Eye tracking complemented HUD for video games
A perception evaluation of information display in FPS games

Emma Andersson
This thesis is submitted to the Faculty of Computing at Blekinge Institute of Technology in partial fulfilment of the requirements for the degree of Bachelor of Science in Digital Game Development. The thesis is equivalent to 10 weeks of full time studies.

The authors declare that they are the sole authors of this thesis and that they have not used any sources other than those listed in the bibliography and identified as references. They further declare that they have not submitted this thesis at any other institution to obtain a degree.

Contact Information:
Author: Emma Andersson
E-mail: emad17@student.bth.se

University advisor: M.Sc. Diego Navarro
Department of Computer Science
Abstract

Background. The heads-up display (HUD) is a useful tool for displaying information to the player in a game, but the HUD is not a part of the game world. This could take away from the desired experience of the game and block important parts of the main action screen. To counteract this the HUD mostly occupies the edges of the screen and avoids drawing the player’s attention away from the main action scene except when it has important information for the player. Only having the HUD visible when it has important information to the player could remove the distraction of the HUD while keeping all the benefits of having one.

Objectives. By using eye tracking to complement the HUD, the HUD can be invisible when the player does not use it, and change how the information is presented depending on where the player is looking. By creating a first-person shooter (FPS) game with a HUD complemented by eye tracking, then comparing it to how a normal HUD differed in terms of visibility and clutter, using a survey.

Methods. The game was created using the Tobii Unity SDK and modifying the FPS demo scene. To create the gaze sensitive HUD three scripts were created to produce the finished result. Giving the HUD the ability to make all HUD elements invisible and able to appear after passing a specific value or when the element has new information, the HUD also has the ability to present information close to the player’s gaze point in the of notifications. The game was then presented to the participants in the form of two videos one using the normal HUD and one using the gaze sensitive HUD. After watching the partisans answered a survey related to the videos.

Results. The gaze-based HUD was generally on par with the normal HUD. The most noticeable significant difference being that the normal HUDs ammunition counter and health bar was proffered over a less visible one.

Conclusions. From the results gathered having a gaze-based HUD does not make it harder to notify the player of important information and does not make the HUD less cluttered, compared to a normal HUD, but there is a difference between them.

Keywords: Eye tracking, Heads-up display (HUD), Gaze, First-person shooter (FPS), Perception evaluation
I want to thank Diego Navarro for helping me figure out a way to do this research while social distancing and giving me feedback and help throughout the whole process. I also want to thank Karin Johansson for being a professional voice when I needed to stop stressing. Lastly, I want to thank the participants that partook in this study, and especially those that helped me spread the word to more participants.
Abstract

Acknowledgments

1 Introduction

1.1 Aim and objectives ........................................ 3
1.2 Research question ........................................ 3
1.3 Document layout ........................................ 3
  1.3.1 Related Work .................................... 3
  1.3.2 Method ...................................... 3
  1.3.3 Results and Analysis ............................ 4
  1.3.4 Discussion ..................................... 4
  1.3.5 Conclusions .................................... 4
  1.3.6 Future Work .................................... 4

2 Related Work

2.1 Overview ........................................ 5
2.2 Gazeover ........................................ 5
2.3 FPS HUD ........................................ 6
2.4 Peripheral notifications ............................... 6
2.5 Not looking in games .................................. 7

3 Method

3.1 Tools ........................................ 9
3.2 The proposed techniques ............................... 10
  3.2.1 Invisible HUD ................................ 10
  3.2.2 Appearing HUD elements ........................ 10
  3.2.3 Eye tracking notification ....................... 10
3.3 Implementation ..................................... 11
  3.3.1 Tobii Unity SDK ................................ 11
  3.3.2 Creation of game elements ..................... 11
  3.3.3 Creating appearing HUD elements that stay visible .... 11
  3.3.4 Creating appearing HUD elements that becomes invisible .... 12
  3.3.5 Creating eye notifications ................... 12
  3.3.6 Recording the HUD ......................... 13
3.4 Survey ........................................ 13
3.5 Test of proportions .................................. 13
The Heads-Up-Display (HUD) is a common and helpful tool to convey information to the player in games [3]. The HUD is a link between the player and the game world, as it is not usually a part of the game world, only superimposed upon [6]. Making it suitable for e.g. gain easy access to information that is not suited to be displayed in the game world, for instance, how the player can perform actions in the game. HUDs can have many different appearances and information to convey, making them usually vary depending on the game and the genre. The main purpose of the HUD is to convey things to the player, but it may also be used as a way to control the game world through interactions with it, the HUD may also be very minimalist or non-existent. Some games decide to make the information diegetic instead of using a HUD, meaning making all information usually present on the HUD a part of the game world [8].

When creating the HUD for a game, it is important to not make it feel intrusive, confusing or irrelevant, because their purpose is to communicate important information about the game to the player [1]. HUDs that display a lot of information can be a nuisance for the player, as it obscures more of the games main action scene. Not having all the elements of a HUD with a lot of information visible, can help the player see and more easily understand the information the HUD is presenting. The HUD should be adaptable and straight forward [6]. When a HUD is displaying a lot of information constantly, the amount and the way it is displayed may be confusing and in the way, making the screen become cluttered with HUD elements, meaning it is perceived as irrelevant or confusing, giving the player to much information to easily find and understand everything the player wants from it [7]. To make the game less cluttered some necessary information may be removed creating a more minimalist HUD but loses the functionality of the removed elements. An other solution is to hide less relevant information. If the game knows what parts of the HUD the player is interested in, unnecessary elements could be removed, make it less intrusive without losing functionality. Some parts of the HUD do not always have to be displayed e.g. the quests the player have to complete and the mini-map are elements of the HUD which can be hidden when not looked at. Because they are helpful to have access to at a glance but are generally not needed to see until the player is looking for them again, this information only needs to be displayed when the player is looking at it or it has important information the player needs to notice. Sometimes relevant information is not something the player is looking for but need to notice [6].
Chapter 1. Introduction

Having the HUD occupy the edges of the screen is advantageous as the player’s peripheral vision is not very detailed making the HUD less of a distraction when the player is not using it, but movement and changes can be noticed, alerting the player of important changes [7]. A problem with this is that sometimes important information is not noticeable enough when needed. Games with a minimalist HUD are usually not very intrusive which makes them more easily prone to not be noticed when needed by the player. By moving elements on the HUD closer to the players gaze or making them more visible when they need to be noticed may make the HUD more noticeable when needed.

