Effectively Communicating Critical Status Information in First-Person Shooter Games

EFFECTIVELY COMMUNICATING CRITICAL STATUS INFORMATION IN FIRST-PERSON SHOOTER GAMES

BY

MARGAREE PEACOCKE, B.Eng.

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AUTHOR:	Margaree Peacocke B.Eng., (Software Engineering) McMaster University, Hamilton, Canada
SUPERVISOR:	Dr. Jacques Carette
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This thesis is dedicated to my parents, for their unwavering support of my education.

Abstract

First-person shooter video games are wildly popular, with developers recently trying to make their games more "immersive" by communicating feedback within the game rather than on the heads-up display (HUD). This makes this genre of games an interesting platform for research into the effectiveness of different methods of communicating critical game information.

This thesis presents four user studies. Each experiment compares multiple methods of communicating one piece of critical game information of remaining ammunition, health, current weapon, and navigational aid. These studies looked at in game and HUD display methods for all pieces of information. Participant performance and preference was compared. Overall, this thesis advises developers of best choices for communicating each piece of critical game information depending on the needs of their game.

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Notation and abbreviations

- FPS = First-Person Shooter
- HUD = Heads-Up Display

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Chapter 1

Introduction

In first-person shooter (FPS) games, the player acts as a gunman seeing the game world from the first-person perspective while completing missions. FPS games are wildly popular. Forbes reports that 3 of the top 10 bestselling games of 2014 were FPS games (Kain, 2015). FPS games have the potential to earn companies enormous profits. For example, Activision's *Call of Duty: Modern Warfare 3* earned $400 million in the first 24 hours after release and $1 billion within 16 days (Hill, 2012). Player engagement with these games is crucial to their success.

Due to the widespread success of the genre and the large user base, FPS games are interesting platforms for HCI research. Although considerable research exists on FPS games (Babu, 2012; Conroy *et al.*, 2013; Fagerholt and Lorentzon, 2009; Fragoso, 2014; Hynninen, 2012; Isokoski and Martin, 2007; Llanos and Jørgensen, 2011; Looser *et al.*, 2005; Vicencio-Moreira *et al.*, 2014; Zaranek *et al.*, 2014), most focuses on input-related issues, for example, improving aiming or navigation. While these input-related tasks are undoubtedly relevant in designing improved UIs for FPS games, it is arguable that information displays have been comparatively underexplored.

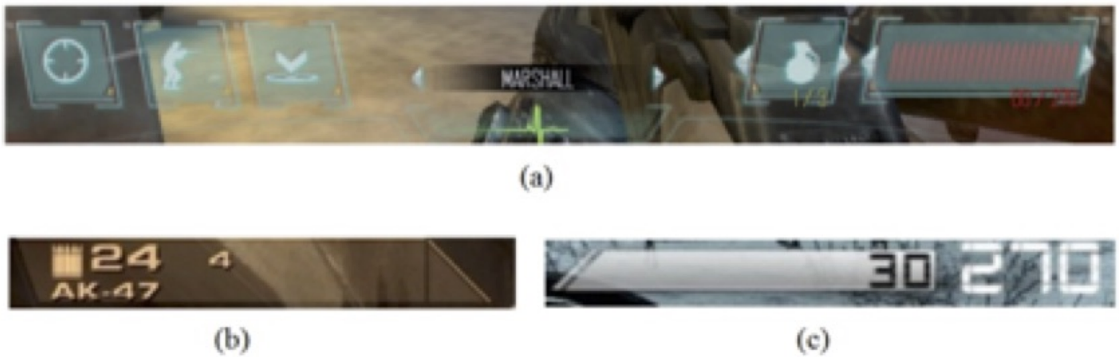


Figure 1.1: Example HUD displays. (a) *Call of Duty: Strike Team*, depicting controls (soft buttons, left-side), health (variation of bar), and ammunition as a number and bar; (b) *Tom Clancy's Rainbow Six: Vegas*, depicting ammunition numerically; (c) *Call of Duty: Ghosts* depicting ammunition both numerically and as a bar/meter.

The focus here is on the output-related task of effectively displaying and conveying in-game information to the player.

Feedback has long been recognized as a crucial factor in user interface design (Norman, 2002; Pagulayan *et al.*, 2002). When displaying in-game information, ¨feedback is crucial for player learning and satisfaction with the game¨ (Pagulayan *et al.*, 2002, p. 19). A migration away from heads-up display (HUD) feedback and towards in-game feedback is currently occurring in FPS games in order to increase player "immersion". Game immersion occurs when players "voluntarily adopt the game world as a primary world and reason from the character's point of view" (Fagerholt and Lorentzon, 2009, p. 69). Schaffer (Schaffer, 2007) argues that HUD elements located on the periphery of the display occupy very little game space. Hence, they do not distract from gameplay, yet effectively present necessary information to the player. Figure 1.1 depicts example HUDs from commercially available FPS games.

Nevertheless, game designers may gravitate away from HUDs, as they increasingly

(a) (b)

Figure 1.2: Diegetic game displays. (a) *Metro 2033*. (b) *Dead Space* displays the health meter (blue bar mounted on player's back) diegetically. The in-game inventory is also presented like an augmented reality display floating in front of the player.

attempt to produce more immersive experiences. HUDs may compromise immersion, so one alternative is the use of so-called diegetic displays (Wilson, 2006). With diegetic displays, game status information is conveyed using an in-game method rather than on the HUD (Fagerholt and Lorentzon, 2009). Information that is both displayed in the game space and recognized in the game fiction is considered diegetic.

Many types of in-game information can be displayed using a diegetic display. For example, displaying the player's current weapon by rendering it held by the character model (rather than showing its name or icon on the HUD) is a diegetic display. The weapon is visible within the game space and is part of the game fiction. Several best-selling FPS games (see Table 2.1) employ diegetic displays in an effort to enhance immersion. Figure 1.2 depicts sample diegetic displays.

Diegetic displays may be especially helpful in FPS games on mobile platforms. Traditional HUD-based displays may be more obtrusive on smaller devices; mobile devices have smaller screens, often lower pixel counts, and consequently have less screen real estate in which to display HUDs. An investigation of the effectiveness of diegetic displays relative to HUDs in terms of both player performance and enjoyment is presented here. There is relatively little quantitative research on the effectiveness of diegetic displays; most work in this realm is qualitative (Fagerholt and Lorentzon, 2009; Fragoso, 2014; Llanos and Jørgensen, 2011). Our primary research question is whether diegetic displays yield player performance comparable to HUDs. If diegetic displays offer better (or at least not worse) performance than HUDs, this makes a strong argument for their use, especially in mobile contexts.

1.1 Purpose

This research is necessary in order to inform the designers of future FPS games of best practices for communicating critical gameplay information. FPS games are increasingly using new display methods, and deviating away from the traditional HUDs. With this deviation comes unknowns, such as whether or not players like a display and, most importantly, will it allow players to succeed. The overall hypothesis of this work is that the best (in terms of both player performance and preference) method of communicating a piece of critical game information will vary between diegetic and non-diegetic depending on what the information is, and not necessarily just be diegetic where possible (when theming allows).

1.2 Overview of this Thesis

The broad topic of this research can be classified as finding the best "widgets" (defined as "an element of a graphical user interface that displays information or provides a specific way for a user to interact with the operating system and application" (Rouse, 2005) e.g., bar, number, etc.) for communicating crucial video game status information.

Chapter 2 describes a games analysis that was done in order to learn the pieces of information that are critical in video games for player success and how those pieces of information are commonly displayed. During this analysis the scope was narrowed to FPS video games because of their current movement away from traditional HUD displays (e.g., bar for health, bar/number for ammunition, etc.) as well as the genre's movement into tablet and mobile games.

Chapter 3 discusses work related to this topic.

Chapter 4 discusses the making of the game that was used for the empirical studies. It was decided that creating a custom game would provide more benefits than using an existing game. This game was created using the Unity game engine, and has a different level for each study (for each piece of game information), with each level having a custom task created to illicit a measurable response to the different displays used for each piece of information.

Chapters 5 - 8 describe 4 empirical user studies that investigated the best widgets for displaying the crucial game information discovered in the games analysis. Empirical studies were selected for their ability to learn about player performance, as performance is arguably the most important gauge of success of a display. When a gamer playing an FPS game is able to perform well, they are able to succeed in the game, and thus the display is also successful. These user studies were controlled experiments with human participants which isolated one piece of information in order to learn what method of communicating that piece of information participants performed best with.

Player preference was then learned through post-study surveys.

Chapter 5 presents a study that compared methods of displaying remaining ammunition in FPS games. Since the remaining ammunition display is important when players need to reload, study participants played a game level with unlimited ammunition but with a finite number of shots per clip. Upon running out of ammunition they had to notice that they had run out and then reload.

Chapter 6 contains the study of health displays. The player character was positioned in the centre of a semi-circular "arena" where enemies surrounded them, shooting at them. The player was tasked with pressing an escape button when their health became low (less than 20% remaining) while also achieving a high score by killing enemies.

Chapter 7 compared methods of displaying the player's currently equipped weapon (herein called "current weapon"). The level was similar to that in the remaining ammunition study: Groups of enemies of different colours would approach the participant's character and the participant would need to shoot them with the correct weapon, which was the one with the same colour as the enemy. An enemy could only be killed when the correct weapon was equipped.

Chapter 8 presents a study into methods of navigational aid. The participants completed a level where they were required to navigate a maze utilizing the navigational aid presented in each condition.

Chapter 9 presents the conclusion to this work, which provides a summary of the results, overall conclusions, and opportunities for future work.

Chapter 2

Games Analysis

An analysis of several popular shooter games across multiple platforms was undertaken. The purpose was to learn what information was consistently displayed in recent commercial games, and how it was displayed. The intent was to narrow down the most critical pieces of information displayed to study experimentally. The games analyzed included:

- Activisions' *Call of Duty: Strike Team, Call of Duty: Black Ops, Call of Duty: Ghosts,* and *Call of Duty: Advanced Warfare*
- Ubisoft's *Tom Clancy's Rainbow Six: Vegas*
- Bioware's *Mass Effect 3* and *Mass Effect Infiltrator*
- EA's *Dead Space*
- THQ's *Metro 2033*
- Microsoft Studios' *Halo 4*.

The analysis involved playing these games, watching gameplay videos, and reading publicly available game reviews. Games selected all contained a single-player campaign mode, as this analysis focused exclusively on this mode, rather than on multi-player modes. Many games selected also came from franchises which made games for PC, consoles, and smaller systems including iOS devices. These games were purposefully selected to compare how information was displayed across screen sizes.

Game	Health Display	Ammo Display	Weapon Display	Navigational Aid
Call of Duty: Black Ops (PC/Consoles, 2010)	Blood splatter	Number (HUD)	Name (HUD) + **In Front**	Arrow + Mini-Map
Call of Duty: Black Ops (Nintendo DS, 2010)	Tunnel Vision	Number (HUD)	Icon (HUD) + **In Front**	Mini-map
Call of Duty: Ghosts (PC/Consoles, 2013)	Blood splatter	Number (HUD) + Bar (HUD) + Icons (HUD)	**In Front**	Arrow
Call of Duty: Strike Team (iOS, 2013)	“Bar” (HUD)	Icons (HUD) + Number (HUD)	Icon (HUD) + **In Front**	Arrow
Call of Duty: Advanced Warfare (PC/Consoles, 2014)	Blood splatter	**Number (in game) + Icons (in game)**	**In Front**	Arrow
Tom Clancy's Rainbow Six: Vegas (PC, 2006)	Blurred Vision	Number (HUD)	Name (HUD) + **In Front**	Arrow
Tom Clancy's Rainbow Six: Vegas (Sony PSP, 2007)	Bar (HUD)	Icons (HUD)	Name (HUD) + Icon (HUD) + **In Front**	Arrow
Mass Effect 3 (PC/Console, 2012)	Bar (HUD)	Number (HUD) + Bar (HUD)	Icon (HUD) + **In Front**	Arrow
Mass Effect Infiltrator (iOS, 2012)	Blood splatter	Bar (HUD)	Icon (HUD) + **In Front**	Arrow
Dead Space 2 (PC/Consoles, 2011)	**Bar (in game)**	**Number (in game)**	**In Front**	**Line**
Dead Space (iOS, 2011)	**Bar (in game)**	**Number (in game)**	**In Front**	**Line**
Metro 2033 (PC/Consoles, 2010)	Blood splatter	**Icons (in game)** + Number (HUD)	**In Front**	**Compass**
Halo 4 (Xbox, 2012)	Bar (HUD) + red periphery	**Number (in game)** + Number (HUD) + Icons (HUD)	**In Front** + Icon (HUD)	Arrow + Mini-map

Table 2.1: Analysis of current game displays for health, remaining ammunition, and current weapon. Diegetic options are set in boldface font.

