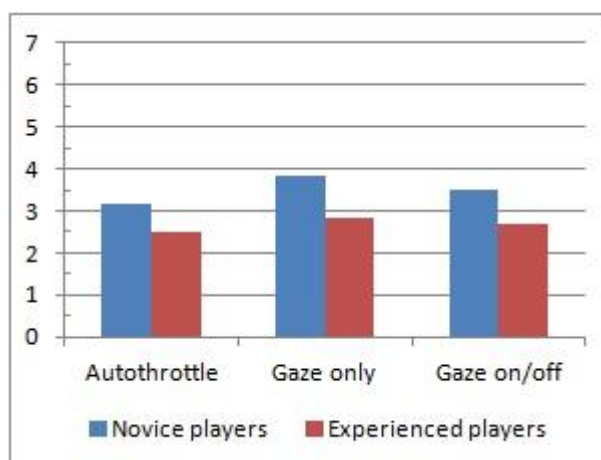
Figure 16. Tiredness of eyes.

One explanation for this is that the experienced players may have been focusing more on being successful in the game and thus paying less attention to the game controls and control method. The novice players may have been more aware about gaze control and how it feels.

7.2.6. Tiredness during racing

Besides answering the questions about how tiring the control methods felt, the participants estimated their overall tiredness and tiredness of their eyes with a questionnaire form before and after racing with each condition. They estimated on a Likert scale from one to seven how tired their eyes felt at the moment, one being "not at all tired", four being "moderately tired" and seven being "extremely tired".

The figures of the tiredness of novice and experienced players are presented in figures 17 and 18. Only one participant (N6) reported a larger change in her eye's tiredness; changing from two to five during the test. All other participants reported little change in tiredness. There is no noticeable difference regarding the conditions or the order of the trials. If one condition would be more tiring than another, this test setup does not reveal the difference.

N6, who's eyes got tired during racing, reported getting overall tired during the test, so it is possible that the change is not caused by playing with gaze control only. The participant simply may have gotten tired during the test because e.g. a poorly slept night.
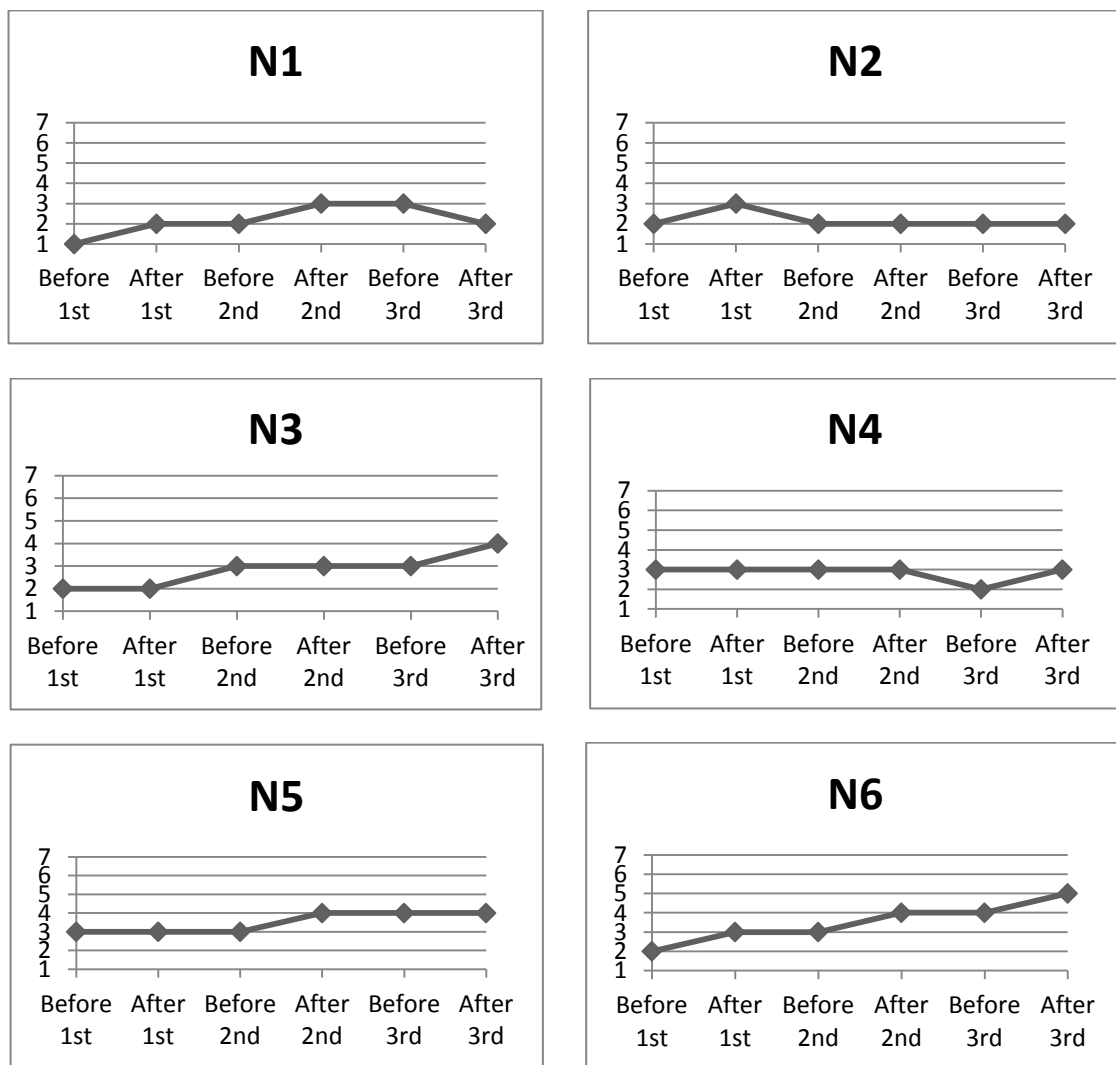
Figure 17. Tiredness of players: Novice players.
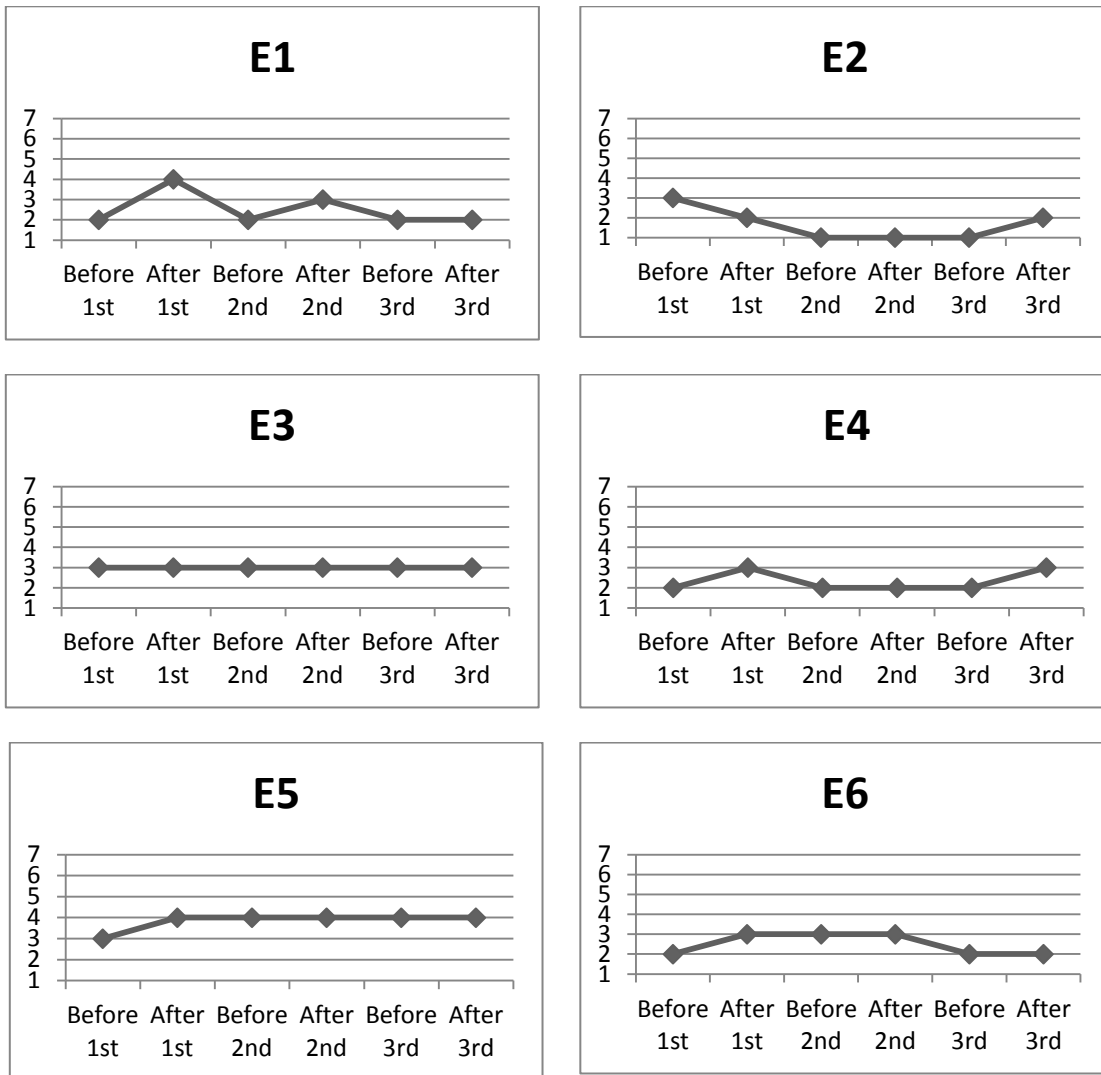
Figure 18. Expert tiredness.