For games where having access to a HUD would be desired, but the aesthetics of the game would suffer from the constant presence of a HUD, and games suffering from having a cluttered HUD, need to find a way to hide the HUD or elements of the HUD. To do this developers can do different things, but having a normal HUD that is just invisible while still accessible may be the best solution [8, 6]. A way to address the issues of displaying all the information intended to be seen by the player without removing elements and not clutter the screen is the use of eye tracking. It may prove to be an efficient solution and knowing where the player is looking may also help the player get more information from a less noticeable HUD, as the game knows where the player is looking. With the use of eye tracking elements can be invisible to present a more efficient HUD and important information can be displayed closer to the player’s gaze. Having elements of the HUD that have been invisible become visible may also alert the player more of there presence then elements that already are visible [7].

Different implementations of eye tracking in games have been explored [11], but the use of eye tracking to complement the HUD have not been broadly explored. Despite this the use of making the HUD invisible using eye tracking has been implemented and is called clean user interface (clean UI) by the industry creating eye trackers for games and games using eye trackers 1.

In an initial literature search no publications have been found documenting the use of clean UI, by the author, but the use of eye tracking to complement the HUD can be used in more ways than just clean UI. With the use of clean UI, the screen is not cluttered with information but important information may not become noticed by the player. Asking the question if everything is hidden how can this be used to make it different from not having a HUD at all? when coming up with solutions, an article from Hartescu and Oikonomou (2011) proposed that eye tracking can be used to move or scale information to be more visible or used to guide the player’s eyes [4]. This combined with the idea of not always hiding the HUD gave inspiration to the techniques for this study. The use of eye tracking may alert the player in a noticeable way of important information and the advantage of having an invisible HUD can be used without the consequences of losing functionality.

---

1Tobii is the main source for this term. It is used as one of their examples of how eye tracking can be implemented in games. https://developer.tobii.com/pc-gaming/design-guidelines/explored-features/clean-ui/
1.1 Aim and objectives

The thesis aims to design and implement novel interaction techniques where eye tracking can become a complementary tool for the HUD to display information in a manner that notifies the player of important information while hiding irrelevant information.

The objective of this study:

- Create a game-like environment with meaningful HUD elements for a first-person shooter (FPS) game.
- The HUD is going to contain a health bar, ammunition counter, notification icon for the health bar, notification icon for the ammunition counter, mini-map, and an objective text-box.
- All HUD elements are going to be affected by gaze and display important information in a way that brings it to the player’s attention.
- A video of these techniques is going to be created as well as one without them.
- A survey is going to be created with questions regarding the videos related to the research. This survey is going to be answered by participants.
- Analyzed the data from the survey.

1.2 Research question

How perception and information display can be affected by an eye tracking complemented HUD when modifying visibility and placement of its elements, in an FPS game?

1.3 Document layout

1.3.1 Related Work

In related works, are all the study’s found related to using eye tracking to complement the HUD. Which are studies proposing eye tracking techniques that could be used on the HUD, the use of eye tracking to substitute mouse-over, and evaluation of different ways to display HUD elements in an FPS.

1.3.2 Method

In method, the method used to conducted this study is presented, then what materials were used when conducted this study, and lastly the process in which this study was conducted. Starting with the proposed techniques to create the HUD complemented by eye tracking. Then explain the implementation process of the proposed techniques and how they were recorded and presented to the participants, and lastly about the survey participants were asked to answer after watching the videos.
1.3.3 Results and Analysis
In results and analysis, the results from the survey are presented, and statistical comparisons of the data collected from the survey. This is presented using the Chi-Square test to evaluate if there are any significant differences.

1.3.4 Discussion
In discussion, the results gained from the previous chapter are discussed to get a better understanding of what they might mean sectioned into the visibility of the HUD, the effectively of alerting the player, and how cluttered it felt.

1.3.5 Conclusions
In conclusion, a summary of the results from this study is made and a concluded answer to the research question.

1.3.6 Future Work
In future work, all ideas of how this research subject can be expanded upon are presented.
Works related to the use of eye tracking to complement the HUD in games are very few and only discusses potential ways eye tracking may complement the HUD. Hartescu and Oikonomou (2011) in their work aims to propose ways eye tracking can be implemented in games to enhance them by studying previews work. In their work, they imply that eye tracking can be used with the placement of HUD elements. They propose that HUD elements the player pay the most attention to can be moved closer to the center of the screen to make it easier to see as it is closer to the player’s gaze. Another proposal they have regarding moving elements on the HUD is that certain information can be position adjacent to the player’s gaze to always be visible without needing to look at it, by taking advantage of peripheral vision. They also suggested that eye tracking can be used to guiding the player’s gaze to important elements. Which was very inspirational for this study.

2.1 Overview

There are many different ways eye tracking has been implemented in games and this study is one of them. Velloso and Carter (2016) in their study have collected and summarised what has been done in the field of using eye tracking in games. In their study, they only mention the HUD in relation to using buttons activated by gaze, that is invisible. By referring to the trend to not display information on the HUD, but through diegetic means [11]. As there has been a trend in not displaying information through a HUD. The effect of removing all non-diegetic displays (the HUD) in an FPS game has been studied and the study found that immersion may increase for expert players when playing without the HUD. [5].