Four pieces of information were common to all games: player health, remaining ammunition, current weapon, and a navigational aid. These are thus arguably the most important pieces of status information communicated to the player in shooter games. The display methods used for health, ammo, weapon, and navigational aid are shown in Table 2.1. Games utilizing diegetic display options are shaded, with the diegetic option set in boldface. The results of the analysis for each piece of information are discussed within Sections 2.2 - 2.5.

2.1 Analysis of Specific Games

2.1.1 Call of Duty: Black Ops (PC/Consoles, 2010)

Figure 2.1: *Call of Duty: Black Ops* (Activision, 2010) for PC/Consoles. *Health*: blood splatter (not shown). *Ammunition*: number (bottom right). *Weapon*: name (bottom right), in front of character (in game). *Navigation*: yellow instructional dot (in game centre), mini-map (bottom right).

Call of Duty: Black Ops (Activision, 2010) was released in 2010 for both computers (PCs and OS X) and consoles (Xbox 360, PlayStation 3, and Nintendo Wii). Despite using multiple HUD widgets to communicate critical game information (see Figure 2.1), the HUD occupies only a small amount of screen space.

Health is communicated using blood splatter. This is a commonly used health display method in games within the *Call of Duty* franchise as well as in other FPS games.

Remaining ammunition is communicated using a number in the bottom right corner of the HUD, which states both the number of rounds in the current clip, and the number of clips remaining. The numbers become red when ammunition is low.

The **current weapon** is communicated by displaying the weapon in front of the player character, as well as displaying the weapon name in the bottom right corner of the HUD. The weapon's name is positioned above the remaining ammunition counts, making it clear to the player that the count is of remaining ammunition.

Navigational aid is done with in-game indicators, which are within the game space. These indicators communicate both instructions and distances. A small mini-map on the HUD is also used, which can be seen in the bottom right corner of Figure 2.1.

2.1.2 Call of Duty: Black Ops (Nintendo DS, 2010)

Along with being released for systems which allowed for larger screen displays, *Call of Duty: Black Ops* was released for the Nintendo DS. This game uses HUD displays to communicate the majority of critical game information, and is able to do this because of the Nintendo DS having two screens. The top screen is used for gameplay and the bottom screen contains status information. Information is able to constantly be displayed on the bottom screen without obstructing the gameplay on the top screen (see Figure 2.2).

Health is communicated using a red blur overlay, also called "tunnel vision", which can be seen in the top screen in Figure 2.2. This is similar to the blood splatter technique used in other *Call of Duty* games.

Remaining ammunition is communicated using a number on the HUD. This is located in the top left corner of the bottom Nintendo DS screen.

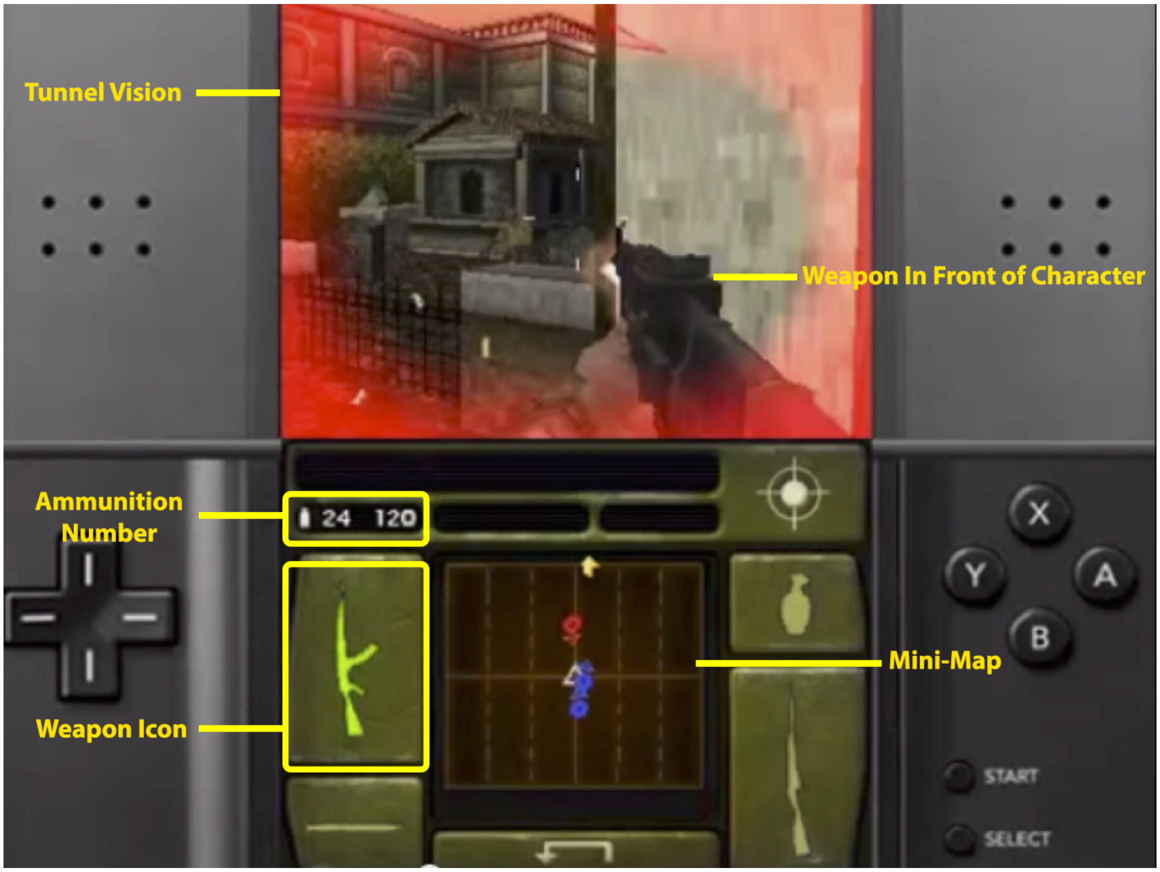


Figure 2.2: *Call of Duty: Black Ops* for Nintendo DS. *Health*: Tunnel Vision (top screen perimeter). *Ammunition*: number (bottom screen top right). *Weapon*: lit icon (bottom screen), in front of character (top screen). *Navigation*: mini-map (bottom screen centre)

The player's **current weapon** is communicated using both an icon on the HUD (bottom screen) and the weapon in front of the player character (top screen). There are three weapons icons that can be seen on the bottom screen, and the currently equipped weapon icon is lit up.

Navigational aid is done using a kind of mini-map, which is located in the middle of the bottom Nintendo DS screen and shows information including location of enemies and what direction to go in.

2.1.3 Call of Duty: Ghosts (PC/Consoles, 2013)

Figure 2.3: *Call of Duty: Ghosts* (Activision, 2013a) for PC/Consoles. *Health*: blood splatter (not shown). *Ammunition*: bar, number, and icons (bottom right). *Weapon*: in front of character (in game). *Navigation*: yellow dot (in game, not shown).

Call of Duty: Ghosts (Activision, 2013a) is a more recent release in the *Call of Duty* franchise. It was released for PC and consoles (PlayStation 3, PlayStation 4, Wii U, Xbox 360, and Xbox One) in 2013. The game's HUD is very minimal, as can be seen in Figure 2.3, and disappears when not applicable.

Health is communicated using blood splatter, as used in most of the other *Call of Duty* games discussed in this chapter.

Remaining ammunition is communicated using both a bar and number on the HUD positioned in the bottom right corner of the display. There is a bar and number to display the amount of ammunition in the current clip, and a number is used to display the remaining number of clips next to the bar. This disappears when the player is not in combat. Comparing this to the previous Call of Duty game, *Call of Duty: Black Ops*, discussed in Section 2.1.1, it is notable that the game information communication changed by using both a bar and number on the HUD rather than just the number. This bar allows players to obtain information at a glance, while the number allows them to receive more detailed information when they are able to take a longer glance, and so combining them may improve player performance. Remaining ammunition information disappears when not in battle.

The player's **current weapon** is communicated by placing the weapon in front of the player character.

Navigational aid is communicated through the in-game indicators, as in *Call of Duty: Black Ops* on PC/consoles.

2.1.4 Call of Duty: Strike Team (iOS, 2013)

Information communication in *Call of Duty: Strike Team* (Activision, 2013b) for iOS (iPad and iPhone) and Android can be described as very "HUD heavy" (see Figure 2.4) when compared to the methods used in recent *Call of Duty* games for larger displays (i.e. consoles and PC). Since the devices used to play this game have minimal buttons, it is necessary for there to be on screen controls for actions including shooting and crouching. These are located in the bottom left corner of the HUD.

The method of communicating **health** is an EKG (electrocardiogram) line which is located in the bottom middle of the HUD. This is a unique health display, and though not diegetic, it could potentially be more immersive to players. However, it may be harder for new players to interpret.

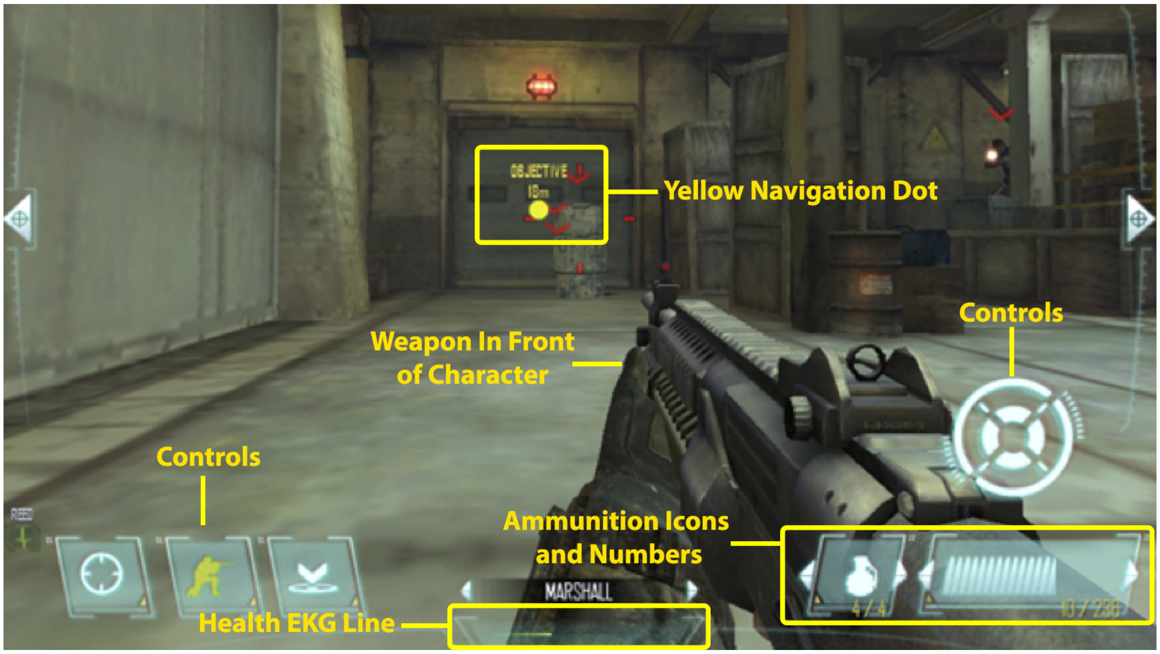


Figure 2.4: *Call of Duty: Strike Team* (Activision, 2013b) for iOS. *Health*: EKG Line (bottom centre). *Ammunition*: Icons and numbers (bottom right) *Weapon*: In front of character (in game). *Navigation*: yellow dot (centre). *Other*: Controls, bottom right and left.

The methods for communicating **remaining ammunition** are both a number and icon on the HUD located in the bottom right corner. The icons are used to display remaining bullets. There is also an icon representing the grenade positioned above the count of remaining grenades (see Figure 2.4). The number communicates the remaining ammunition and remaining clips.

The player's **current weapon** is communicated through the weapon in front of the player character.

Navigational aid is communicated through in-game indicators, as in the previously discussed *Call of Duty* games. One can be seen in Figure 2.4 in the centre of the screen in yellow.