It is worth noting that the tiredness estimate after a trial and before the next one may not be the same, since there was filling of forms and practicing the next condition between estimating the tiredness.

7.3. Discussion

The autothrottle condition was the fastest condition; the other two conditions were a few seconds slower. The autothrottle condition was also found easiest to learn and to control. Male participant, age 20: *"It was easier, you just have to concentrate on steering left or right"*

In the test setup, the track was of such nature that the player could drive at full speed most or all of the time and braking was rarely needed. If the player wanted to brake, it could be done with a finger switch. Being able to focus only on steering, the participants could effectively steer with less mistakes and thus achieve faster racing speed.

The gaze on/off condition allowed the players to switch gaze control off. Some players used it frequently but some used it only a couple of times. The most common reasons to use the switch were to check lap times or to look at other information on the screen. A male participant, age 20, commented: *"Didn't use it much, because it's easier to concentrate when you have to control all the time. I did check lap times, though."*

Those who felt the option to be useful used it mainly on straight parts of the track with full speed, which would not cause improvement in the lap times. It is also possible that the participants who used the switch only a couple of times did not fully understand the meaning of the switch and did not use it where it would have been useful.

One could have expected experienced players to be faster than novice players. However there was no evidence found of significant difference in the lap times between novice and experienced players within a condition. If there was any difference, it could not be found with this kind of test setup.

Collecting points was not necessarily easy with gaze control; a novice participant said that *"[it was] hard to steer to the bottles, you look at them and forget the gaze steering."* The experienced players were able to collect more points with all conditions than the novice players. This indicates that previous gaming experience helps being more efficient, even though the control method would be new.

8. Testing with the target user group

The evaluation of gaze interaction techniques is often based on trials with able-bodied participants and conventional usability criteria, such as speed and accuracy. It is rare that these kind of studies verify their findings in some way with members of the actual target user group. However using able-bodied participants can give us base-line data for comparative purposes. (Istance et al., 2012)

The problem with using conventional usability criteria is that they may not apply with the target users: they may be willing to accept faults because otherwise they could not use the software at all. For example, players may enjoy playing a racing game — even with problems while playing — because the mere possibility to play gives enough satisfaction to the gaming to be enjoyable.

8.1. Ethics regarding tests with participants with disabilities

Empirical experiments and usability testing have to be done with caution and respect to the general guidelines of testing with humans. As the name of the field, Human-Computer Interaction, suggests, we are dealing with people when performing experiments and tests. Following ethical guidelines is always important, but especially important it is if we have experiments that involve special user groups, e.g. children or people with disabilities. There may be special needs which have to be considered when conducting experiments that include people with disabilities participating.

The UPA code of conduct instructs researchers to *"[…] review for special needs when working with the elderly, the disabled and children. Precautions taken to avoid risks associated with such groups shall be clearly identified and reviewed by the client or the employer."* (UXPA, 2005a)

The Association of Computing Machinery has published guidelines (ACM, 1992) that should be followed whenever performing experiments that involve humans. These guidelines are rather general and are meant to support other, more specific instructions for researchers.

The ACM guidelines are: As an ACM member I will…

-Contribute to society and human well-being
-Avoid harm to others
-Be honest and trustworthy
-Be fair and take action not to discriminate
-Honor property rights including copyrights and patent
-Give proper credit for intellectual property
-Respect the privacy of others
-Honor confidentiality

As we can see, these guidelines are rather general, but very comprehensive. The Usability Professors' Association has also published a set of ethical principles (UXPA, 2005b) that are quite similar to the ACM ethical code.

It is important to follow ethical procedure whenever conducting research, not only because of the human participants but also because of the reputation of the research field. Unethical action by a researcher can and will cause harm to other researchers and therefore is damaging to the whole field of science.

8.2. Ash Field Academy in Leicester, England

Istance et al. (2012) argue that in order to get the characteristics of the target user group at the centre of the design process, at least some verification that the techniques evaluated with able-bodied participants can be used with various types of disabilities is required.

In order to get insight about the STK racing game and verification if it is playable with the target players, another test was conducted at a special needs school in the United Kingdom, Ash Field Academy. It is *"an academy for 125 pupils aged 4-19 who have a wide range of abilities with a main presenting disability of a physical nature combined with one or more of a sensory, communication, learning, medical, emotional or behavioural difficulty. "* (Ash Field Academy, 2014)

Co-operation with people, or an organization, where participants with disabilities are coming from, is of great importance. When testing experimental software or devices, it is quite possible that sometimes while they look promising, they will never be fully functional or available to the public. To avoid the participants and organizations feeling exploited, researchers should thoroughly explain the experiment to the participants and avoid creating false or too high hopes. They should carefully explain beforehand what greater good can be achieved with the experiment, if instant benefits cannot be achieved.

Gaze researchers at the University of Tampere have for long collaborated with the gaze research team at De Montfort University in Leicester, UK. They have a long co-operation relationship with Ash Field Academy, and especially have taken care that the relationship benefits the pupils at Ash Field. The older pupils from Ash Field have visited DMU and participated in e.g. programming workshops.