2.2 Gazeover

Aslan, Dietz, and André (2018) in their work are using eye tracking as a tool to see where the user is looking and similarly to how mousing-over something gives the user information on what it is or how it is used. Their technique they call gazeover fulfills the same purpose and is intended as a proposed solution to gain mouse-over functions on a device that uses touch instead of a mouse. It may also be useful as a part of the HUD similar to this study and especially for games not using a courser. Using
Chapter 2. Related Work

this technique, users unfamiliar with the interface can get helpful information only by looking at it. In their work they used the Eye Tribe eye-tracker which has software that allows the user to change the input for the cursor to the user’s gaze point and hide the cursor, using this to create the gazeover technique. Participants that tested using the gazeover technique and the mouse-over technique concluded that the gazeover technique felt more natural and as they state "... the gazeover technique seems to have the potential to satisfy users' desire of self-improvement (i.e., HQS), and thus, may improve feelings associated with competence and flourishing." [2] the eye tracking technology was unfortunately lacking, making the partisans need more focus to succeed and making it harder to work with [2].

2.3 FPS HUD

Peacocke, Teather, et al. (2018) in their work are comparing different methods of displaying important information in FPS games to see how effective they are. The same as in this study, but in their work, they look at ammunition counters in the form of a bar, icons, and numbers on the HUD and icons and numbers placed to represent diegetic information in the game. To evaluate the different methods, they have participants shoot enemies and can only reload when the ammunition counter reaches zero. From this, they collect data about the number of shoots the participants shot before they realized they were out of ammo and the time it took to for the participants to reload after running out of bullets. The number displayed in the game as diegetic did the best in both tests, but this might be because it was closer to the center and the participants did not need to move their gaze to see it. They did similar tests to evaluate the display of the health and found that HUD options gave the best results and health represented as a bar was preferred the most despite it not giving the best results in the tests. The visual representation of the type of gun the player was using was tested similarly and none of the presented options showed results to prove it was better, but having the gun visible in the game and as an icon on the HUD was preferred over the other methods. The navigational aids were tested in a maze and the number of wrong turns and how long it took to reach the appointed area were recorded. Using a line that starts from the player’s position and follows the shortest path to the appointed area was as expected very good and showed the best results. The use of a mini-map to get to the appointed area was the second best after the line out of the tested options. Having a rotating mini-map showed a better result, but the none rotating mini-map was more preferred [8, 9].

2.4 Peripheral notifications

Mairena, Gutwin, and Cockburn (2019) are looking at peripheral notifications on a large display and how effective they are, in their study, which is useful for understanding this study’s notifications. A visual notification should be noticeable, but not distracting. As notability drops in peripheral vision the farther away from the
2.5. Not looking in games

In Gomez and Gellersen’s (2019) study, they look at how not looking in games can be a part of the game-play. Just like the HUD created for this study, the fact that the player is not looking at something has value. In their study, they present five categories of not looking in games, which range from looking to not seeing at all. In the category gaze effects, the player’s gaze has an impact on the game, and looking at something might have unintended consequences. In the category gaze attention, the player is forced to look at a fixed point in the game world while trying to continue to fulfill the main objective in the game. In the category gaze awareness, your opponent can see what you are looking at and you can see what your opponent is looking at. This means that the player needs to avoid looking at what they plan to do, to avoid the opponent seeing it. In the category gaze aversion, the player will be penalized if they are looking at something they are not supposed to look at and need to use their peripheral vision to avoid looking at objects they are not supposed to look at. The last category is gaze absence, which is when the player is not looking at all by closing one’s eyes as a part of the game [10].
Chapter 3

Method

The methodology used for this study is a User Study, evaluating the user’s perception. The method decided on to answer the research question was to first implement different ways of using eye tracking, that may affect the visibility of situational relevant information and make the HUD feel less cluttered. To evaluate if the created techniques made any difference the method of using a survey was decided on as the most fitting option to get the required data to do hypothesis testing, to answer the research question. Because of the COVID-19 pandemic participants answered the survey from home for safety and the invitation to partake in this study was given to contacts the author knew that are over 18 and have video game experience, as participants needed to have played an FPS game before partaking in the survey. The chosen participants were aware of the impatiens of answering seriously and were asked to spread it to potential participants. This method is not the most appropriate, but with the current circumstances, it was the best that could be done. Having participants actually play the game, in a controlled environment and more randomly selected participants would be better. Because with this method the participants can actually feel the difference of having a gaze-based HUD and therefore be able to answer which HUD they rather use. Actually creating the game the players were watching was more appropriate because its a controlled environment that can easily be modified and reproduced to only contain elements related to the study. The techniques in this study to the author’s knowledge do not all exist in one game, Making the creation of a game made for this study the best option.

3.1 Tools

For the implementation of the of the technique and the survey the following was used:

- Laptop model GL502vmk from ASUS Republic of Gamers, that has an Intel Core i7 7700HQ Processor and NVIDIA GeForce GTX 1060 graphics.
- Tobii eye tracker connected to the laptop.
- Unity, a game engine.
- Visual studio, to write the code for Unity in.
- Tobii Unity SDK.
• Krita, a drawing program.
• Google forms, for the survey.
• OBS, used to capture the videos.
• Tobii ghost to display the player gaze in the video.
• Google sheets.

3.2 The proposed techniques

To create a HUD that uses eye tracking and may influence the visibility of situational relevant information and make the HUD feel less cluttered, four techniques were decided on.

3.2.1 Invisible HUD

The first technique is to make all elements of the HUD invisible when not looked at. This technique was inspired from the idea of not having constantly displayed HUD elements to improve immersion and aesthetic of the game, but having constantly displayed information on the HUD can give the player easy access to information that can be very helpful. To have easy access to information through the HUD while keeping the aesthetic of not having a HUD, having a HUD that is only visible when looked at could be a solution to the problem.