2.1.5 Call of Duty: Advanced Warfare (PC/Consoles, 2014)

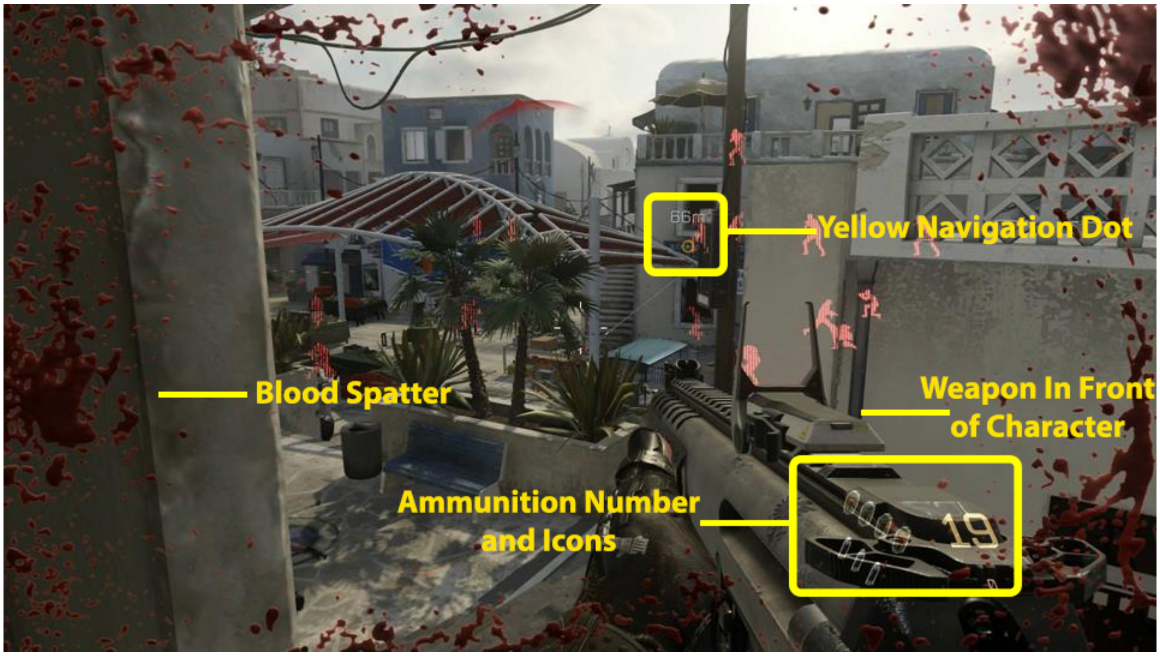


Figure 2.5: *Call of Duty: Advanced Warfare* (Activision, 2014) for PC/Consoles. *Health*: blood splatter. *Ammunition*: number and icons on gun (in game). *Weapon*: in front of character (in game). *Navigation*: yellow dot (centre).

Call of Duty: Advanced Warfare (Activision, 2014) is the most recent release in the Call of Duty franchise, and was released for PC and consoles (PlayStation 3, PlayStation 4, Xbox 360, and Xbox One). This game has no HUD, choosing to display critical game information in diegetic or semi-diegetic ways (see Figure 2.5).

Health is communicated through blood splatter and red "vision" (the screen becomes increasingly red as more damage is taken). The blood splatter is mostly around the perimeter of the game space, growing denser rather than shrinking the game space as more damage is taken. The red vision filter affects the entire game space.

Remaining ammunition is communicated through numbers and icons on the weapon. A large number on top of the player's current weapon communicates the number of bullets remaining in the current clip, while icons along the side of the weapon show the number of remaining grenades and clips. The weapon is futuristic and "hi-tech" enough that this display fits with theming.

The **current weapon** is communicated through the weapon in front of the player character.

Navigational aid has stayed consistent through the *Call of Duty* games released for PC/consoles in this game analysis in that this game again uses the yellow in-game indicator which is accompanied by instructions and distances.

2.1.6 Tom Clancy's Rainbow Six: Vegas (PC/Consoles, 2006)

Tom Clancy's Rainbow Six: Vegas (Ubisoft, 2006) for PC and consoles has a HUD occupying the bottom portion of the screen. Its translucent appearance allows it to not cover the game space. Other information including character position (crouched, standing, etc.) is also displayed on the HUD.

Health is communicated through blurred vision, which gets increasingly blurred as health decreases.

Remaining ammunition is communicated through a number on the HUD located in the translucent overlay in the bottom middle of the HUD. An on screen indicator in the centre of the screen also says "Low Ammo" when low on ammunition.

The **current weapon** is communicated through both the weapon in front of the player character and the name on the HUD. The name is located with the remaining ammunition number in the bottom middle, clarifying that the count is for that specific weapon's remaining ammunition.

Figure 2.6: *Tom Clancy's Rainbow Six: Vegas* (Ubisoft, 2006) for PC/consoles. *Health*: blurred vision (not shown) *Ammunition*: number (bottom middle). *Weapon*: name (bottom middle), in front of character (in game). *Navigation*: Arrow (not shown)

Navigational aid is done through an **arrow** in game.

2.1.7 Tom Clancy's Rainbow Six: Vegas (PSP, 2007)

Tom Clancy's Rainbow Six: Vegas (Ubisoft, 2007) was also released for Sony's PlayStation Portable (PSP) and mobile phones. The majority of critical game information in the PSP release of this game is communicated on the HUD.

Health is communicated using a bar on the HUD, located in the bottom left corner. It is a vertical bar, rather than the traditional horizontal bar. This is presumably to preserve space in a small display.

Remaining ammunition is communicated using icons and numbers on the HUD.

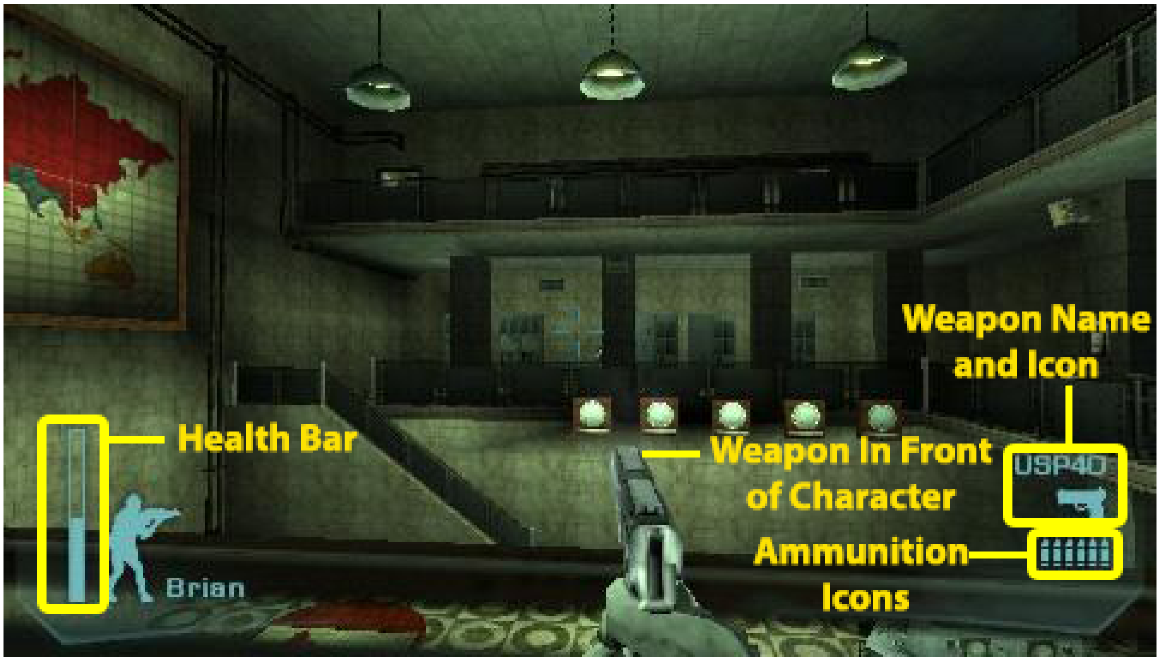


Figure 2.7: *Tom Clancy's Rainbow Six: Vegas* (Ubisoft, 2007) for Sony's PSP. *Health*: bar (bottom left). *Ammunition*: icons and number (bottom right). *Weapon*: name and icon (bottom right), in front of character (in game). *Navigation*: arrow (not shown).

The icons on the HUD are used to display the number of bullets left in the current clip. A number next to an icon is used to display the number of clips remaining. These are located in the bottom right corner of the HUD.

The player's **current weapon** is communicated by showing the weapon in front of the player character, as well as through an icon and name on the HUD. These are located in the bottom right corner. The name and icon are positioned above the icons communicating remaining ammunition.

Navigational aid is done through an in-game arrow, which also communicates instructions.

2.1.8 Mass Effect 3 (PC/Consoles, 2012)

Figure 2.8: *Mass Effect 3* (Bioware, 2012a). *Health*: bar (bottom middle). *Ammunition*: bar and number (bottom left). *Weapon*: icon (bottom left), in front of character (in game, not shown). *Navigation* (not shown)

Mass Effect 3 (Bioware, 2012a) is a third-person shooter game released for PC and consoles (PlayStation 3, Xbox 360, and Wii U) in 2012. Third-person shooter games were also looked at in this games analysis as they provide further inspiration for diegetic display options. This game primarily displays important game information on the HUD. The HUD elements are styled in a unique way that fits with the game's theming (see Figure 2.8).

Health is communicated through a bar which takes up a large portion of the bottom middle of the HUD.

Remaining ammunition is communicated using both a bar and a number on the HUD. The bar provides information that is quick to view, while the number provides more detailed information when the player has time for a longer glance. This is located in the bottom left corner of the HUD.

The player's **current weapon** is communicated using both the weapon in front of the player character and an icon on the HUD. The icon is positioned with the remaining ammunition bar and icon in the bottom left corner of the HUD.

Navigational aid is provided through an **in game arrow**.

2.1.9 Mass Effect Infiltrator (iOS, 2012)

Figure 2.9: *Mass Effect Infiltrator* (Bioware, 2012b) for iOS. *Health*: blood splatter (not shown). *Ammunition*: bar (top right). *Weapon*: icon (top right), in front of character (in game). *Navigation* arrow (not shown). *Other*: Powers (top left).

Mass Effect Infiltrator (Bioware, 2012b) is a third-person shooter game released for iOS in 2012. The HUD is relatively minimal, avoiding on-screen controls unlike *Call of Duty: Strike Team* (see Section 2.1.4). Controlling tasks such as aiming and shooting are instead done by having the player touch certain parts of the screen without having an indicator present. The gameplay can be seen in Figure 2.9.

Health is communicated through blood splatter on the screen.

Remaining ammunition is communicated through a "heat meter" located in the top right corner of the HUD. This becomes increasingly red as more shots are taken, symbolizing the weapon "overheating" once it is full. When the weapon is overheated, no more shots can be taken. Similar to regenerating health, the level of red decreases with time, allowing the player to take more shots once no longer full.

The **current weapon** is communicated through icons on the HUD, in the top right corner, which represent what style of weapon the player currently has equipped.

Navigational aid is done through an arrow located in the top middle of the game space.

2.1.10 Dead Space 2 (PC/Consoles, 2011)

Dead Space 2 (EA, 2011a) is a third-person shooter survival horror game released for PC and consoles (PlayStation 3 and Xbox 360) in 2011. It is highly praised for its lack of HUD; its futuristic theming allows for all important game information to be communicated using diegetic methods. Much is communicated through hologram. Gameplay can be seen in Figure 2.10.

Health is communicated through a bar on the player character's back that decreases towards the bottom as health is lost.