The trials with the target group participants were decided to be carried out at Ash Field Academy, even though it meant travelling to Leicester from Tampere. To create a

similar relationship with a similar local organization and to conduct the trials at Tampere would have been hard and time consuming.

8.3. Conducting the test at Ash Field Academy

8.3.1. Participants

The participants in the test were seven pupils (ages between 11 and 13 years, two female and five male) from Ash Field Academy. The participants all had muscular dystrophy that weakens their muscles and hinders their ability to move their arms. That makes it hard or impossible for them to use traditional game controllers.

8.3.2. Stimulus

A similar test setup was used as in the able-bodied experiment, but the driving task was simplified and the test situation was shorter. Each participant used two out of three conditions. An identical test as with the able-bodied participants would have been too strenuous to the participants. Thus the aim of the test was to collect information and opinions about the conditions from actual target group players.

8.3.3. Procedure

Compared to the experiment with the able-bodied participants, the test situation was simplified. A teaching assistant, who was familiar with the students, was present all the time. The participants did not practice and they were not instructed to collect points. In order to prevent the participants to become too tired, they raced with two of the three conditions. They were driving either for five laps or ten minutes with both conditions. Even though the racing was not explicitly asked to be as fast as possible, the lap times and performance do indicate the suitability of the conditions for racing. The participants were given verbal encouragement if they encountered problems while racing.

The setup is not comparable to the able-bodied test setup, but it can still be used to observe the test data and make conclusions. Like in the able-bodied experiment, a video of the screen was recorded for further analysis. We did not aim to get the same kind of data as was gathered from the able-bodied tests, but rather qualitative data by observing the participants and discussing the control conditions with them. Figure 19 presents the test situation at Ash Field.

Figure 19. A participant playing STK racing.

8.4. Results

8.4.1. Average lap times

Since the number of laps driven by the participants varied and some of them had technical problems which slowed down racing, it is not justified to look strictly at the lap times. The eye tracker had problems with tracking the gaze of participants 3, 4 and 6. The time when they could not drive due to the eye tracker losing the participants' eyes has been removed from the reported lap times.

The average lap times are presented in table 8. The lap times are slower than with the able-bodied participants. However, the fastest lap times are almost as fast as with the other group. The average lap time and the slowest and fastest lap times from the able-bodied tests are included in the table for comparative purpose. The number of the laps completed is also presented in brackets.

	P1	P2	P3	P4	P5	P6	P7	Able-bodied lap times		
								Average	Fastest	Slowest
Autothrottle	-	1:44 (2)	2:23 (4)	1:51 (5)	-	2:18 (3)	1:51 (1)	1:42	1:39	1:46
Gaze only	2:33 (3)	2:36 (2)	-	2:45 (2)	2:10 (4)	-	3:14 (1)	1:46	1:41	1:52
Gaze on/off	1:50 (5)	-	3:09 (3)	-	2:21 (2)	2:57 (2)	-	1:45	1:41	1:52

Table 8. Average lap times of the target group. The number of laps completed is shown in brackets.

The lap time difference with the autothrottle condition is at its best small; the fastest target group lap time is just two seconds slower than the average lap time in the able-bodied tests. The differences with the gaze only and gaze on/off conditions are bigger; the gaze only lap times are much slower than the lap times of the able-bodied participants. The fastest lap time with the gaze on/off condition is comparable to able-bodied lap times, but the other target group lap times were much slower.

We have to bear in mind that the times are not directly comparable because of the different test situation and different player groups, but they are indicative of the easiness of learning and suitability for racing of the conditions. The lap times do suggest that players with disabilities benefit from automating controls.

8.4.2. *Observations during racing*

The participants had the possibility to race using two conditions. They were explained how the controls work and then let race for five laps or ten minutes. Some participants played the game for less than that because of technical problems; the gaze tracker lost the eyes temporarily with a few participants.

Considering that the participants had very little time to prepare, it was surprising how well they were able to adapt to a completely new experience: playing a racing game with their eyes. They were almost immediately able to race reasonably successfully, in spite of occasionally running off the track. Many participants had difficulties in keeping the gaze in the throttle area, which suggests that the border of the area for throttling the car was slightly too high. The individual racing experiences are discussed in the following paragraphs.

Participant 1. Male, 13 years old. P1 used the gaze only and gaze on/off conditions. He had difficulties in keeping the gaze in the throttle area, leading to the car stopping several times. The gaze fell a little too low on the screen, causing the racing to be jerky with the car starting to move and stopping. Had the throttle area reached a bit lower on the screen, the racing most likely would have been much more smooth and successful.

With the gaze on/off condition, P1 used the switch frequently. He used it to keep the throttle on, thus avoiding the problem of the gaze falling too low, and to look around.

He also used it to rest his eyes and, rather surprisingly, to gain more accuracy for steering: if the switch was pressed during a corner, the car would stop turning and continue straight ahead. P1 used this feature to stop turning in the end of a corner. Using the switch lead to clearly improved lap times.

Participant 2. Male, 12 years old. P2 used the gaze only and autothrottle conditions. His gaze wandered strongly in the very top and corners of the screen. P2 steered back and forth from left to right in the gaze only condition, resulting in driving out of the track several times. However despite driving off track frequently, P2 was able to drive back to the track; losing time but being able to continue racing. Maintaining speed was also problematic: P2's gaze was wandering around strongly and frequently moved away from the throttle area, causing the car to stop.

With the autothrottle condition, P2 still kept steering back and forth. It was obviously hard for P2 to keep his gaze focused in a certain part of the screen. The automation of the throttle lead to a great improvement in the lap times, since P2 did not have to concentrate in keeping his gaze in the throttle area.

Participant 3. Male, 13 years old. P3 used the gaze on/off and the autothrottle conditions. There were technical problems with the tracker with both conditions, which caused driving off the track several times. The tracker lost the participant's eyes several times. In the gaze on/off condition he had to be restored back to the track. Recovering from steering off the track was easy with the autothrottle condition, because reversing the car back to track was done with the switch, not using gaze.

Despite the technical problems, it seemed that the participant quickly improved his performance. In the beginning he was struggling to race, but his performance improved quickly, suggesting that the conditions are easy to learn. A quick change in performance indicates that the conditions are easy to learn and reasonably satisfying racing can be achieved in a short amount of time.

Participant 4. Female, 13 years old. P4 used the autothrottle and the gaze only conditions. She had no big problems with the autothrottle condition, except she steered off the track a couple of times, because she looked at the map of the track while racing, which caused the car to turn left. The obvious disadvantage of not being able to switch gaze control off and to look around did cause problems to the participant.

With the gaze only condition, she had difficulties in turning the car back towards the track in the end of a corner. She also had problems in keeping the gaze in the throttle area, which caused the car to stop frequently and led to noticeably slower performance than with the autothrottle condition.

Participant 5. Male, 13 years old. P5 used the gaze on/off and gaze only conditions. He did not have any noteworthy problems during racing. The participant used the switch to switch gaze off to rest his eyes on straight parts of the track and to look at objects on the side of the track. The lap times for both conditions were rather similar; gaze only being slightly faster. With both conditions the performance of P5 improved in a few laps, suggesting that he learned the controls rather quickly.