3.2.2 Appearing HUD elements

For a HUD that is only visible when looked at to be a viable option, it should perform as well as a normal HUD or better. To improve the usability of the HUD it needs to alert the player that it is there when it has important information for the player. To alert the player that the HUD has important information that the player should know about, two techniques were considered. One is to have the HUD element constantly displayed as long as the situation does not change. The other technique is to display it until looked at, and after being looked at it returns to the invisible state. The first technique seems fitting to remind the player that the health is low even after looking at it, it would still be there as a reminder in the player’s peripheral until the player has more health. The seconded technique seems more fitting to messages like when the player gets a new objective, and it is important to know that the objective has changed, but the player may never need to look at the objective until it changes.

3.2.3 Eye tracking notification

While researching the use of eye tracking and the HUD, a research paper discussing the potential uses of eye tracking in games proposed that eye tracking can be used to place elements on the HUD, directed the players gaze and elements like health and ammunition can follow the players gaze to always have it visible without shifting ones gaze [4]. This inspired the last technique of using eye tracking to display a
notifying icon close to the players gaze point to maybe increase the possibility of the player noticing it no matter where they look.

3.3 Implementation

3.3.1 Tobii Unity SDK

To create the HUD used in this study the Tobii Unity SDK was used as a base. The scene used as the base was the scene where the player could try eye tracing in first person perspective called 04-FirstPersonExample. In the scene the player could aim and shoot and the SDK already included a HUD object that used Clean UI For Canvas script which lowered the transparency of the object when not looked at. This script was used to turn all HUD objects invisible when not looked at.

3.3.2 Creation of game elements

To create the game environment and everything needed for the study. It was decided that Krita would be used to create the needed icons. Which where then placed and made functional in Unity, where the game was created. Some simple enemies were created using the existing Target Dummy script of hitting targets and modified to remove themselves if hit enough, instead of making a noise and failing down. The enemies had a range in which they will shoot and move towards the player, only stopping when faced with a wall.

3.3.3 Creating appearing HUD elements that stay visible

To make HUD objects that are able to stay visible even when not looked at only after passing a user specified value, a script named Important Clean UI was created. Important Clean UI was used instead of Clean UI For Canvas to control transparency, but Clean UI For Canvas was used for detecting if the players gaze was intersecting with the object and the fade in and out time when looking at the object. Important Clean UI faded and appeared similarly to Clean UI For Canvas, by first saving the objects original transiency as the expected max value and when the player gazes at the object the script transitions object to its original transparency from whatever level of transparency it had. When the player is not looking at the object the transparency transitions to a transparency level decided by the user using a curve where 1 means completely transparent and 0 original transparency. To determine where on the curve to get the transparency level from for the object when it is not looked at, a variable was used to decide where on the curve to sample from. This variable can be accessed and determined by other scripts. If the element was a bar it will give a 1 when the bar is full and 0 when the bar is empty and anywhere in between when neither full or empty, if it was for a numbers it uses the number itself as the indicator. By creating a curve where only the part representing the low health or low ammunition has a transparency level close to 0 meaning the original transparency while everything higher than whats considered low health or low ammunition is 1 which makes the object completely transparent when not looked at. This script was
used for the health bar and ammunition counter. In figure 3.2 the health is low and the script makes it visible without the player needing to look at it, but the ammunition counter is invisible. In figure 3.3 the player is out of ammunition and the counter is visible, but the health is close to full and therefore not visible.

3.3.4 Creating appearing HUD elements that becomes invisible

To have an object become visible when it contains new information, but is not looked at, and then after being looked at by the player it returns to being invisible when not looked at, the script Notifying Clean UI was created. It is only influencing the transparency value for the script Clean UI For Canvas instead of replacing it. This script has a function that makes the object visible even when not looked at, that can be called by other scripts. Both the script that handles objectives and the mini-map calls this function in Notifying Clean UI to make it visible when desired. To turn the element visible Notifying Clean UI modifies the placement of Clean UI For Canvas key in the graph that determine the visibility when not being looked at. This key is only moved in the axis that determine visibility, not in time. Before ever moving the key the keys original values are saved and the values of the new key which makes the object visible when not seen is also saved, to easily replicate the effect without the values accidentally being shifted. When the player looks at the object when it is visible when not being looked at, the script Notifying Clean UI returns the key to its original position and makes the object invisible again when not looked at. The mini-map and objective uses this script. The mini-map appears when an enemy enters its area, but the player have already looked at it in figure 3.2 and 3.3. The objective appear after the player have completed an objective and a new objective have append in figure 3.2 the player have not looked at the new objective yet and is visible in figure 3.3 have the objective already been looked.

3.3.5 Creating eye notifications

When creating the appearing notifications Clean UI For Canvas is not being used. The notification follows the players gaze-point, but to avoid it blocking and disturbing the things the player is doing it needed to be placed with an offset from the players gaze. To create this offset the notification is given a fixed position beside or on the element on the screen it is notifying the player to look at (this is also the position used for displaying the notification without using eye tracking). By giving the notification a fixed position the position of the notification can be aimed towards the element of interest and moved along the vector until it is not being distracting, while still noticeable. This also create the effect of polling the players eyes in the right direction. By having it constantly visible and moved with the gaze-point created the effect that if the player tried to look at the notification it moved away from the players gaze which made the players eyes chase after it until it stopped at the element it tried to notify the player of. This effect was interesting but also annoying because it was almost always impossible to look directly at it. In the video the health notification was constantly moving with the gaze while the ammunition notification only updated its position when it appeared. To make the notifications
3.4 Survey

appear and fade away the script Eye Notifications used a function which could be
called by health and ammunition to activate the notification. When the function was
called a variable called opacityValue was set to 1, and was used to move along the
curve that determined the level of transparency the object had. To make it gradually
more transparent the variable called opacityValue was lowered until it reached 0 and
the notification was invisible again. Figure 3.2 and 3.3 displays the end resulting
notification that uses this script. The lower image in the figures uses the gaze to
position the notification, while the other uses the fixed position.