Remaining ammunition is communicated through a hovering number on top

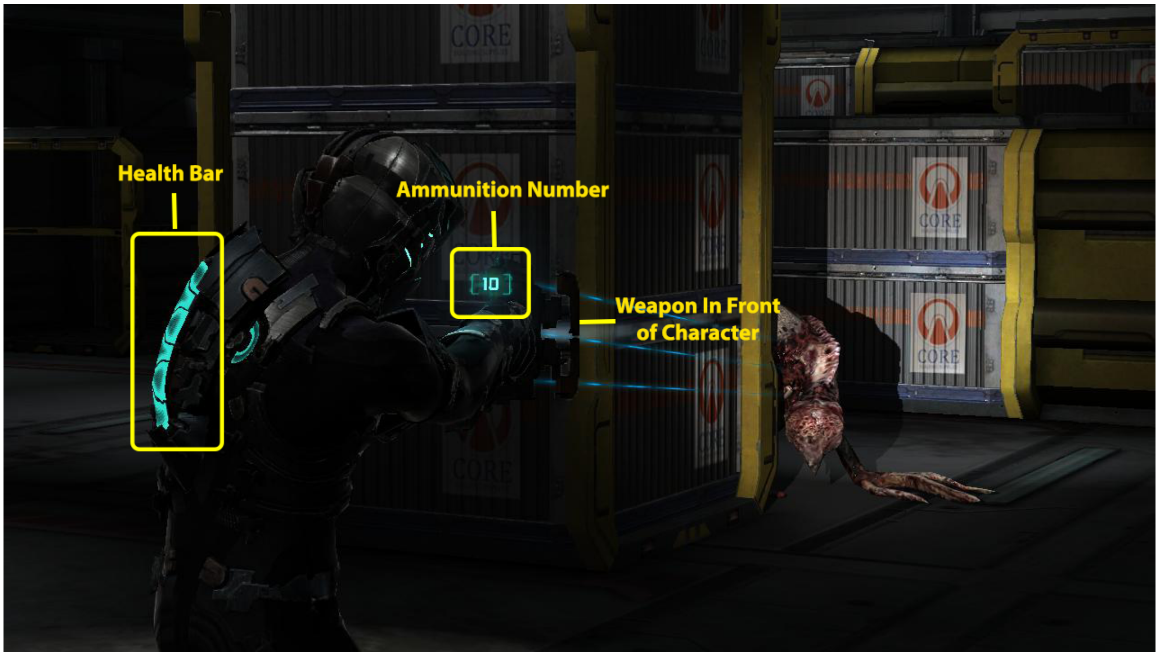


Figure 2.10: *Dead Space 2* (EA, 2011a) for PC/Consoles. *Health*: bar (in game, on character). *Ammunition*: number (on gun, in game). *Weapon*: in front of character (in game). *Navigation*: line (not shown)

of the front of the player character's weapon.

The **current weapon** is communicated through the weapon in front of the player character.

Navigational aid is communicated using a locator system, which appears as a navigation line directing the player to their objective.

2.1.11 Dead Space (iOS, 2011)

Dead Space (EA, 2011b) is a third-person shooter survival horror game released for mobile devices, including iOS, Blackberry, and Android platforms, in 2011. Though it is a third-person shooter, it functions very similarly to a first-person shooter, and because of its innovative methods to communicate critical game information, it is of

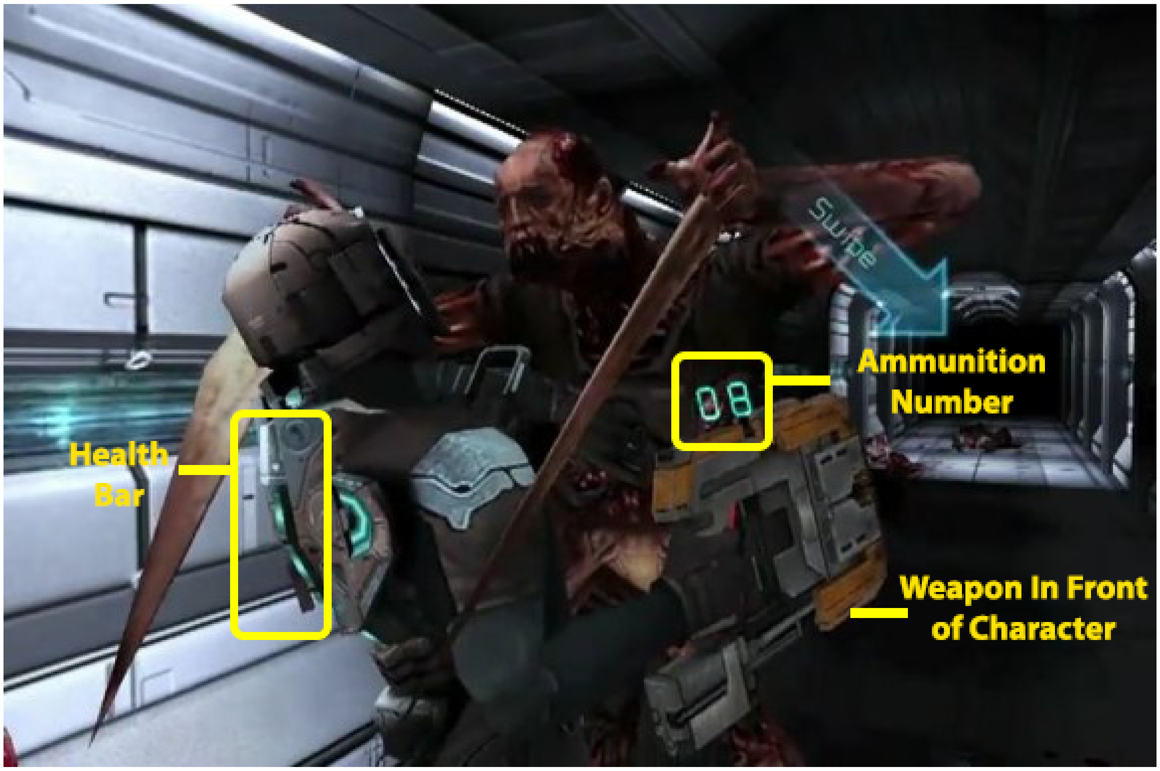


Figure 2.11: *Dead Space* (EA, 2011b) for iOS. *Health*: bar (on character, in game). *Ammunition*: number (on gun, in game). *Weapon*: in front of character (in game). *Navigation*: line (not shown)

great use to this analysis and to first-person shooter games. As with *Dead Space 2*, this game has no HUD. As in *Mass Effect Infiltrator*, the game is controlled through location specific swipes and taps on the screen, as well as through tilt. Instructions for using the swipes can be seen in Figure 2.11.

Health is communicated through a bar on the player character's back that decreases towards the bottom as health is lost.

Remaining ammunition is communicated through a hovering number on top of the front of the player character's weapon.

The **current weapon** is communicated through the weapon in front of the player character.

Navigational aid is communicated using a locator system, which appears as a navigation line directing the player to their objective.

2.1.12 Metro 2033 (PC/Consoles, 2010)

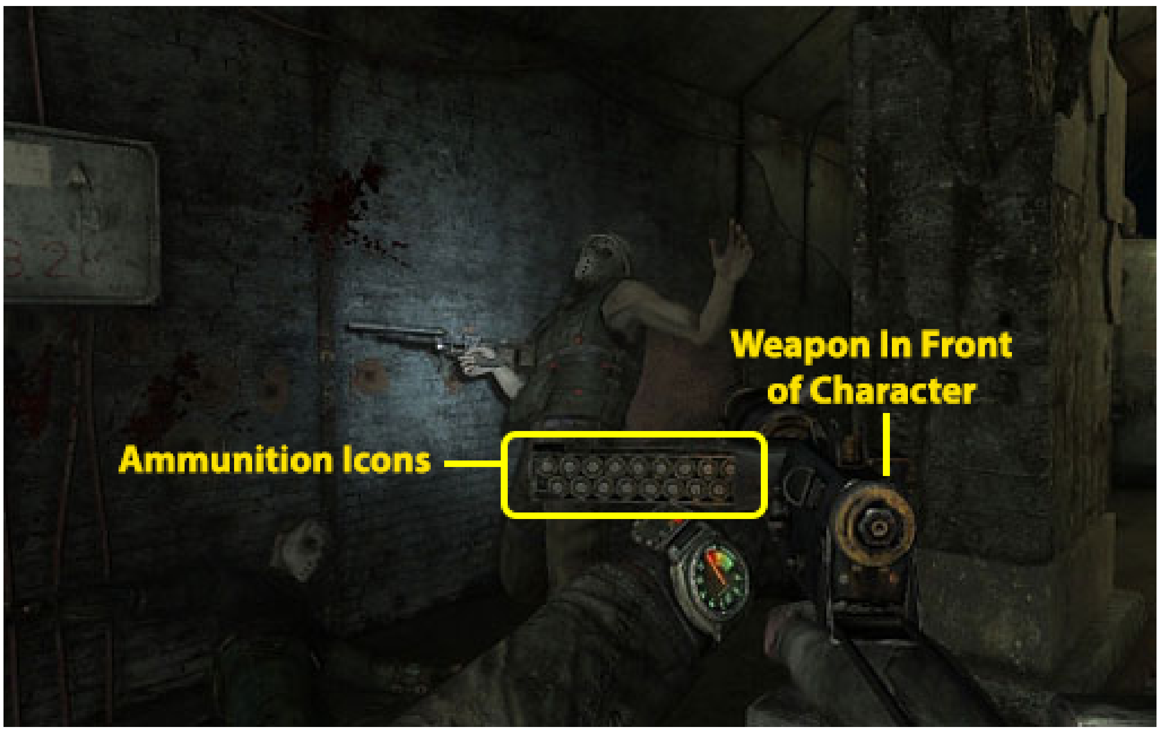


Figure 2.12: *Metro 2033* (THQ, 2010) for PC. *Health*: red periphery (not shown). *Ammunition*: icons on gun (in game). *Weapon*: in front of character (in game). *Navigation*: compass (not shown)

Metro 2033 (THQ, 2010) is a first-person shooter survival horror game released for computer systems (PC, OS X, and Linux), and consoles (Xbox 360, PlayStation 4, and Xbox One). The game favours diegetic and semi-diegetic communication methods over traditional HUDs. An example of gameplay can be seen in Figure 2.12.

Health is communicated through having the edges of the screen appear increasingly red as well as an audible heart beat.

Remaining Ammunition is communicated through partly visible bullets on the gun. When in battle, numbers representing the number of clips and bullets remaining are visible on the HUD.

Current weapon is communicated by showing the weapon in front of the player character.

Navigational aid is communicated through a compass, which must be accessed by looking at the character's journal and so is not always on screen.

2.1.13 Halo 4 (Xbox, 2012)

Figure 2.13: *Halo 4* (Studios, 2012). *Health*: bar (top middle). *Ammunition*: number on gun (in game), icons (top right) and number (top right). *Weapon*: in front of character (in game). *Navigation*: mini-map (bottom left)

Halo 4 (Studios, 2012) is a first-person shooter game released for Xbox 360 and Xbox One starting in 2012. This game favours HUD communication of critical game status information. An example of gameplay can be seen in the screenshot in Figure 2.13.

Health is communicated using a bar in the top middle. When health gets low the screen also gets red in the periphery and an alarm sounds.

Remaining Ammunition is communicated using different methods which depend on the weapon equipped. One futuristic weapon, shown equipped in Figure 2.13, places the number of bullets remaining on the gun as a number, along with icons in the top right of the HUD. With another gun equipped, there is a bar with a percentage of ammunition remaining which appears in the top right of the HUD. With a pistol equipped, an icon bar shows the remaining ammunition in the top right of the HUD.

The **current Weapon** is communicated through the weapon in front of the player character, as well as by an icon in the top right corner, located with the remaining ammunition information.

Navigational aid is communicated using an informational arrow with objective distance information. There is also somewhat of a mini-map in the bottom left corner, though this does not contain navigation information other than location of enemies.

2.2 Health Analysis Conclusions

Throughout the games analyzed in this chapter, variations on “blood splatter” (e.g., blurred vision, red periphery, etc.) were the most common method used to communicate health. It was seen in 6/8 of the games analyzed for PC/consoles and 2/5 of the games analyzed for smaller devices (see Table 2.1). Blood splatter is considered to be a meta-perception because it is not in the game space but represents something within the game's fiction (Fagerholt and Lorentzon, 2009). Developers use this method in an attempt to create more immersion, rather than displaying the information on the HUD (e.g., as with a bar on the HUD). However, past studies (Fragoso, 2014) have observed that gamers do not necessarily prefer this display method due to its obstruction of the game space causing more damage in some cases. This therefore would have the opposite effect of the immersion that developers are striving to create. This blood splatter was one of the conditions tested in the health study in Chapter 6, and the condition was named splatter (S).

Interesting to note is the evolution of the blood splatter in the Call of Duty games. Earlier releases used red "tunnel vision" which then evolved into the blood splatter effect, often paired with blurred vision. The blood splatter in the most recent release, *Call of Duty: Advance Warfare*, has been changed to occupy less of the game space, instead just growing denser around the perimeter as health reduces. The screen also develops a red tint.

The bar (whether on the HUD, or in the game as in *Dead Space*) is viewed as being useful for relatively large quantities and can be read at a glance (Adams, 2010). The positioning of the health bar varies. In the games analyzed here, where it appears on the HUD, it appears on the HUD in the bottom middle in 2/4 games, top middle in 1/4 games and bottom left in 1/4 games. For this reason when the bar was tested in the health study presented in Chapter 6 it is tested in three positions, the bottom centre of the display (bar-on-HUD-bottom, BHB), the top left of the display (bar-on-HUD-left, BHL), and the top centre of the display (bar-on-HUD-top, BHT).