Participant 6. Male, 13 years old. P6 used the autothrottle and the gaze on/off conditions. He had problems with the gaze tracker; it lost the participant's eyes several times, leading to driving off the track and losing speed. The participant's performance was disturbed by the tracker losing the eyes frequently for brief periods of time. With the on/off condition, the participant used the switch to maintain direction on the track.

Participant 7. Female, 11 years old. P7 used the autothrottle and the gaze only conditions. She used conditions for a very short amount of time and could not race for ten minutes with either condition. With the autothrottle condition P7 was able to keep the gaze more or less in the middle of the screen, making surprisingly small and subtle steering movements. Her performance was immediately surprisingly good; the very first lap was among the fastest laps altogether. The gaze only condition was more problematic; there were a couple of eye tracker errors leading to steering off track.

Overall impression. Considering that the participants were not familiar with the game or the control methods, they were briefly explained how the controls work and they did not get to practice at all, it was surprising how well they played. Some showed improvement after only a few laps. We can assume that with practice they would have narrowed the difference to the able-bodied participants' lap times significantly, eventually racing as well as the other group did. The only thing that would prevent the target group reaching the same level with the able-bodied group would be the possible lack of ability to move the eyes as well as able-bodied participants can, and physical fatigue in a longer racing session.

The participants' success indicates that the conditions are intuitive and suitable for racing with gaze. However, a long term study is required to find out if the conditions would be satisfying and accurate enough for long gaming sessions. Also a thorough study is required to figure out if the game would still satisfy players with lots of experience of gaze racing, since there are limitations in the control methods compared to traditional game controllers that allow more precise and simultaneous controls.

8.4.3. Subjective opinions

After racing, the participants were asked questions about the condition. The questions were both Likert scale questions and open questions. The Likert scale questions and the

scales are presented in table 9. The questions that were asked were thought to be the most important ones in finding out if the game was playable and enjoyable.

Question	Scale from 1 to 7
How difficult did it feel to control the car?	1=not at all, 2=scarcely, 3 a little, 4=moderately, 5=considerably, 6=really and 7=extremely difficult
How precisely were you able to control the car?	1=not at all, 2=scarcely, 3=a little, 4=moderately, 5=considerably, 6=really and 7=extremely precisely
Was it enjoyable to play the game using this control method?	1=not at all, 2=scarcely, 3=a little, 4=moderately, 5=considerably, 6=really and 7=extremely enjoyable
How tiring did playing the game using this control method feel to your eyes?	1=not at all, 2=scarcely, 3=a little, 4=moderately, 5=considerably, 6=really and 7=extremely tiring

Table 9. Likert scale questions.

Gaze only condition

The subjective evaluations of the participants about the gaze only condition are presented in figure 20.

Difficulty. The participants felt that it was not too difficult to control the car; the answers varied from scarcely difficult to moderately difficult. No one thought controlling the car to be considerably or more difficult.

Figure 20. Questionnaire answers: gaze only.

Precision. One participant estimated that he was able to control the car scarcely precisely. All other participants estimated the control to be moderately precise at the worst, but even really or extremely precise.

Enjoyment. All participants thought that gaze control was enjoyable; the answers varying from considerably enjoyable to extremely enjoyable. However the possibility to play a racing game in a new way, especially if it has been impossible or difficult to play with traditional control methods, causes great enjoyment, and it is possible that after the novelty factor wearing out, the participants would be more critical towards the game.

Tiredness. There was difference in the overall tiring of the eyes of the participants. One thought gaze control to be very tiring whereas one did not feel it to be tiring. Others found gaze control to be a little or moderately tiring.

Gaze on/off condition

The subjective evaluations of the participants about the gaze on/off condition are presented in figure 21.

Difficulty. The participants felt that it was not too difficult to control the car; the answers varied from not at all difficult to moderately difficult. No one thought controlling the car to be considerably or more difficult.
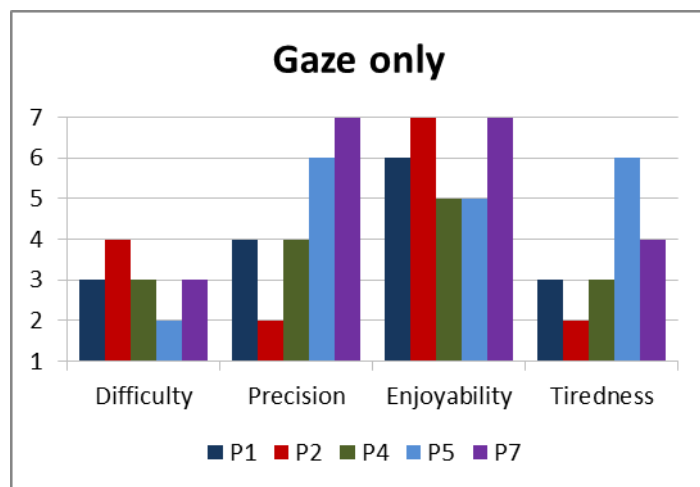
Precision. All participants estimated the control to be a little precise at best. There is a difference compared to gaze control; adding the switch caused the participants to estimate their ability to control the car less precise. This is noteworthy because the idea of introducing the switch is to provide more control on the car and thus more precision.

Figure 21. Questionnaire answers: gaze on/off.

Enjoyability. All participants thought that gaze control was enjoyable; the answers varying from really enjoyable to extremely enjoyable. Again the novelty factor wearing off would probably make the participants more critical towards the game.

Tiredness. There was great difference in the overall tiring of the participants. Two participants thought the gaze control on/off condition to be not at all tiring or scarcely tiring, one estimated it to be moderately tiring and one thought it to be really tiring.

Autothrottle condition

The subjective evaluations of the participants about the autothrottle condition are presented in figure 22.

Difficulty. One participant thought the autothrottle condition to be extremely difficult. Others thought it to be scarcely or a little difficult. The participant who thought it to be very difficult, commented that it was hard because she could not stop the car; it moved all the
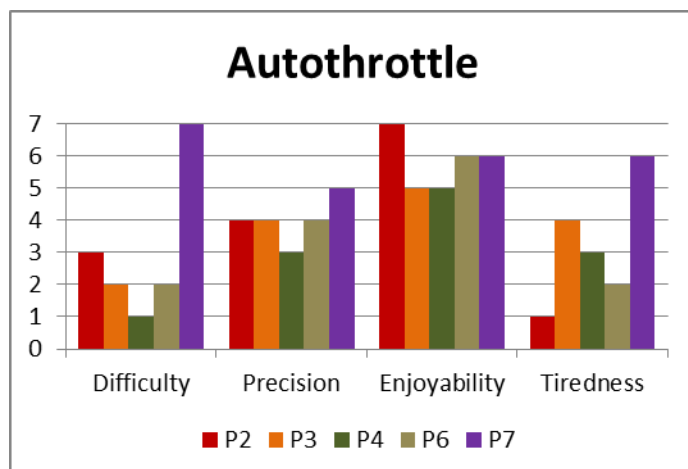
Figure 22. Questionnaire answers: autothrottle.

time either forwards or backwards.

Precision. All participants found the autothrottle condition to be around moderately precise to play. The difference to the other conditions is that there was no great variation in opinions.

Enjoyability. All participants found the condition highly enjoyable, like the other conditions.

Tiredness. There was great difference in the overall tiring of the participants. Two participants thought the autothrottle condition to be not at all or scarcely tiring, two thought it to be a little or moderately tiring and one thought it to be really tiring.