3.3.6 Recording the HUD

After creating the techniques and testing the game by fulfilling all the objectives.
All the eye tracking related code was deactivate to create a HUD that had the same
capabilities and looked the same as the one that used eye tracking. After fulfilling all
the objectives using this HUD to and seeing that it did not suffer any problems, the
game was ready to be recorded with OBS. The recordings of the HUDs were created
by the author recording herself fulfilling all the objectives using first the HUD with
the eye tracking techniques, then the HUD that did not use eye tracking, and allowing
herself to be hit to show all the created techniques.\(^1\)

3.4 Survey

In the survey the two videos were referred to as gaze HUD (G-HUD) and visible
HUD (V-HUD), G-HUD representing the HUD with the eye tracking techniques and
V-HUD representing the always visible HUD. Throughout the rest of this study any
references to one of the videos or the HUD the video is presenting is going to be
referred to as G-HUD or V-HUD depending on which HUD is discussed. The survey
was set up using google forms where participants could read about the study, what
they needed to do as participants, and about the data collected from the study. To
participate in this study participants needed to be over 18 and have experience in
playing FPS games. All participants were first informed that they were to watch the
two videos before answering more questions and informed of what the two videos
showed to explain what they were about to watch. After watching the two videos
the participants answered questions regarding the videos to finish the survey.

3.5 Test of proportions

For evaluating if the results showed any significant differences between the different
results the Chi-Square test was performed. The Chi-Square test was chosen because
the data acquired by the survey is categorical and some questions have more than two
options. To perform the Chi-Square test all the answers for the different categories
options the question had were placed in the observed section split into categories,
for the expected section the same number of answers were split up evenly between

\(^1\)Here are links to the videos that were created. G-HUD: https://youtu.be/z17Vo3yZBnA
V-HUD: https://youtu.be/mrh42AdNKBQ
categories to represent the null hypothesis, which is that the categories are answered evenly. E.g. the health bars preferred level of visibility from figure 4.1 used the Chi-Square test. The Chi-Square tests observed section contained the results from the survey (12, 2, 1, 0), and the expected section contained the number of participants divided with the number of answers (3.75, 3.75, 3.75, 3.75) if the test showed significance. The categories were compared two at a time. E.g. V-HUD (12) compared to G-HUD (2) with the expected section having the same number of participants (7, 7). The function CHISQ.TEST() in Google sheets was used to perform the test.

Figure 3.1: This is an image take from the game using the V-HUD. The G-HUD has all four of the elements in the same plays only difference being the transparency of the different elements. The mini-map in the top left corner, objective on the right and health and ammunition in bottom left corner. (the blue circle displays where the player is looking)
Figure 3.2: In this figure the player have just been hit to a critically low level. On the top using the V-HUD the notifying icon have appeared by the health bar to notify the player. On the bottom using the G-HUD the notifying icon have appeared close to the players gaze point to notify the player. (the blue circle displays where the player is looking)
Figure 3.3: In this figure the player is firing the last bullet. On the top using the V-HUD the notifying icon have appeared by the ammunition counter to notify the player. On the bottom using the G-HUD the notifying icon have appeared close to the players gaze point to notify the player. (the blue circle displays where the player is looking)
Chapter 4

Results and Analysis

In this study there were a total of 15 participants that watched the videos and answered the survey. The participants did not need to have played a first person shooter often, resulting in the participants having a mixture of experience, ranging from participants that play weekly to participants that do not do it very often. Having an always visible HUD is more preferred by the participants, but both HUDs preformed equally well at presenting important information. The only significant difference being that the G-HUD had significantly more participants that noticed the health notification, while the V-HUD had no significant difference in visibility. When it came to removing clutter the HUDs showed no significant difference either. But the results suggests that the participants may considered G-HUD to be less cluttered than the V-HUD.

Having a V-HUD was more preferred, especially for ammunition and health which were significantly more preferred over the less visible options. The objectives and mini-map showed no significance difference between the V-HUD and G-HUD, only the less visible options showed significantly lower preference (figure 4.1).

![Figure 4.1: Shows how visible the participants preferred the different HUD elements health, ammunition, objectives and mini-map to be.](image)

The two HUDs were often very evenly matched in performance. When it came to the perceived ability to present important information in a noticeable fashion there was no significant difference between the HUDs. The V-HUD was perceived slightly better by the participants (figure 4.2 and figure 4.3). In figure 4.3 none of
the participants perceived both the HUDs to be equally good at alerting the player of important changes, and there were significantly more participants that perceived either the V-HUD or the G-HUD to be better than the other at alerting the player of important information.

![Graph showing perceived ease of noticing important information]

Figure 4.2: Shows which of the two HUDs the participants perceived to be the easiest to notice important information with. For the ammunition counter the important information to notice is when the player runs out of ammo, the health bar when it is critically low and objectives when a the player is given a new objective.

![Graph showing results of question]

Figure 4.3: Shows the results from the question "Were important changes on the HUD more easily noticed using one of the HUDs?" where the participants could answer Yes the V-HUD, Yes the G-HUD, or No.

The icons that append to notify the player that they have run out of ammo or have critically low health were noticed by the majority of the participants, but only the G-HUDs health notification had a significantly greater portion of participants that noticed the notification (figure 4.4 and figure 4.5). The placement of the icons was seen as equally good (figure 4.6).

Both the HUDs were perceived to show mainly necessary information, but the V-HUD was perceived by a minority to show unnecessary information while the G-
Figure 4.4: Shows the results from the question "Did you notice the appearing icon when the player ran out of ammo?" for both the V-HUD and the G-HUD.