Dead Space took the bar health display and attempted to make it more immersive for gamers by placing the bar on the back of the player character, thus putting a bar display within the game space and the game's fiction. Because of *Dead Space* being a third-person shooter game this is possible. In order to recreate this in a first-person shooter game, some creativity is necessary. For the health study, the diegetic bar was positioned in the player character's arm and is presented as the bar-in-game (BG) condition.

In addition to the displays mentioned previously, widgets that were used for other pieces of game information but not for health were also tested. This was done in order to learn if these widgets were effective in communicating health. These included the number and icons on the HUD. Each of these was tested in the same 3 positions that the bar on the HUD was tested in. The icons were also tested on the player character's arm in the same method as the bar-in-game (BG) and the condition was named icons-in-game (IG).

This games analysis overall led to 12 health displays being tested to learn which one led to best player performance. This study is presented in Chapter 6.

2.3 Remaining Ammunition Analysis Conclusions

As seen in Table 2.1, the most common HUD ammunition displays are numeric, icons displayed in a bar, and bar/meter. In the experiment, these displays are referred to as number-on-HUD (NH), icons-on-HUD (IH), and bar-on-HUD (BH) respectively. These are non-diegetic HUD displays since they are not within the game's fiction and are not a part of the 3D game space. Numeric displays show a numeric count, typically on a HUD (see Figure 1.1b). They are useful for displaying "amounts of things for which you would normally use digits in the real world" (Adams, 2010, p.

225), such as ammunition. Numeric displays are especially useful for relatively large quantities. Bars (see Figure 1.1c) are also useful for large quantities (Adams, 2010) These are often presented like a meter that is full at the maximum quantity, and empties as appropriate. The primary benefit of presenting information this way is that bars can be interpreted at a glance.

Icon bars (Figure 1.1a), or "small multiples" (Adams, 2010), are best for small-integer numeric data. Icons are thus useful for indicating the quantities of around five items or less. Players have difficulty taking in greater than five items at a glance, and will have greater difficulty remembering the number (Adams, 2010). However, Adams suggests using graphical indicators rather than text or numbers because they are more easily read at a glance (Adams, 2010). This analysis indicates that the bar and numeric displays are sometimes used together. This offers players the ability to both read at a glance and receive more detailed information as desired.

An interesting finding from this analysis is that there is little consistency in diegetic ammunition displays. Since this is a new area, design standards are not yet defined. It is important to develop best practices early. This helps inform the design of future games, which "follow the trends set by the gaming community to shorten the learning curve" (Federoff, 2002). *Dead Space* (see Figure 2.10), praised for its lack of a HUD, relies on diegetic displays: Ammo is displayed using a numeric count positioned directly above the weapon. This coheres well with its futuristic theming.

Halo 4 uses a display similar to *Dead Space* when the player has more futuristic weapons equipped, though the ammo count is built into the gun rather than above it. Another diegetic option is used in 4A Games' *Metro 2033*, which directly visualizes bullets through the gun. This is a diegetic variant of the HUD icon bar, with the icons now displayed in game. A similar display to *Halo 4* (a numeric count on the weapon) was implemented for the remaining ammunition study presented in Chapter 5 because of the game's popularity, and refer to this ammunition display as number-in-game (NG). A display similar to that used by *Metro 2033* was implemented and called irons-in-game (IG). This game displays bullet icons in-game beside the player's gun.

Based on this analysis, an experiment was conducted comparing five of the most common ammunition display options. These include the previously mentioned bar-on-HUD (BH), number-on-HUD (NH), icons-on-HUD (IH), number-in-game (NG), and icons-in-game (IG).

2.4 Current Weapon Analysis Conclusions

In all FPS games in this analysis, the current weapon is communicated by displaying it in front of the player character as though they are actually carrying it. Several games which often already use HUD widgets to communicate other game information will also use either the name, icon, or both to communicate current weapon. When this occurs the name/icon is positioned with the remaining ammunition display, clarifying that the bar/number is representative of the ammunition and not health.

The study in this thesis isolated the different displays in order to learn how they performed separately and in different corners of the display. A weapon in front of the player character was used as one display, named in-front (IF). The icon was tested as well, appearing in the bottom right and top left corners, in order to test the effect of positioning on performance and preference. These icon displays are known as icon-on-HUD-right (IHR) and icon-on-HUD-left (IHL). The name display was also tested in the bottom right and top left corners. These displays are called name-on-HUD-right (NHR) and name-on-HUD-left (NHL). This study is presented in Chapter 7.

2.5 Navigational Aid Analysis Conclusions

The majority of games in this analysis used a form of arrow/in game indicator in the game space for navigation. The in game indicator often will contain information such as distances or other commands to assist in navigation. In most games this is not considered to be a diegetic element, because although it is in the game space it is not within the game's fiction. This display method is a "geometric element", because it exists in the game space but is not explained by the game's fiction. This is tested in the navigational aid study in this paper as the wayfinding arrow (WA) navigation display.

The mini-map was only seen used in three games in this analysis. However, this analysis was only concerned with the single-player campaign mode and not with multiplayer mode (where mini-maps are usually more common because of their ability to aid in locating team members). The mini-map has two implementations in the study presented in this work. Both are non-diegetic HUD elements which used to be very common in games.The first implementation, mini-map still (MMS), which shows a small map depicting an overhead view of the game positioned at the bottom-left corner of the screen. The player is represented as an arrow, and the 'north' direction is always 'up' on the map (hence the player arrow rotates on the minimap to indicate the direction the player is facing in-game). The player is represented by an arrow on the map and the arrow will rotate depending on the direction that the player is facing. The second implementation, mini-map rotate (MMR), also has the mini-map in the bottom left corner, but the mini-map rotates so that the participant's arrow is always pointing up.

The compass, a diegetic element (it exists in the game's fiction and the game space), functions very similarly to the wayfinding arrow (WA) but in a way which is in both the game space and the game's fiction. It provides a real-world navigation experience. It was another display tested in the study presented in Chapter 8, and is referred to as compass (C) in the study.

Another display discovered in the games analysis, the objective locator line in *Dead Space*, was also tested in the navigation display study. This option, if used in FPS games, requires appropriate theming in order for it to be appropriate for use. It is referred to as navigation line (NL) in the navigation display study, and is considered a diegetic element.

One other navigational aid was tested in the navigation display study in Chapter 8 which was not discovered in this games analysis: a light pillar, as seen in *The Legend of Zelda*. This was selected in order to learn how navigation displays from other genres would perform when brought into the FPS genre. This navigation display would be considered a diegetic display so long as the game's fiction is able to explain it. In the study it was referred to as light pillar (LP).

Chapter 3

Related Work

There is a great deal of research on FPS games in the HCI literature (Klochek and MacKenzie, 2006; Natapov and MacKenzie, 2010; Vicencio-Moreira *et al.*, 2014; Zaranek *et al.*, 2014). Most has focused on techniques to improve aiming (Vicencio-Moreira *et al.*, 2014), improving understanding of targeting in the context of pointing tasks (Looser *et al.*, 2005; Zaranek *et al.*, 2014), and improved metrics for empirical evaluation of FPS UIs (Klochek and MacKenzie, 2006). Other work has focused on developing or evaluating input devices (Hynninen, 2012; Isokoski and Martin, 2007; Natapov and MacKenzie, 2010), and immersion (Babu, 2012; Brown and Cairns, 2004; Fagerholt and Lorentzon, 2009). To date, the comparative performance of HUD and diegetic displays has received little attention.

Recent studies on FPS information displays have primarily been qualitative in nature (Fagerholt and Lorentzon, 2009; Fragoso, 2014; Llanos and Jørgensen, 2011). Results indicate that participants support the use of diegetic interfaces to enhance immersion, as long as it does not negatively affect (perceived) performance. Similarly, if information is clearly communicated, players tend not to care if it is displayed using a HUD or a diegetic display (Fragoso, 2014; Llanos and Jørgensen, 2011). Directly applicable game interface design heuristics also exist. For example, Federoff states that "The interface should be as non-intrusive as possible" (Federoff, 2002, p. 13) and that "a player should always be able to identify their score/status in a game" (Federoff, 2002, p. 13). It is argued here that empirical studies on the effectiveness of these displays are needed to complement existing qualitative work and design heuristics.

3.1 In HUDs

Zammitto (Zammitto, 2008) conducted a visual analysis of Valve's Half Life 2 in order to assess if visualization design principles were applied in the presentation of game information. They found that the game applied two principles to its HUD ammunition display: silhouette and colour coding. The silhouette principle was employed by showing a bullet icon to indicate that the player should reload their weapon. Colour coding was employed through changing the numerical ammunition indicator on the HUD from yellow to red when ammunition was low. The use of red is appropriate because it carries connotations of "danger" in Western cultures. A similar approach was used in the game's health indicators. Overall, Zammitto concluded that information visualization is not well used in video games, as it is a developing field.

Bowman et al. (Bowman *et al.*, 2012) share this sentiment, and suggest that because data visualization in games is new, it is relatively underutilized. They analyzed visualization in games and proposed a design framework. Their framework's "primary purpose" dimension classifies critical game information as Status, noting that "visual representations are often chosen in lieu of a simple number ... because the game designers feel that visualization is more immersive and easier to read quickly" (Bowman *et al.*, 2012, p. 1961). They recommend considering the target audience before deciding on a particular visualization and argue to ensure that "the visualization is in spirit with the game's atmosphere and integrated within the game" (Bowman *et al.*, 2012, p. 1962). This is consistent with research mentioned earlier (Fagerholt and Lorentzon, 2009). The consensus is that players value cohesion in games. Proper data visualizations improve players' awareness of their current state.

3.2 In FPS Games

Conroy et al. (Conroy *et al.*, 2013) studied the level of agreement between players' anticipated and actual responses to specific game scenarios in Quake III. Players were first asked how they would respond to a specific scenario. Then, they played the game while encountering these scenarios. More experienced participants demonstrated substantially higher levels of agreement between their questionnaire responses and actual responses. They tended to have better awareness of in-game information, such as ammunition levels. Less-skilled players handled their resources (e.g., ammo) more poorly, resulting in greater deviation between their anticipated responses to scenarios. This suggests that the choice of in-game displays is highly relevant to novice players. Nevertheless expert players are likely to also benefit from more effective displays.

3.3 In FPS Critical Gameplay Information

There is little empirical work comparing performance of diegetic and non-diegetic elements. Yet player performance is an important aspect of enjoyment, and directly impacts player effectiveness. For example, Babu (Babu, 2012) compared immersion levels in two games with diegetic displays, Metro 2033 and Dead Space, with two games with HUDs, Bioshock and Resident Evil 5. Immersion was assessed through self-reporting on a 5-point Likert scale, and was not significantly different between the display types. Participants instead suggested that graphics and storyline had a stronger impact on their sense of immersion.

Galloway (Galloway, 2006) introduced the terms diegetic and non-diegetic to the study of video games. The terms originated in literary and film theory. He defines game diegesis as “the game’s total world of narrative action” (Galloway, 2006, p. 7), and non-diegetic as “gamic elements that are inside the total gamic apparatus yet outside the portion of the apparatus that constitutes a pretend world of character and story” (Galloway, 2006, p. 7-8). He concludes that the HUD is a non-diegetic element.

Fagerholt and Lorentzon (Fagerholt and Lorentzon, 2009) built on this work, developing a descriptive model categorizing FPS UI elements based on two factors: whether the element exists (or not) in the fictional world, and if it is a part of the 3D game space (or not). They recommend considering the game’s fiction when deciding if information should be displayed diegetically, arguing that game coherence is paramount. For example, diegetic options make sense in a game like Dead Space, as its futuristic setting allows designers to explain diegetic displays as future technologies such as augmented reality displays or holograms. Ultimately, the authors suggest using diegetic displays whenever appropriate and cohesive. However, the merit of this suggestion is questionable in the absence of empirical results assessing the potential performance impact of such a design choice.

Similarly, Fragoso (Fragoso, 2014) conducted a qualitative study on the effects of diegetic displays on player immersion. Participants played EA's Battlefield 3, which is considered more immersive than other games due to the minimal use of the HUD. The diegetic displays used include positioning the weapon in front of the user and blood splatter used to indicate health status. Participants reported that their gameplay was disrupted by a lack of meaningful feedback due to the relative vagueness of the displays. The authors conclude that effective feedback is actually more important than realism. They further report that HUD-based UI elements were less disruptive than their diegetic counterparts. These sentiments are echoed by Llanos and Jrgensen (Llanos and Jørgensen, 2011) who report that while players liked the aesthetic appeal of diegetic displays, they more greatly valued clear communication of game information. However, they also note that players become annoyed when excessive amounts of information are displayed on HUDs.