Difficulty, precision, enjoyment and tiredness between conditions
Figure 23 presents the participants' views about difficulty, precision, enjoyment and tiredness between conditions. Except participant 7 with the autothrottle condition, all participants thought all conditions to be somewhat difficult at the worst. All conditions were estimated to be on the easier side, even though the participants had no experience in gaze control and did not practice, just race. The answers suggest that the conditions are intuitive and easy to learn.

The opinions on how precise the conditions were vary a lot; from scarcely precise to extremely precise. The majority of answers settle around a little or moderately precise. The answers suggest that while the conditions are playable, improvement in precision must be sought if serious racing is to be desired.
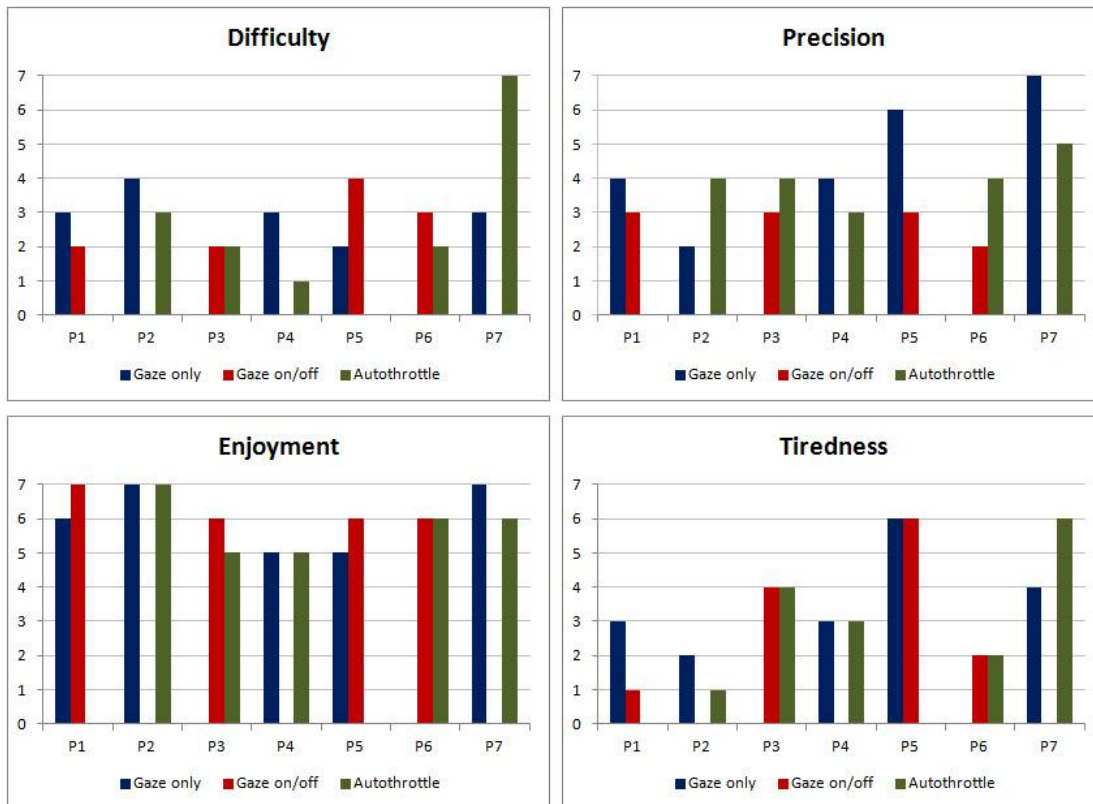
Figure 23. The participants' views about difficulty, precision, enjoyment and tiredness.

All conditions were found highly enjoyable. The mere possibility to play a racing game with gaze causes great enjoyment. Even if the gaming experience would include problems and the performance would not be great, it is possible to reach a satisfying gaming experience by simply providing a possibility to play.

There is great variation in the tiredness caused by playing with gaze. No condition seems to cause more tiredness than another. However it is obvious that playing with gaze caused the participants to get tired.

Five participants reported getting their eyes more tired during racing, as seen in figure 25. It seems that the condition did not affect getting tired, the mere playing the game with gaze caused the participants' eyes to get tired. The difference to the able-bodied participants is clear; the able-bodied participants did not get tired during a much longer gaming session whereas the participants with muscular dystrophy reported tiredness after a short gaming session. When gaze control methods are being developed, the tiredness factor must be taken into account by providing a possibility to rest the eyes.

The overall tiredness figure (24) looks much like the eye tiredness figure; four participants did get more tired during racing. One reported no change in his overall tiredness, even though reporting a slight increase in the tiredness of the eyes. Two participants reported getting a bit less tired during the gaming session.
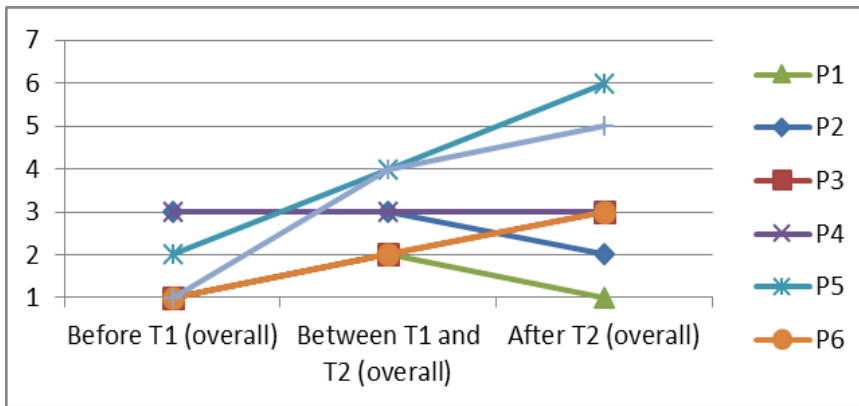
Figure 24. Questionnaire answers: overall tiredness during playing
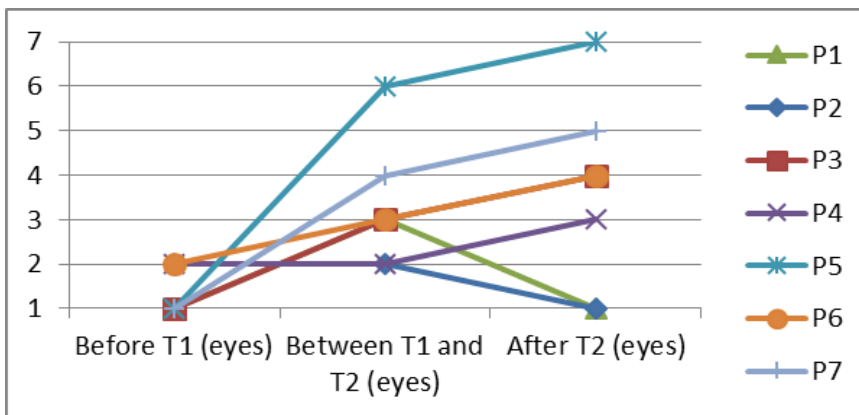
Figure 25. Questionnaire answers: tiredness of eyes during playing.

The favourite condition of the participants

After racing the participants were asked which one of the two conditions they preferred and why. The answers are presented in table 10.