Figure 4.5: Shows the results from the question "Did you notice the appearing icon when the player had critically low health?" for both the V-HUD and the G-HUD.

HUD was not perceived to show unnecessary information by any of the participants (figure 4.7). When it came to if any of the HUDs felt more cluttered no significance was found, but only about 13 percent perceived the G-HUD to be more cluttered, which is a third of the number of participants that perceived the V-HUD to be more cluttered, and also less than half of the number of participants that perceived them to be equally cluttered. (figure 4.8).
Chapter 4. Results and Analysis

Figure 4.6: Shows the results from the question "Which placement of the appearing icon did you like the best?" for both the health notification icon and ammunition.

Figure 4.7: Shows how necessary all the shown elements on the HUD were perceived by the participants for both the G-HUD and the V-HUD. From 1 (No, it showed unnecessary elements) to 4 (Yes, it is only showed necessary elements). Positive answers (3, 4) are represented on the right side of 0 and negative answers (1, 2) on the left side and by a minus before the number of participants.

Figure 4.8: Shows the results from the question "Did any of the HUDs feel more cluttered than the other?" where the participants could answer Yes the V-HUD, Yes the G-HUD or No.
Chapter 5

Discussion

In general, the two different HUDs did not seem to have any big differences to easily conclude that one is better than the other when it comes to visibility and handling clutter. In this study the focus is centered around how the G-HUD compares to a normal HUD that does not use the eye tracking techniques, in terms of the perceived level of clutter and visibility.

The research question is, How perception and information display can be affected by an eye tracking complemented HUD when modifying visibility and placement of its elements, in an FPS game? From the results, perception and information display was not significantly affected by the use of an eye tracking complemented HUD. The only significant visibility difference is that significantly more participants noticed the health notification on the G-HUD while the V-HUD did not show any significance. The V-HUD showed being a significant preference for the health bar and ammunition counter. These findings suggest the HUDs being very equal in displaying information. These results could also be affected by preferring what they are used to or loving the idea of having a gaze affected HUD. The result may also be more accurate to how the HUD performs for the audience that watches game-play of games using a G-HUD. Making this study more useful for gauging how videos of game-play using a G-HUD is seen by the spectates if this is the case.

5.1 HUD visibility

In general, having all the HUD elements always visible was more preferable by the participants. This might be because they are used to always have it visible as eye tracking equipment is still very uncommon to have or need when playing games. The participants were only able to see the HUD from a spectator’s perspective and not the players when watching the video and could not experience the responsiveness of the HUD reacting to where you are looking. Which might have made the HUD feel unresponsive to the participants and made them feel that it was more inconvenient to use the G-HUD than it actually was, simply because the player didn’t look where the participants wanted to look. It might also mean that the participants preferred having the HUD always visible in their peripheral vision compared to not. This could be because the participants might not trust the game to display information when it is important to the player, and would rather have it always visible to have more control over the status of the HUD elements.
A majority of the participants preferred to have all the HUD elements always visible, but when it comes to informing the player the gap was not as big as the difference between health’s and ammunition’s preferred visibility. This suggests that some participants preferred having health and ammunition always displayed, but perceived the G-HUD to have more easily noticeable important information. This might be because they were more accustomed to always having the HUD visible and then will prefer it.

The objectives are not always visible in some games and some games do not use a mini-map for navigation which makes them less essential than health and ammunition, this might be why more participants desired the V-HUD over the G-HUD when it came to ammunition and health. There was none of the participants that wanted any of the HUD elements to be constantly invisible, suggesting that the participants believed all the chosen HUD elements to be important and wanted by the participants.

By giving the HUD the ability to become visible even when the player is not looking, was more wanted by the participants, especially when it comes to the objectives. This suggests that the techniques created to alert the player of changes on the HUD was more appreciated than not having them, but mainly when it came to objectives (figure 4.1).

### 5.2 Alerting the player

As for noticing important information there was no significance difference between the HUDs, this might be because both methods were perceived as equally efficient. For the ammunition counter, health bar, and objectives the survey did not give participants the option to choose that both methods can be equally efficient, making it a possibility that some of the participants perceived both to be equally good, but needed to choose one HUD over the other (figure 4.2). For the HUD in general the participants were given the option to choose that they were equally good, but none of the participants choose that, making it more plausible that both HUDs were seen as better at alerting the player of important changes. For some participants always having the HUD visible felt more advantageous while the others felt the opposite (figure 4.3). Having an option to make the V-HUD to a G-HUD could be a good option for the participants that felt that the G-HUD was better at alerting the player, while the rest could continue using a V-HUD. It seems that preference might be the biggest difference between the two different HUDs.

A lot of participants did not notice the notification when the player ran out of ammunition. This is probably because they were spectators instead of players and did not notice when the player tried to shoot, or because the notification did not follow the spectators eye position like the players (figure 4.4). It could also be that the notification only append ones while the other appeared more then ones if the player got hit again before healing.

But rewatching was not suggested or mentioned in the survey, to allow partici-
pants to rewatch the videos if they felt they needed to because of external factors or to better understand the survey, without influencing them to think rewatching was a part of the survey. Because of these circumstances the probability of people rewatching the G-HUD video to see the ammunition notification and see the health notification is higher and might have influenced some participant’s answers. But this might make it more accurate because the participant’s eyes are focused closer to where the player is looking, and the technique is meant to present the notification close to where the player is looking (figure 4.5).