Chapter 4

Game Implementation

The choice was made to create a game rather than modify an existing one for its ability to offer greater experimental control (McMahan *et al.*, 2011; Teather and MacKenzie, 2014) and to facilitate data collection. A secondary advantage is that using a custom game avoids participant bias towards existing games, a problem noted by Fagerholt and Lorentzon (Fagerholt and Lorentzon, 2009).

The game developed contains 4 levels - one for each of the 4 user studies done. Each level contains a task which isolates a piece of critical game information (remaining ammunition, health, current weapon, and navigational aid) in order to learn what the best method is to communicate that piece of information. Tasks were initially presented in a poster (Peacocke *et al.*, 2014) then later modified as necessary to be more appropriate for the studies, as discussed in the following sections. The game was built using the Unity Pro game engine. This engine was selected because it is straight forward to build first-person shooter games on it, and it has a good developer community with active forums and many online tutorials.

The code for game functionality was developed with the assistance of the Unity forums (`http://forum.unity3d.com/`). Video tutorials by MisterNinjaBoy (`https://www.youtube.com/user/misterninjaboy`) were also useful in getting started.

Ample testing was done on each level prior to running the studies with actual participants. This included beta testing wherein the game was played by another person while observations were noted, including possible improvements and beta tester feedback.

Figures showing each level can be found in the subsequent chapters which contain each of their respective studies.

4.1 Remaining Ammunition Level

This level was designed to contain a task which made remaining ammunition a crucial piece of information that would effect the participant's performance. When originally proposed, the task for this level involved participants having a certain amount of ammunition, and a number of enemies to kill that was slightly smaller. They then had to kill all enemies without running out of ammunition. The problem with this task was that performance was more dependent on participant accuracy than the display of remaining ammunition. The game space was the same as the end task result: a warehouse setting with many enemies walking slowly towards the participant's character, who was unable to move but could rotate the camera viewpoint and shoot. The problems with the originally proposed task became apparent during beta testing, and so the task was then changed so that the participant had unlimited ammunition, but only a certain amount per clip, and once they ran out of ammunition they needed to reload in order to continue shooting the enemies. This task brought out the differences in performance of each ammunition display tested. This can be read about further in Chapter 5.

The setting of this level was an industrial environment available for free on the Unity Asset store (Yaman, 2014). The soldier characters were obtained from Unity's Bootcamp demo. Due to this being the first level worked on, tasks that were simple for later levels were more time-consuming at this point. These included data recording, smoothing the gun animation, having realistic control movement, and proper gun shot audio.

4.2 Health Level

This level was designed to contain a task which made remaining health a crucial piece of information that would effect the participant's performance. The objective of this level was to have participants need to notice that they were at a specific level of health and to perform an action once this was reached. The task soon became that participants were being shot at and would need to hit the "Escape" button when their health was below 20%. However, it soon became apparent that this was a simple reaction time task since all a participant would need to do would be to watch their health. In order to ensure that the participant was not just looking at their health, they were then given the ability to shoot and tasked with shooting enemies in order to get a high score. The number of points per hit increased the lower the participant's character's health got, and so it was advantageous for participants to remain in the game longer while still keeping watch of their health.

This level was set within a turret (D'Amore, 2014). The enemy soldiers and weapon were the same as in the remaining ammunition level. In terms of implementation, more difficult tasks included having the enemies that participants killed come back to life after a certain time period, creating a bar on the character's arm which moved realistically when the participant would have the character fire a shot, and making the sound effects realistic when there were problems with having so many weapons firing at approximately the same time.

4.3 Current Weapon Level

This level was designed to isolate the communication of the player's currently equipped weapon in an FPS game. The task therefore needed to require that participant knowledge of which weapon was equipped would be crucial to game success. Creating an actual task that necessitated this was one of the biggest challenges for building this level. When originally proposed the task was that participants would be walking through a game level and encounter different areas that would require different weapons, necessitating them being aware of what weapon they had equipped and what weapon that they needed to have equipped at each moment. However, a large problem with this was that participants would need to be trained in which weapon was required in each situation. It would then be hard to interpret results. If participants were unable to properly recall what weapon was necessary in a specific situation, then the additional time of them remembering the correct weapon would contaminate results, as this is not what is being measured. This task evolved to involve colour coding: Participants would need to kill an enemy of a certain colour (red, green, blue, or yellow) with a gun of the same colour (e.g., a blue gun kills only a blue enemy). This eliminated the necessity of training. The task also evolved from having participants walking through a level to actually using the same setting as the remaining ammunition level but modifying it slightly; instead of having all enemies approach the participant's character at the same time, a small group of 3 enemies of the same colour would appear, then once those enemies were killed, the next group of a different colour would appear, and so on until all groups were killed.

Though the most difficult part of creating this level was deciding on the task, implementation difficulties included ensuring enemies would die only if killed by a weapon of the same colour, and having enemies appear in same-coloured groups one group at a time when a previous group was destroyed.

4.4 Navigational Aid Level

It was decided early on that the obvious setting for this level, which would necessitate participants being aware of their location, would be a maze, since this is a difficult navigation task that would best show differences in performance with different navigational aid. One problem with using a maze is that not all navigation aids tested are well-suited for a maze, which is discussed in Chapter 8. Difficult implementation tasks for this level included the actual maze creation, and creating the compass. The map was generated at runtime using code modified from that found on the Unity forums (tombali, 2013). This code was modified so that the maze would be the same every time - as it was, the maze would be random each time - so that each participant would be playing the level with the same map and therefore results could be compared between participants. The code for the mini-maps was a modified version of a tutorial online (feillyne, 2010).

Chapter 5

Remaining Ammunition Study

5.1 Introduction

This chapter presents an experiment comparing several remaining ammunition displays which are both on the HUD and within the game (diegetic). The ammunition displays were chosen based on the results of the analysis of recent FPS games.

An initial pilot study was done for this piece of information, followed by this study, in order to test the software after completion. This study increased numbers of participants and trials, and tested some different display methods. The number of participants was increased from 7 to 20 and the number of trials was increased from 5 to 15 per ammunition display. Participants used in this study were all regular gamers, instead of casual gamers. This was changed because of regular gamers being able to learn the controls and how to play the game much quicker. In this study three common HUD and two diegetic ammunition displays were compared. In the pilot study, the same HUD ammunition displays were compared as well as the number-in-game (NG) diegetic display (though it was positioned slightly differently in that study). The

position was changed for this study because it was universally hated in the previous study, and it was found that in two recent FPS games (*Halo 4* and *Call of Duty: Advanced Warfare*) the position of the number on the gun is more on the gun than on top of it, as in *Dead Space*.
The ammunition displays (and their short-hand names) used in this study are:
HUD:

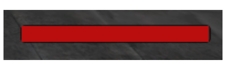
1. Bar-on-HUD (BH)
2. Number-on-HUD (NH)
3. Icons-on-HUD (IH)

Diegetic:

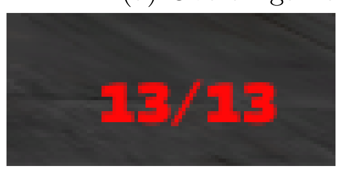
4. Number-in-game (NG)
5. Icons-in-game (IG)

Participants were solicited who regularly play FPS games, since skilled gamers can quickly assess their status, while novice players cannot (Conroy *et al.*, 2013). Hence expert gamers should be skilled enough to elicit differences between the conditions studied. In contrast, novice participants require training to get to this level of skill, and thus may not reveal differences between the experimental conditions.

(a) Overall game



(b) Bar-on-HUD (BH)



(c) Number-on-HUD (NH)

(d) Icons-on-HUD (IH)

(e) Number-in-game (NG)

(f) Icons-in-game (IG)

Figure 5.1: Overall gameplay (with bar on HUD ammunition display) and five conditions.

Figure 5.2: A participant completing the remaining ammunition study.

5.2 Methodology

5.2.1 Participants

Twenty paid participants (16 male) took part in the study. Ages ranged from 18 to 38 years (mean 22.35, SD 4.31). Half reported that their preferred system was a console, and the other half reported that they preferred gaming on a PC. All participants were regular gamers, playing between 1 and 10 hours per week. Their FPS gaming habits were also solicited: 16 reported playing FPS games every week.

5.2.2 Apparatus

The experiment was conducted on a 3.4 GHz quad-core i7 based computer, with 8 GB of RAM running Windows 7. A 75 in. Samsung Series 7 x 7100 Smart TV (1920 x 1080 pixel resolution) was used for the display. The display was set to run in game mode to minimize latency. Participants sat on a couch approximately 5.6 m. from the display. This corresponded to a comfortable seating distance with the entire display visible without excessive gaze shifts. This distance was chosen to avoid biasing the results in favour of any display due to gaze shifts. The setup is shown in Figure 5.2.

The software was capable of displaying the player's ammunition level using any of the five ammunition displays shown in Figure 5.1. The ammunition displays, as described earlier, included bar-on-HUD (BH), number-on-HUD (NH), icons-on-HUD (IH), number-in-game (NG), and icons-in-game (IG). Each presented the same information, but visualized it differently.

The software automatically recorded the number of clips used, hits and misses during each clip, enemies remaining, shots before reload, and time before reload. For each shot taken, the time was recorded along with the remaining ammunition and whether the shot hit or missed an enemy.

5.2.3 Procedure

Upon arrival, participants were greeted and the purpose of the experiment was explained. Participants gave informed consent before proceeding.

Participants were instructed to play the game to the best of their ability, shooting all enemy soldiers as quickly and accurately as possible. They were informed that they had unlimited ammunition, but each clip only had a certain number of shots. Consequently, participants had to reload upon running out of ammo. They were then instructed on the controls and were allowed to begin. A trial ended when all enemies were killed.

Upon starting the trial, and after reloading the gun, each clip had a pseudo random number of rounds. The number of rounds per clip ranged from 7 to 16 (decided once per trial). Using a random number of shots per clip was intended to impose a greater awareness of the ammunition level. This helped prevent participants from mentally tracking ammunition, and thus was expected to help elicit differences between the test conditions. Upon running out of ammunition, participants had to manually reload (and could not reload prior to running out of ammunition). This task was representative of real game playing tasks: Ammunition level becomes crucial when it is low in a battle situation. The task necessitated that participants were highly aware of their ammunition level.

Participants completed 15 trials for each of the five ammunition displays, completing 75 trials in total. After each trial participants could take a break before continuing. Each trial took between 30 and 45 seconds. In total, the experiment took approximately one hour.

Upon finishing all trials, participants completed a questionnaire about prior experience with FPS games, and soliciting feedback on a 5-point Likert scale on the level of immersion they experienced and the perceived effectiveness of each ammunition display.

5.2.4 Design

The study employed a 5 × 15 within-subjects design. The independent variables and levels were as follows:

Ammunition Display: BH, NH, IH, NG, and IG

Trial: 1, 2, 3, ..., 15

The ammunition display conditions are depicted in Figure 5.1 and were described earlier. The ordering of ammunition display was counterbalanced according to a Latin square.

The dependent variables were the number of shots before reload (count, the number of trigger presses between running out of ammunition and pushing the reload button) and time before reload (seconds, the amount of time between running out of ammunition and pushing the reload button).

5.3 Results/Discussion

Results were analyzed using a repeated measures ANOVA.

5.3.1 Shots Before Reload

Shots before reload is the average number of shots fired from the time when the participant ran out of ammunition to the time when the reload button was pushed. It thus required that the participant notice that they had no ammunition left. A higher number of shots before reload is indicative of a decreased awareness of ammunition levels. Shots before reload is summarized for each ammunition display in Figure 5.3.