	Conditions used		Preferred condition	Comment from participant
P1	Gaze only	Gaze on/off	Gaze on/off	"you can rest your eyes, and it's easier to steer with the switch"
P2	Gaze only	Autothrottle	Autothrottle	"it was easy to learn and easy to control"
P3	Gaze on/off	Autothrottle	Autothrottle	"it was easier than the other one"
P4	Autothrottle	Gaze only	Autothrottle	"it was easier"
P5	Gaze on/off	Gaze only	Gaze on/off	"you can rest your eyes, and look around too"
P6	Autothrottle	Gaze on/off	Gaze on/off	"it was a little bit easier"
P7	Autothrottle	Gaze only	Gaze only	"I liked this better because the car could be stopped"

Table 10. The preferred condition.

Both participants who used gaze only and gaze on/off conditions preferred the on/off condition. Both mentioned the possibility to rest the eyes as a reason to prefer the on/off condition.

Of the participants who used the gaze only and autothrottle conditions two preferred the autothrottle and one the gaze only condition. Reasons for preferring the autothrottle were the easiness of the condition. Participant 7 preferred the gaze only condition, because the car could be stopped.

Of the participants who used autothrottle and gaze on/off conditions one preferred autothrottle and the other the gaze on/off condition. Both participants found their preferred condition to be easier than the other.

Noteworthy is that participant 5, who estimated the gaze only condition to be more precise and less difficult than the gaze on/off condition, still preferred the gaze on/off condition because of the possibility to rest eyes and look around. Although it is the subjective opinion of one participant, it suggests of the importance of providing the player a chance to rest eyes and look around with a safe mode.

9.   Summary and conclusions

In this work we have discussed special user groups, who are not able to use conventional control methods but need alternate methods to control a computer. The ability to use a computer is of high importance for these users. We presented examples of accessible interfaces, and covered gaze as means of input for users with disabilities.

Games are often not accessible for users with physical disabilities. We examined how games can be made accessible for them. Possible ways are using middleware between the player and the game and changing the game. We analysed what kind of characteristics of different game genres have an effect on making a game playable with gaze. Some genres are hard to play with gaze control, but for several game genres it is possible, although modifications may be needed.

We selected racing games to be the genre investigated further. We analysed game interaction in the genre, and selected Super Tux Kart racing to be changed into a gaze controlled game. The game interaction in STK racing was analysed and a gaze interface was created based on the analysis. We then evaluated the implementation both with able-bodied players and players with disabilities. Evaluating the implementation with the target gamers is of high importance; testing with able-bodied players only is not enough to indicate that the game is playable by the target gamers. Testing with able-bodied participants helps reducing the design space of solutions. If able-bodied participants experience difficulties, it is likely that the target group participants experience similar difficulties.

9.1.   Evaluation with able-bodied participants

The designed and implemented gaze control methods proved to be intuitive and easy to learn. They were accurate enough to allow players to race around a track successfully. A participant (male, 22) compared gaze racing to racing with conventional control methods: *"Don't need to remember the keyboard commands, as you do when playing with controller or keyboard."*

The unsatisfactory feature with the gaze only and autothrottle conditions was that the players were in constant control of the car, and glancing at e.g. the map of the track was not possible without steering at the same time. A participant (male, 26) complained that *"[it was] hard to look at the information on the edge of the screen."*

A possibility to switch the gaze control off provides more freedom to the players. They may use the option to rest their eyes, which is important in a longer gaming session. The able-bodied players did not report any noteworthy tiredness during playing, but

nevertheless, several participants stated that the possibility to rest eyes was important to them, even though they did not use the feature.

In addition the option to switch gaze control off provides the player a possibility to check information on the screen, such as lap times, racing position or the map of the track. The more demanding the game, the more likely this kind of information is needed for successful gaming. *"More enjoyable when you can look at the map, speedometer, the car and you can enjoy the graphics of the game"* (Female participant, 35).

The autothrottle condition proved to be easy to learn and allowed successful racing. It is a rather simple setup with a weakness: it is not possible to stop the car to be still. However, it is rare that the player would want to stop the car while racing. The autothrottle condition was estimated to be the easiest to learn and to control, thus it would be especially suitable for beginner players to get used to the concept of gaze control. Since the condition does not require high gaze tracking precision, it can be suitable also for people who have difficulties in getting an accurate calibration with the gaze tracker.

9.2. Testing with the target user group

The aim of testing with the target players was not to get quantitative data as in the experiment with able-bodied players. The aim was to see how the control methods worked with the intended players and to find out what they thought about gaze controls. Our expectations were met: the participants were immediately able to play the game at the least at a satisfying level. It was remarkable how fast the participants got familiar with the controls and were able to race around the track. Interestingly, the possibility to switch gaze control off was used also to gain more precision in controlling the car.

The comments from the participants after racing were positive: some liked the autothrottle condition the most, some preferred the on/off condition, but all conditions were estimated as very enjoyable. Some part of the enjoyment can be explained with novelty effect, but even if the biggest enjoyment would subside after playing for a while, the possibility to play a game with alternate control methods brings lots of enjoyment.

The possibility to rest the eyes was appreciated, as our tests with the target user group showed that they got tired quickly and therefore an option to rest the eyes is of high importance. A participant (male, 13), who preferred the gaze on/off condition over the gaze only condition, said that *"you can rest your eyes, and it's easier to steer with the switch."* Especially with a long session using gaze control, it is essential to have a feature which allows the user to switch gaze control off for a while.

9.3.   Glance to the future

We produced an interaction technique that allows gamers with physical disabilities to successfully play a racing game with gaze control. There was lots of variation between the participants, and the lap times were slower than with the able-bodied group, but the difference at best is not big. Automating some selected controls seems to equalize the difference between able-bodied and gamers with disabilities. It is possible that gaze racers could eventually play on an equal footing a multiplayer game with players using conventional control methods. In any case, the mere possibility to play a racing game, however simple it may be, can be a highly enjoyable experience, if otherwise it would not be possible to play the game at all.

It can be expected that there will be demand for gaze control as an input modality as low-cost eye trackers are coming onto the market. Already passive tracking of eyes brings exciting possibilities for gaming. An experimental horror game, "Sophia", demonstrates how passive gaze interaction can be used to provide a game environment that analyses the player's visual focus and generates individual real time user content, sound and visual effects (Dechant, 2013). Passive gaze interaction is easy to implement and could very well make gaze interaction to break through to mass market gaming.

Gaze interaction could be used to enhance conventional interaction methods. Tobii has presented ways to enhance games with gaze interaction (Tobii, 2014). They suggest that eye tracking could be used to increase immersion and to control games. They give examples, such as increased artificial intelligence that is based on the computer knowing where the player's visual focus is. Another example is changing weapons faster in an FPS game through gaze triggered quick switch menus. They suggest that horror games could be made scarier through limiting the player's peripheral vision on the screen.

More demanding games with more controls get harder to play with gaze controls. More research is required to further improve and develop interaction techniques, which allow playing versatile games requiring a high level of precision and simultaneous controls from the player. If gaze interaction becomes a mainstream interaction technique along other means of interaction, ways of using gaze will become more advanced and versatile. That would mean advancement also with programs and games intended for users with disabilities. However, regardless of gaze tracking becoming mainstream or not, it is of high importance to continue designing, developing and evaluating software for users with disabilities.