5.3 Clutter

As for removing the clutter having the HUD only show necessary elements may make it feel less cluttered, but both the G-HUD and the V-HUD were seen as showing necessary elements. This might be because the four different HUD elements were easy to understand and are very common in games. Making the HUD not seem cluttered to the majority, making it hard to create a less cluttered HUD. Two participants believed that the V-HUD did showed unnecessary elements or it often showed unnecessary elements. This might be because they agreed that elements like objectives and mini-map might not be necessary to display all the time or the V-HUD looked cluttered to them because compared to the G-HUD it was in their eye (figure 4.7). About half of the participants did not feel that one of the HUDs was more cluttered than the other. This might be because the HUD was the same in both videos, the only difference being that the G-HUD was not always visible and the notification for health and ammunition did not have a fixed position. However it can also mean that they felt that they were equally cluttered by the participants that noticed some clutter, but the V-HUD felt the closest to being cluttered because it was always present, and the G-HUD because it appeared and disappeared without the participants knowing why yet, or when more than one appears and wants the player’s attention, giving them a feeling of it being equally cluttered as when it was always displayed.
Chapter 6

Conclusions

6.1 Conclusions

In conclusion, to answer the research question, How perception and information display can be affected by an eye tracking complemented HUD when modifying visibility and placement of its elements, in an FPS game? Having an eye tracking complemented HUD did not make the HUD less usable. The G-HUD showed very similar capabilities to the V-HUD, making the G-HUD a suitable option, as the results from this study shows that it is not a lesser version of the V-HUD. The G-HUD feeling less cluttered could not be proven, but showed results of being seen as less cluttered, but it was not a significant enough. Close to half of the participants believed the G-HUD made it easier to notice important changes on the HUD, while the bigger half believed the V-HUD made it easier to notice important changes on the HUD. That shows that almost half of the participants believed the G-HUD was superior when it came to presenting important information, while having the option to choose both to be equal. This shows that the techniques used to create the G-HUD were seen as improving the ability to alert the player by some participants. Having the added techniques to alert the player, especially for the objectives, was generally preferred over not using them, but only significantly for the objectives. Making the technique to present new information until it has been seen a good technique to use for a gaze based HUD.

The use of eye tracking to notify the player through a notification that appears close to the player’s eyes seems to be just as good as having it stationary, if not better, and from a spectators point of view having a HUD that disappears is almost as good, if not equally as good as an always visible one. As there were no significant difference in clutter between the HUDs. Makes the G-HUD more of a different method of presenting the HUD than improving it in terms of removing clutter and presenting information. Making the desired aesthetic of an invisible HUD one of the stronger reasons to use one.
Chapter 7

Future Work

7.1 Use a cluttered HUD

The HUD used for this study was very simple and all elements were seen as useful. This made it harder to make it less cluttered as it was not seen as cluttered by the participants. For future work having a HUD that is seen as cluttered use the techniques used in the G-HUD may give a better understanding of if the techniques can improve a cluttered HUD.

7.2 Other genres

FPS games do not need a lot of core HUD elements to classify them as a FPS game. Fast pace game-play may have a different impact on the effects of a gaze based HUD. For future work the same techniques for displaying the HUD could be tested on a turn based HUD to see if the techniques are more fitting for a turn based game. The techniques can also be tested in an role-playing game (RPG) setting which often have a lot of menus and different HUD element.

7.3 Playing the game

Having participants play the game instead of watching someone else play it may give other results, because the participants are then experiencing the HUD as a player and not a spectator. If participants were also able to choose which of the different techniques they prefer to have on the different element on the HUD, could give us a more element specific displacement preference and what composition of techniques may feel the best for players. In this study some participants seemed to like the gaze HUD, but disliked how low the visibility of the health and ammunition was. If the participants were able to modify which techniques the different elements should use there might have been a significant amount of participants that wanted the G-HUD, but have the health and ammunition constantly displayed. This could be handled similarly to Peacocke, Teather, et al.(2018) method where the participants tested all the options one by on [9], but giving the participants at the end the ability to combine techniques to make their perfect HUD.


7.4 Notification

The notifications were created in a way that polled the players attention to a specific object which could be used to guide the players attention. Future work could be to see if it is useful as a tutorial device or if it can be used for something else. Since this study could not be performed by participants playing the game, the notifications did not follow their eyes. This made it hard to tell if the two different methods of displaying the notifications where perceived to perform differently. For future work a study of the effects of having the notification constantly move with the players eyes and how it may perform differently to a notification that appears close to the players gaze and stays in that position.
References


Appendix A

Letter of invitation
Appendix A. Letter of invitation

Invitation letter to participate in the study of using eye tracking as a complementary tool to the heads-up display to remove clutter and present relevant information in a first-person shooter game

The heads-up display (HUD) is a useful tool to present information to the player. By using eye tracking this study aims to create a technique that makes the game feel less cluttered by the HUD and makes information relevant to the situation stand out more to easily inform the player. To evaluate if the technique makes the HUD feel less cluttered and relevant information more visible you are invited to participate.

As a participant you need to be 18 years or above, have played first-person shooters (FPS) before, play games weekly and it is recommended to have access to a computer with a normal size screen to play the included videos for this study, to get a more accurate experience of the needed eye movement to see the different elements of the HUD.

This study is voluntary and you can quit any time if you want to, it will only about 10 minutes.

As a participant you are going to watch two videos of the player following objectives and shooting in enemies in first-person using a constantly visible HUD in one video and a gaze interactive HUD in the other. After watching the videos, the participant is going to answer questions regarding the HUD in a survey.

The data collected from participants is anonymous and cannot be linked to you personally. All the data for this study is collected through the survey.

If you want to participate press the link below:

https://docs.google.com/forms/d/e/1FAIpQLScOSLG6sqqvTg3Jljy5M2w1EGCLrQ3xIrJGNxeXQDwCsmvwBnw/viewform?usp=sf_link

This study is for a student’s thesis at Blekinge Institute of Technology. If you have any questions you can contact us.