The main effect for ammunition display was statistically significant ($F_{4,19} = 9.22$, $p < .0001$). A Tukey-Kramer post-hoc analysis revealed that the difference between number-in-game (NG) and all other ammunition displays was statistically significant ($p < .05$). The rest of the ammunition displays were not significantly different from each other. The main effect for trial on shots before reload was not significant ($F_{14,19}$

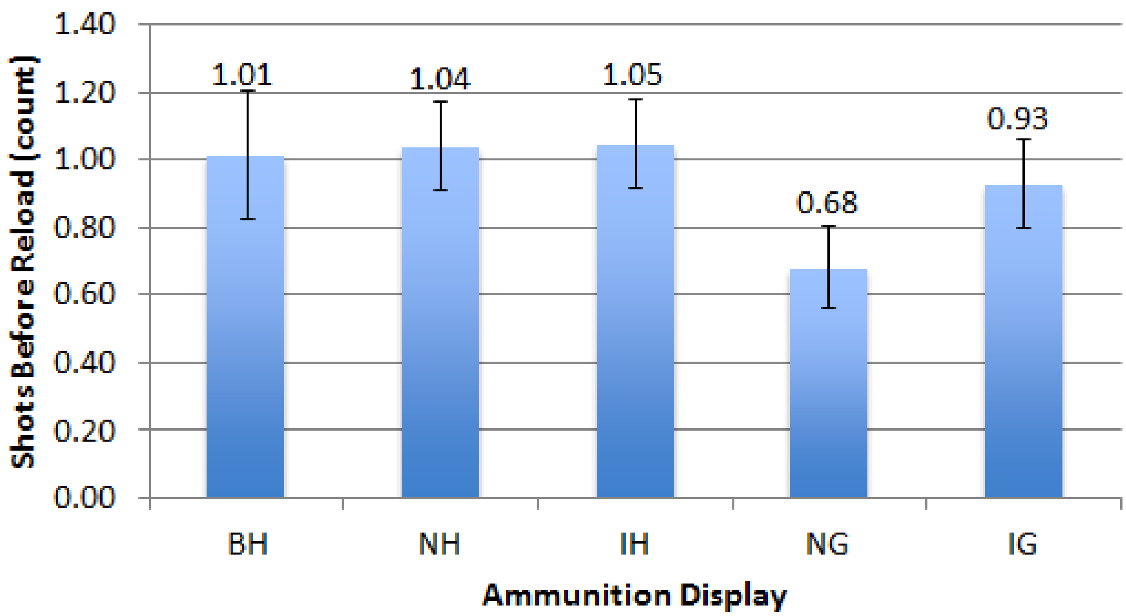


Figure 5.3: Shots before reload by ammunition display. Error bars show ±1 SD.

= .94, ns), nor was the interaction effect between ammunition display and trial ($F_{56,19}$ = 1.03, $p > .05$).

The worst performing ammunition displays were the HUD options. All three had comparable scores (slightly over 1 each) and were not significantly different from one another. Although icons-in-game (IG) performed slightly better, the difference was not significant. The best performing option was number-in-game (NG), which had a score of 0.68 shots fired before reload. Number-in-game resulted in an average 35% fewer shots before reload than the worst performer, icons-on-HUD (IH).

Participants noted that number-in-game was very easy to see, as the ammunition count was almost directly where they were looking while aiming. The HUD-based displays were in the bottom right corner, requiring more glancing. These ammunition displays performed very similarly, suggesting a relationship between performance and

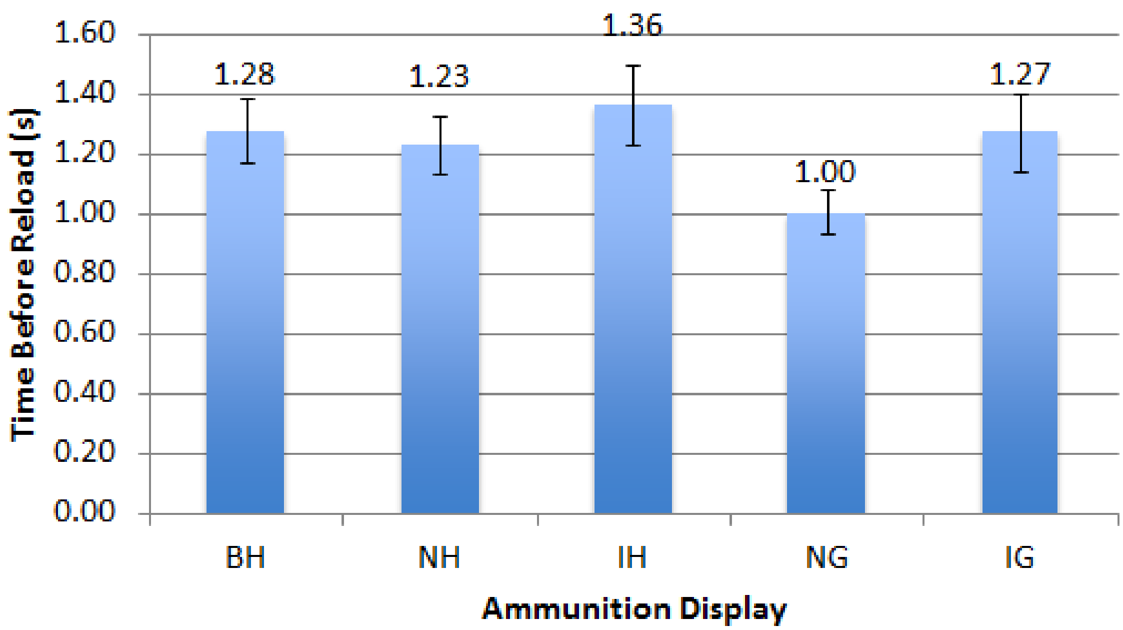


Figure 5.4: Time before reload by ammunition display. Error bars show ±1 SD.

display location. It is speculated that positioning the HUD in a different location (e.g., another corner of the screen) is unlikely to yield a substantial performance difference, unless they are placed much closer to the screen centre.

5.3.2 Time Before Reload

Time before reload is the time between when the participant ran out of ammunition and when the reload button was pushed. Like shots before reload, higher scores were worse: the greater this time was, the lower the awareness of the ammunition level. Average time before reload for each ammunition display is depicted in Figure 5.4.

There was a significant main effect for ammunition display on time before reload ($F_{4,19} = 4.26$, $p < .005$). A Tukey-Kramer analysis indicated that there was a significant difference between number-in-game (NG) and all other ammunition displays.

The main effect for trial was not significant ($F_{14,19} = 1.61$, $p > .05$), nor was the interaction between ammunition display and trial ($F_{56,19} = 0.92$, ns).

Like shots before reload, the icons-on-HUD (IH) ammunition display performed worst, and the number-in-game (NG) ammunition display performed best. NG offered the lowest time before reload, with an average time of 1 s, approximately 20% lower than the next best performing ammunition display, number-on-HUD (NH). The most substantial difference was between icons-on-HUD (IH) and number-in-game (NG) ammunition displays. NG was approximately 26% faster than IH.

The results are surprisingly consistent for both dependent variables. It appears the central location of the number-in-game ammunition display allows for better performance than the other displays. This is most likely because it reduces the amount of gaze shifting or glancing required.

5.3.3 Questionnaire

Participants completed a questionnaire soliciting their feedback on the ammunition displays studied. They were asked to rate on a 5-point Likert scale how helpful each ammunition display was. Specifically, they were asked "Did each of the ammunition displays help or hinder your gameplay?" with response options ranging from "Really hindered" to "Really helped". Figure 5.5 depicts the percentage of participants for each response level.

Overall, the number-in-game (NG) ammunition display was considered the most helpful, with 80% of participants reporting they found it helpful or really helpful. Opinions toward icons-in-game (IG), icons-on-HUD (IH), and number-on-HUD (NH) ammunition displays were more mixed. The bar-on-HUD (BH) ammunition display

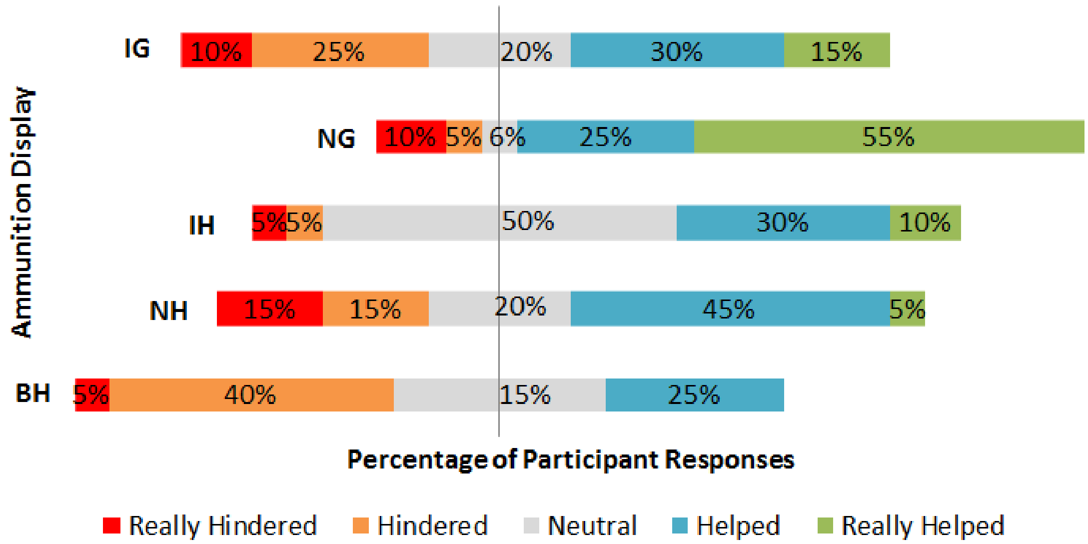


Figure 5.5: Percentage of participant responses on helpfulness of each ammunition display.

was thought to hinder gameplay by 45% of participants. A Friedman non-parametric test deemed the differences statistically significant ($\chi^2 = 11.564$, $p < .05$, $df = 4$). A post hoc analysis revealed significant differences between number-in-game (NG) and bar-on-HUD (BH), number-in-game (NG) and number-on-HUD (NH), and number-in-game (NG) and icons-in-game (IG).

Participants were also asked to rate their immersion on a 5-point Likert scale. Specifically, they were asked "How immersed into the game did you feel with each remaining ammunition display?" Participants felt that number-in-game (NG) was most immersive. Opinions were mixed for icons-in-game (IG), and icons-on-HUD (IH), though opinion leaned towards immersive. Bar-on-HUD (BH) and number-on-HUD (NH) were considered distracting. The differences were significant ($\chi^2 = 15.040$, $p < .005$, $df = 4$). A post hoc analysis revealed significant differences between bar-on-HUD and number-in-game, bar-on-HUD, and icons-in-game, and number-on-HUD and

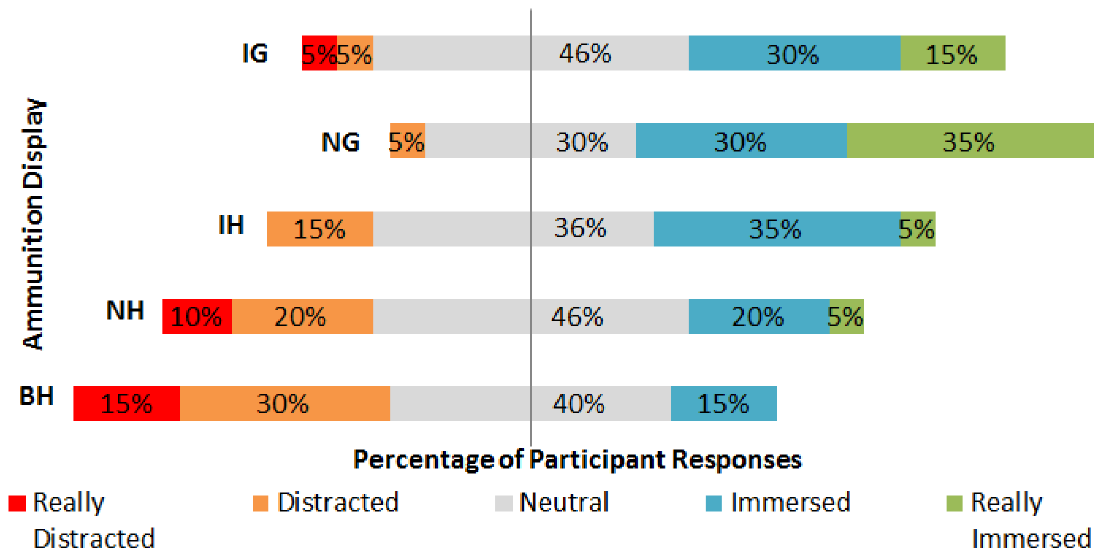


Figure 5.6: Percentage of participant responses on immersiveness for each ammunition display.

number-in-game. The immersion rating results are seen in Figure 5.6.

Finally, participants were asked about their preference toward each ammunition display. Favourite and least favourite ammunition displays are depicted in Figure 5.7. Overall, 70% of participants felt number-in-game was their favourite. There was more variety in least favourite ammunition displays: 35% of participants chose bar-on-HUD, 30% of participants chose number-on-HUD, and the rest were split. The preference of favourite and least favourite ammunition display was statistically significant (χ^2 = 15.90, $p < .005$). A post hoc analysis revealed significance differences between number-in-game and bar-on-HUD, and number-in-game and number-on-HUD.