References

ACM (Association for Computing Machinery). (1992). ACM Code of Ethics and Professional Conduct. Available at http://www.acm.org/about/code-of-ethics (retrieved on 9.10.2014)

Alt Controller. (2013). Making PC games more accessible. Available at http://www.altcontroller.net (retrieved on 16.10.2014)

Ash Field Academy. (2014). Prospectus. Available at http://www.ashfield.leicester.sch.uk/about/prospectus.html (retrieved on 22.10.2014)

Bardzell, S. (2008). Systems of Signs and Affordances: Interaction Cues in 3D Games. In O. Leino, H. Wirman and A. Fernandez (Eds.), Extending Experiences: Structure, Analysis and Design of Computer Game Player Experience (pp. 191-209). Rovaniemi: Lapland University Press

Bates, R., and Istance, H. (2002). Zooming Interfaces! Enhancing the Performance of Eye Controlled Pointing Devices. In *Proceedings of the Fifth International ACM Conference on Assistive Technologies* (pp. 119–126). NY: ACM

Bergman, E. and Johnson, E. (1995). Towards Accessible Human-Computer Interaction. *Advances in Human-Computer Interaction, 5*(1), 87-114.

Dechant, M. (2013) SMI Eye Tracking Creates Thrill in Sophia Survival Horror Game - with passive gaze interaction. Available at https://www.youtube.com/watch?v=CRJpxu5NQes (retrieved on 23.10.2014)

Dorr, M., Böhme, M., Martinetz, T., and Barth, E. (2007). Gaze beats mouse: a case study. In *Proceedings of the 3rd Conference on Communication by Gaze Interaction - COGAIN 2007: Gaze-based Creativity and Interacting with Games and On-line Communities* (pp. 16-19).

ETU-Driver. (2014). Oleg Spakov's personal page. Available at http://www.sis.uta.fi/ ~csolsp/projects.php (retrieved on 13.10.2014)

FIFA 14 Career Mode. (2013). Available at http://www.easports.com/fifa/news/ 2013/fifa-14-career (retrieved on 18.9.2014)

FIFA Soccer. (2014). FIFA Soccer Video Games | EA SPORTS. Available at http://www.easports.com/fifa (retrieved on 14.10.2014)

Gajos, K., Wobbrock, J., and Weld, D. (2008). Improving the Performance of Motor-impaired Users with Automatically-generated, Ability-based Interfaces. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1257–1266). NY: ACM.

Hyrskykari, A., Majaranta, P., and Räihä, K. (2003). Proactive Response to Eye Movements. In *Proceedings of the International Conference on Human-Computer Interaction (INTERACT '03)* (pp. 129–136). Amsterdam: IOS Press.

Isokoski, P., Joos, M., Spakov, O., and Martin, B. (2009). Gaze controlled games. *Universal Access in the Information Society, 8*(4), 323–337.

Isokoski, P., and Martin, B. (2006). Eye tracker input in first person shooter games. In *Proceedings of the 2nd Conference on Communication by Gaze Interaction - COGAIN 2006: Gazing into the Future* (pp. 78-81).

Istance, H., Bates, R., Hyrskykari, A., and Vickers, S. (2008). Snap Clutch, a Moded Approach to Solving the Midas Touch Problem. In *Proceedings of the 2008 Symposium on Eye Tracking Research & Applications* (pp. 221–228). NY: ACM

Istance, H., Hyrskykari, A., Immonen, L., Mansikkamaa, S., and Vickers, S. (2010). Designing Gaze Gestures for Gaming: An Investigation of Performance. In *Proceedings of the 2010 Symposium on Eye-Tracking Research & Applications* (pp. 323–330). NY: ACM

Istance, H., Vickers, S., and Hyrskykari, A. (2012). The Validity of Using Non-representative Users in Gaze Communication Research. In *Proceedings of the Symposium on Eye Tracking Research and Applications (ETRA'12)* (pp. 233–236). NY: ACM

Jacob, R., and Karn, K. (2003). Eye Tracking in Human–Computer Interaction and Usability Research: Ready to Deliver the Promises. *Mind, 2*(3), 4.

Jönsson, E. (2005). If looks could kill - An evaluation of eye tracking in computer games. Master's Thesis, Royal Institute of Technology, Stockholm. Available at http://kiosk.nada.kth.se/utbildning/grukth/exjobb/rapportlistor/2005/rapporter05/jonsson_erika_05125.pdf

Kinect for Windows. (2014). Kinect for Windows features. Available at http://www.microsoft.com/en-us/kinectforwindows/meetkinect/features.aspx (retrieved on 18.9.2014)

Kumar, M., and Winograd, T. (2007). GUIDe: Gaze-enhanced UI Design. In *CHI '07 Extended Abstracts on Human Factors in Computing Systems* (pp. 1977–1982). NY: ACM

Mollenbach, E. (2010). Selection strategies in gaze interaction. Doctoral Thesis, Loughborough University. Available at https://dspace.lboro.ac.uk/dspace-jspui/handle/2134/8101

NHL Hockey. (2014). EA SPORTS NHL Hockey Games. Available at http://www.easports.com/nhl (retrieved on 14.10.2014)

Tobii. (2014). Eye Experience. 10 ways to use eye tracking in games by Tobii. Available at https://www.youtube.com/watch?v=UJEA9Z3SaUo (retrieved on 23.10.2014)

UC San Diego. (UC San Diego Center for ALS Research and Therapy), 2014. ALS - What is Amyotrophic Lateral Sclerosis (Lou Gehrig's Disease)? Available at http://als.ucsd.edu/about-als/Pages/default.aspx (retrieved on 22.10.2014)

UXPA (User Experience Professionals Association). (2005a) UXPA Code of Professional Conduct. Available at http://www.usabilityprofessionals.org/about_upa/leadership/code_of_conduct.html (retrieved on 9.10.2014)

UXPA (User Experience Professionals Association). (2005b) UXPA Ethical Principles. Available at http://www.usabilityprofessionals.org/about_upa/leadership/code_of_conduct.html (retrieved on 9.10.2014)

Vickers, S., Istance, H., and Smalley, M. (2010). EyeGuitar: Making Rhythm Based Music Video Games Accessible Using Only Eye Movements. In *Proceedings of the 7th International Conference on Advances in Computer Entertainment Technology* (pp. 36–39). NY: ACM

Ware, C., and Mikaelian, H. (1987). An Evaluation of an Eye Tracker As a Device for Computer Input. In *Proceedings of the SIGCHI/GI Conference on Human Factors in Computing Systems and Graphics Interface* (pp. 183–188). NY: ACM

Yuan, B., Folmer, E., and Harris, F. (2011). Game accessibility: a survey. *Universal Access in the Information Society, 10*(1), 81–100.

Zagal, J., Mateas, M., Fernández-Vara, C., Hochhalter, B., and Lichti, N. (2007). Towards an Ontological Language for Game Analysis. *Worlds in Play: International Perspectives on Digital Games Research, 21*, 21-35.

Appendixes.

Participant questionnaire form.

Participant number..

Means of controlling racing (   )

Please rate how it was to control the racing car on the following scales:

a) How easy was it to learn the controls for racing the car?

1	2	3	4	5	6	7
Extremely easy	Considerably easy	Somewhat easy	Neither easy nor difficult	Somewhat difficult	Considerably difficult	Extremely difficult

b) How did you feel about the speed of the car?

1	2	3	4	5	6	7
Far too slow	Too slow	A little too slow	Suitable speed	A little bit too fast	Too fast	Much too fast

c) How difficult did it feel to control the car?