Student: Emma Andersson
Email: emad17@student.bth.se

Supervisor: Diego Navarro
Email: dna@bth.se
Appendix B

Consent form
Appendix B. Consent form

Consent form

This study is about the use of eye tracking to complement the heads-up-display (HUD) in removing clutter and alerting the player of important information in a first-person shooter (FPS) game. You as a participant are going to watch two videos one where all the HUD elements are visible all the time and one that uses eye tracking to affect the visibility and placement of HUD elements. After you have watched the videos you are going to answer questions regarding the different HUDs in the videos, in a survey.

To participate in this study you need to be over 18 years old and have experience in playing first-person shooter games. You consent to participate in this study by saying yes to the question "Do you want to participate and are over 18 years old?". Your participation is compliantly voluntary and you can quit and retract your consent any time you want.

The data collected from this study through the survey is going to be used for a student’s thesis at Blekinge Institute of Technology and it can not be traced back to any individual person.

If you have any questions regarding this study you can contact us.

Student: Emma Andersson
Email: emad17@student.bth.se

Supervisor: Diego Navarro
Email: dna@bth.se

*Obligatorisk

1. Do you want to participate and are over 18 years old? *

   Markera endast en oval.

   □ Yes
   □ No

2. Have you played first-person shooter games before? *

   Markera endast en oval.

   □ No
   □ Yes every week
   □ Yes every month
   □ Yes but not very often

https://docs.google.com/forms/d/1OJzLVMSnkWVxTScScJULVr_0 limitlessAH_zZtvjy/edit
Appendix C

Survey
Appendix C. Survey

Survey

First, you are going to watch two videos of the player playing a short game. The player has a list of objectives to follow visible on the upper right side of the game telling the player what they need to do to progress and finish the test. In the upper left corner of the game is a minimap following the player and exists to help the player see the surrounding enemies. In the bottom left corner of the game are the player’s health and ammunition counter.

When the ammunition counter reaches zero a yellow notifying icon will appear to signal that the player has run out of bullets and the player can’t shoot until they press the reload button. When the player’s health is one to two shots away from losing all their health a red notifying icon will appear to warn the player that they need to get away and heal. When watching the videos you can see the player’s gaze point (the moving blue circle) to give you a greater understanding of what the player is looking at.

In the first video eye tracking has no effect on the HUD and it is visible throughout the game. This HUD is going to be referred to as visible HUD (V-HUD) throughout this survey, the second video is using eye tracking to affect the HUD and is referred to as gaze HUD (G-HUD) throughout the survey.

Look at the two videos in full screen and in which order you want. You can click the Youtube button to open the video on Youtube to watch it in full screen.

After watching the videos answer the questions below.

*Obligatorisk

Visible HUD (V-HUD)

http://youtube.com/watch?v=mrh42AdNK8Q

Gaze HUD (G-HUD)

http://youtube.com/watch?v=z17Vo3yZ8nA

Ammunition counter
3. (V-HUD) Did you notice the appearing icon when the player ran out of ammo? *

![Icon Image]

The icon looks like this.

Markera endast en oval.

☐ Yes
☐ No

4. (G-HUD) Did you notice the appearing icon when the player ran out of ammo? *

Markera endast en oval.

☐ Yes
☐ No

5. Which placement of the appearing icon did you like the best? *

Markera endast en oval.

☐ G-HUD
☐ V-HUD

6. How visible do you want the ammunition counter to be? *

Markera endast en oval.

☐ Always visible (V-HUD)
☐ Only visible when looked at and when out of ammo (G-HUD)
☐ Only visible when looked at
☐ Not visible
Appendix C. Survey

7. Which HUD made it the easiest to notice when the player ran out of ammo? *
   - Markera endast en oval.
     - G-HUD
     - V-HUD

   Health bar

8. (V-HUD) Did you notice the appearing icon when the player had critically low health? *
   - The icon looks like this
     - Markera endast en oval.
     - Yes
     - No

9. (G-HUD) Did you notice the appearing icon when the player had critically low health? *
   - Markera endast en oval.
     - Yes
     - No

10. Which placement of the appearing icon did you like the best? *
    - Markera endast en oval.
      - G-HUD
      - V-HUD
11. How visible do you want the health bar to be? *

   *Markera endast en oval.

   - Always visible (V-HUD)
   - Only visible when looked at and when critically low (G-HUD)
   - Only visible when looked at
   - Not visible

12. Which HUD made it the easiest to notice when the player had low health? *

   *Markera endast en oval.

   - G-HUD
   - V-HUD

Objectives

13. How visible do you want the objectives to be? *

   *Markera endast en oval.

   - Always visible (V-HUD)
   - Only visible when looked at and when given a new objective (G-HUD)
   - Only visible when looked at
   - Not visible

14. Which HUD made it the easiest to notice the new objective? *

   *Markera endast en oval.

   - G-HUD
   - V-HUD

Minimap
15. How visible do you want the minimap to be? *

*Markera endast en oval.*

- [ ] Always visible (V-HUD)
- [ ] Only visible when looked at and when enemies are close (G-HUD)
- [ ] Only visible when looked at
- [ ] Not visible

The HUD in general

16. Did you feel that G-HUD only showed necessary elements on the HUD *

*Markera endast en oval.*

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>No, it showed unnecessary elements</td>
<td></td>
<td></td>
<td></td>
<td>Yes, it only showed necessary elements</td>
</tr>
</tbody>
</table>

17. Did you feel that V-HUD only showed necessary elements on the HUD *

*Markera endast en oval.*

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>No, it showed unnecessary elements</td>
<td></td>
<td></td>
<td></td>
<td>Yes, it only showed necessary elements</td>
</tr>
</tbody>
</table>

18. Were important changes on the HUD more easily noticed using one of the HUDs? *

*Markera endast en oval.*

- [ ] Yes the G-HUD
- [ ] Yes the V-HUD
- [ ] No
19. Did any of the HUDs feel more cluttered than the other? (feels more like it is in the way) *

Markera endast en oval.

☐ Yes the G-HUD
☐ Yes the V-HUD
☐ No