1	2	3	4	5	6	7
Not at all difficult	Scarcely difficult	A little difficult	Moderately difficult	Considerably difficult	Really difficult	Extremely difficult

d) How precisely were you able to control the car?

1	2	3	4	5	6	7

Not at all precisely	Scarcely precisely	A little precisely	Moderately precisely	Considerably precisely	Really precisely	Extremely precisely

e) How responsive did you feel the control method to be?

1	2	3	4	5	6	7

Not at all responsive	Scarcely responsive	A little responsive	Moderately responsive	Considerably responsive	Really responsive	Extremely responsive

f) Was it enjoyable to play the game using this control method?

1	2	3	4	5	6	7

Not at all enjoyable	Scarcely enjoyable	A little enjoyable	Moderately enjoyable	Considerably enjoyable	Really enjoyable	Extremely enjoyable

g) How tiring was it to control the car?

1	2	3	4	5	6	7

Not at all tiring	Scarcely tiring	A little tiring	Moderately tiring	Considerably tiring	Really tiring	Extremely tiring

Please state briefly **one positive** thing and **one negative** thing about this way to control the car.

 (positive..)

 (negative..)

Any other comments..

Participant tiredness form.

Participant:

Before condition 1

Please rate your overall feeling of tiredness at this moment

1	2	3	4	5	6	7

Not at all tired	Scarcely tired	A little tired	Moderately tired	Considerably tired	Really tired	Extremely tired

Please rate how tired your eyes feel at this moment

1	2	3	4	5	6	7

Not at all tired	Scarcely tired	A little tired	Moderately tired	Considerably tired	Really tired	Extremely tired

after condition 1

Please rate your overall feeling of tiredness at this moment

1	2	3	4	5	6	7

Not at all tired	Scarcely tired	A little tired	Moderately tired	Considerably tired	Really tired	Extremely tired

Please rate how tired your eyes feel at this moment

1	2	3	4	5	6	7

Not at all tired	Scarcely tired	A little tired	Moderately tired	Considerably tired	Really tired	Extremely tired

Before condition 2

Please rate your overall feeling of tiredness at this moment

1	2	3	4	5	6	7
Not at all tired	Scarcely tired	A little tired	Moderately tired	Considerably tired	Really tired	Extremely tired

Please rate how tired your eyes feel at this moment

1	2	3	4	5	6	7
Not at all tired	Scarcely tired	A little tired	Moderately tired	Considerably tired	Really tired	Extremely tired

after condition 2

Please rate your overall feeling of tiredness at this moment

1	2	3	4	5	6	7
Not at all tired	Scarcely tired	A little tired	Moderately tired	Considerably tired	Really tired	Extremely tired

Please rate how tired your eyes feel at this moment

1	2	3	4	5	6	7
Not at all tired	Scarcely tired	A little tired	Moderately tired	Considerably tired	Really tired	Extremely tired

Before condition 3

Please rate your overall feeling of tiredness at this moment

1	2	3	4	5	6	7
Not at all tired	Scarcely tired	A little tired	Moderately tired	Considerably tired	Really tired	Extremely tired

Please rate how tired your eyes feel at this moment

1	2	3	4	5	6	7
Not at all tired	Scarcely tired	A little tired	Moderately tired	Considerably tired	Really tired	Extremely tired

after condition 3

Please rate your overall feeling of tiredness at this moment

1	2	3	4	5	6	7
Not at all tired	Scarcely tired	A little tired	Moderately tired	Considerably tired	Really tired	Extremely tired

Please rate how tired your eyes feel at this moment

1	2	3	4	5	6	7
Not at all tired	Scarcely tired	A little tired	Moderately tired	Considerably tired	Really tired	Extremely tired

Informed Consent Form

Note: The form is in Finnish. The tests in Tampere were Finnish language tests.

<div style="text-align:center">

Suostumuslomake – Katseella käytettävä ajopeli

</div>

Tutkimuksessa vertaillaan erilaisia katseohjausmetodeja keskenään. Tutkimuksen kohteena ovat metodien suorituskyky, niiden miellyttävyys sekä niiden rasittavuus. Testissä osallistuja suorittaa testitehtävän jokaisella ohjausmetodilla.

Tutkimukseen kuuluu:

- Katseenseurantalaitteen kalibrointi ja käyttäminen.
- Kolmen eri katseohjaustavan harjoitteleminen.
- Viiden kierroksen ajaminen jokaista ohjaustapaa käyttäen.
- Kyselylomakkeiden täyttäminen jokaisen ohjaustavan yhteydessä.

Voit lopettaa testitehtävän milloin tahansa tehtävän aikana. Voit lopettaa testitilanteen milloin tahansa testin aikana. Tehtävän tai testin lopettamisesta ei aiheudu mitään seuraamuksia.

Kaikki tutkimusaineisto käsitellään nimettömänä ja luottamuksellisesti. Kenenkään osallistujan yksilöityjä vastauksia ei anneta muiden kuin tutkijan käyttöön. Tutkimusaineisto raportoidaan siten, että ketään tutkimukseen osallistujaa ei voida tunnistaa.

SUOSTUMUS

Suostun vapaaehtoisesti osallistumaan tähän tutkimukseen ja olen lukenut sekä hyväksynyt tässä suostumuslomakkeessa olevat tiedot.

Nimi: _____ Päiväys: _____

Nimen selvennys: _____

Participant background information form

Note: The form is in Finnish. The tests in Tampere were Finnish language tests.

Taustatietolomake

Tällä lomakkeella kerätään taustatietoja osallistujista. Kaikki tiedot käsitellään luottamuksellisesti.

Ikä _____ vuotta   Sukupuoli [ ]Mies   [ ]Nainen

Onko näkösi normaali tai korjattu?

[ ] Normaali, ei silmälaseja tai piilolinssejä

[ ] Korjattu silmälaseilla

[ ] Korjattu piilolaseilla

Kuinka monta tuntia pelaat tietokone- tai videopelejä viikossa tällä hetkellä?

[ ] Yleensä 0, en pelaa pelejä tai pelaan vain harvoin.

[ ] 1 - 7 tuntia / viikko.

[ ] 7 - 14 tuntia / viikko.

[ ] yli 14 tuntia / viikko

Listaa peli tai pelit, joita pelaat eniten tällä hetkellä.

Jos olet aiemmin pelannut jotain peliä säännöllisesti, mutta et pelaa sitä enää, listaa tähän peli ja kuinka kauan sitten pelasit sitä.

Arvioi kokemuksesi autopelien pelaamisessa?

[ ] ei kokemusta

[ ] vähän kokemusta

[ ] kohtalaisen paljon kokemusta

[ ] paljon kokemusta

Mitä mieltä olet autopeleistä peligenrenä?

[ ] ei laisinkaan miellyttävä peligenre

[ ] jonkin verran miellyttävä peligenre

[ ] huomattavan miellyttävä peligenre

[ ] erittäin miellyttävä miellyttävä peligenre

Onko sinulla aiempaa kokemusta katseen käyttämisestä vuorovaikutustapana?

[ ] ei

[ ] jonkin verran kokemusta

[ ] paljon kokemusta

Onko sinulla tällä hetkellä mitään sairautta tai lääkitystä, joka voisi vaikuttaa näköösi tai silmän liikkeisiisi?

[ ] ei

[ ] kyllä; _____

Kiitos osallistumisesta tutkimukseen!