5.4 Discussion

Overall, results of the study indicate that the number-in-game ammunition display offered the best performance in terms of how long it took participants to recognize

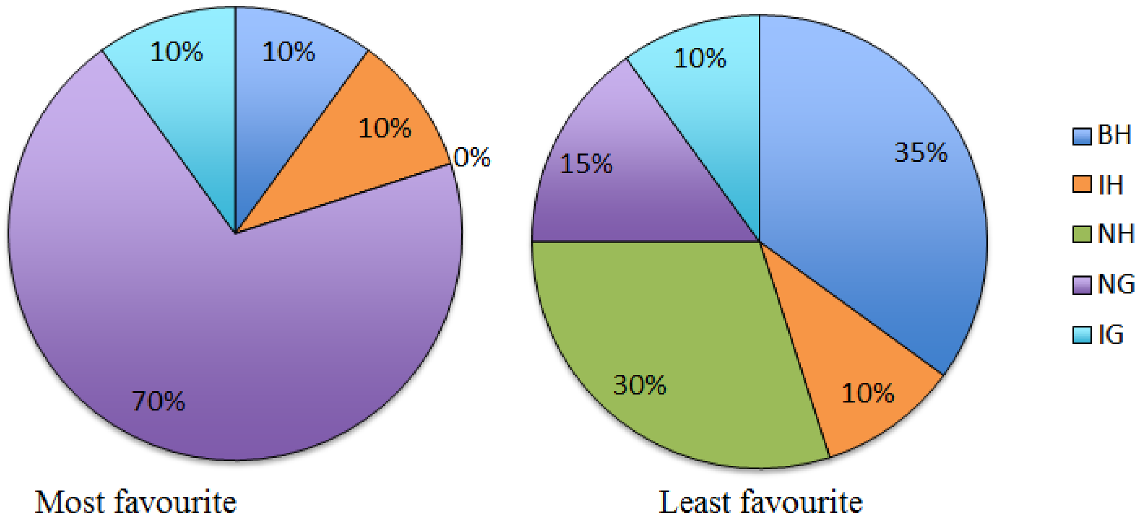


Figure 5.7: Percentage of responses indicating favourite and least favourite ammunition displays.

they were out of ammo. This is likely due, at least in part, to the placement of the display. Since it was co-located with the player's gun, no additional glancing to HUD elements was required. Participants were able to effectively track their ammunition while otherwise playing the game normally.

Interestingly, this also yielded higher levels of immersion in the game, perhaps because constant glancing at HUD displays reduces immersion. It is likely that participants were intuitively aware of both their performance and their level of immersion. This likely also explains their overall preference toward the number-in-game ammunition display. As noted by previous research (Fragoso, 2014; Llanos and Jørgensen, 2011), players are not inherently opposed to diegetic options if they are effective. The number-in-game ammunition display was clearly the most effective.

That said, the other diegetic display, icons-in-game, tended not to perform as well. It is possible that this is related to a higher cognitive load in counting icons (even if they are located beside the gun) compared to quickly viewing a number. Nevertheless, there seems to be potential for diegetic displays. As mentioned earlier, this bodes well for mobile games with limited screen real estate, as comparatively large HUD elements might be replaced by equally (or more!) effective diegetic options.

This research can assist in the development of future games, as it supports the use of diegetic displays for ammunition with empirical performance results. Developers should always keep in mind that game coherence comes first, as recommended in other research (Fagerholt and Lorentzon, 2009). But, if one of the diegetic displays studied here fits with the theming of the game, and its in-game placement improves player performance, then its use is recommended.

Second, ammunition display was studied in isolation from other displays. This is appropriate from an experimental control point of view, and thus enhances the internal validity of the results. However, it decreases the generality of the results. Most games show multiple displays simultaneously (e.g., see Figure 1.1), sometimes even combinations of diegetic displays and HUDs, as reported in Table 1. Studying a single display in isolation is not fully representative of this more complex task of monitoring multiple displays at once. However, it is expected that even with multiple displays present, those that are individually demonstrated to offer better performance are likely to offer better performance together. Hence, it is believed studying multiple display types in isolation is worthwhile to “chip away” at the more complex problem of monitoring multiple displays at once. Future work will focus on this goal.

5.5 Conclusion

Our results show that diegetic ammunition display methods are a good alternative to the traditional HUD display methods. Participants both performed better and preferred the number-in-game (NG) diegetic ammunition display method. Since a numerical count of remaining ammunition was in the participants' line of vision, they were aware of the current count of remaining ammunition more readily than alternative methods, which require more glancing and a higher cognitive load. Ultimately, the number-in-game ammunition display performed more than 27% better than the alternatives at average shots fired between running out of ammunition and reloading.

This is not to say that diegetic display methods allow gamers to play better, but rather that diegetic displays put information in reasonable locations that allow better performance. In contrast, consider that a HUD element could be positioned in the centre of the game space and may yield comparable performance. However, it would be distracting and look out of place, compromising immersion. Instead, diegetic options allow designers to accomplish this in a way that coheres with the game fiction. Per these subjective results, this can be enjoyable, and even preferable to players.

Chapter 6

Health Study

6.1 Introduction

This chapter presents a study which compared methods of communicating player health in FPS games. In this study participants were required to "escape" when their health was less than 20%. In order to escape, they needed to push an escape button on their controller once their character's health reached this low level. When they did this, their character would be moved to safety and the level would end. This was selected as the primary task because how well a health display communicates the total amount of health remaining would have a large effect on performance. A secondary task of shooting enemies to get a high score was added in order to prevent this from being a simple reaction time task. The health displays tested in this study were selected based upon those found in the games analysis in Chapter 2 as well as health displays common to other genres. The study in this chapter compares the health displays in terms of both participant performance and preference. It also looks at the effect of position by testing the 3 HUD displays (bar, icons, and number) in 3 locations (bottom middle, top left, and top middle).

The 12 health displays tested were:

HUD:

1. Bar-on-HUD-bottom (BHB)
2. Bar-on-HUD-left (BHL)
3. Bar-on-HUD-top (BHT)
4. Icons-on-HUD-bottom (IHB)
5. Icons-on-HUD-left (IHL)
6. Icons-on-HUD-top (IHT)
7. Number-on-HUD-bottom (NHB)
8. Number-on-HUD-left (NHL)
9. Number-on-HUD-top (NHT)

Diegetic:

10. Bar-in-game (BG)
11. Icons-in-game (IG)

Meta-perception:

12. splatter (S)

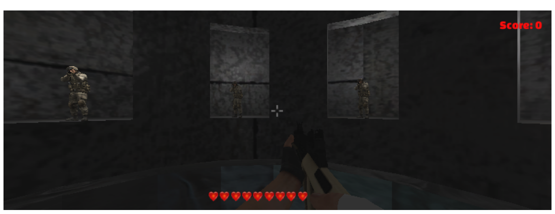
(a) Bar-on-HUD-bottom (BHB)

(b) Bar-on-HUD-left (BHL)

(c) Bar-on-HUD-top (BHT)

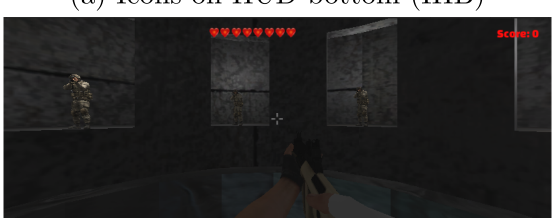
(d) Bar

Figure 6.1: Bar-on-HUD health displays: Figures 6.1a - 6.1c show overall gameplay with each bar on the HUD health display. Figure 6.1d shows a closeup view of the bar.

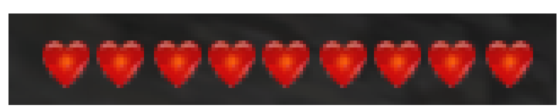


(a) Icons-on-HUD-bottom (IHB)

(b) Icons-on-HUD-left (IHL)



(c) Icons-on-HUD-top (IHT)

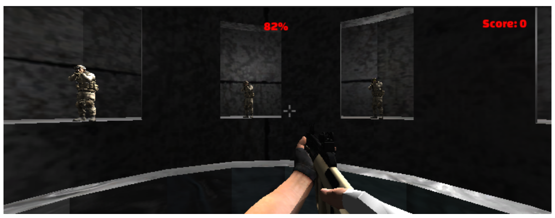


(d) Icons

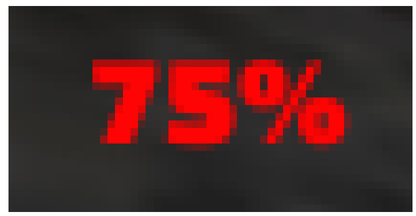
Figure 6.2: Icons-on-HUD health displays: Figures 6.2a - 6.2c show overall gameplay with each icons on the HUD health display. Figure 6.2d shows a closeup view of the icons.

(a) Number-on-HUD-bottom (NHB)

(b) Number-on-HUD-left (NHL)



(c) Number-on-HUD-top (NHT)



(d) Number

Figure 6.3: Number-on-HUD health displays: Figures 6.3a - 6.3c show overall gameplay with each number on the HUD health display. Figure 6.3d shows a closeup view of the number.

6.2 Methodology

6.2.1 Participants

24 paid participants (21 male, 3 female) took part in the study. Their ages were from 19 to 53 years (mean 25.42, SD 7.23). All participants were regular gamers, with 58% playing video games for more than 10 hours per week, and 86% playing first-person shooter games every week. The majority of participants were used for all three studies in Chapters 6 - 8.

6.2.2 Apparatus

Hardware Setup

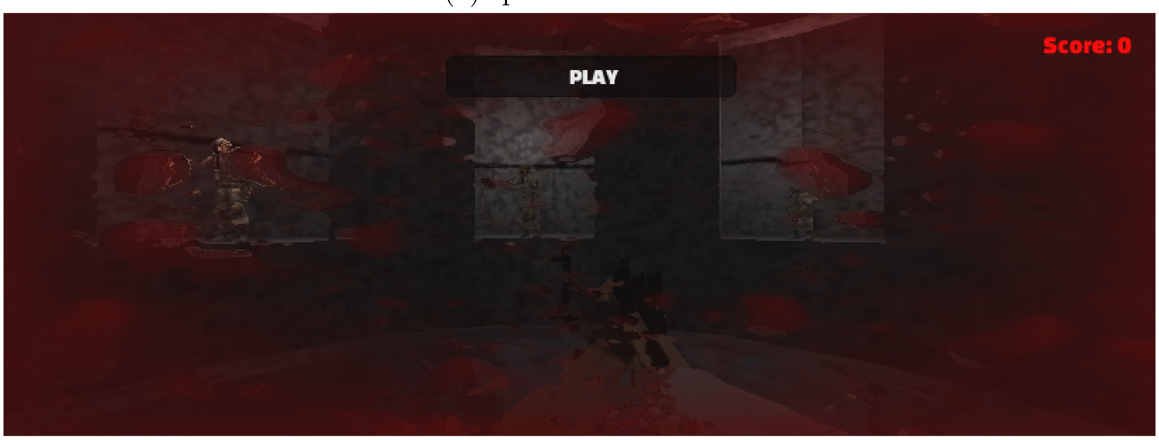
The system and position were the same as that described in Section 5.2.2. Participants used a Microsoft Xbox One controller to play the game. Viewpoint rotation/aiming

(a) Bar-in-game (BG)

(b) Icons-in-game (IG)

Figure 6.4: Diegetic health displays: Both displays appear on the player character's arm and drain towards the bottom of the screen.

(a) splatter condition



(b) splatter condition, no health remaining

Figure 6.5: splatter (S) condition: Figure 6.5a shows display with some damage and Figure 6.5b shows splatter with no health remaining.

was controlled by the right joystick. Movement was disabled. The right trigger button was used to shoot, and the left bumper button was used to escape. Escaping was only possible when less than 20% of player health was remaining.

Software Setup

This study uses the game level discussed in Section 4.2. The software was capable of displaying the player's health level using any of the 12 health displays shown in Figures 6.1 - 6.5. The health displays included bar-on-HUD-bottom (BHB), bar-on-HUD-left (BHL), bar-on-HUD-top (BHT), icons-on-HUD-bottom (IHB), icons-on-HUD-left (IHL), icons-on-HUD-top (IHT), number-on-HUD-bottom (NHB), number-on-HUD-left (NHL), number-on-HUD-top (NHT), icons-in-game (IG), bar-in-game (BG), and splatter (S). Each presented the same information, but visualized it differently. The game was set within a turret with 5 enemies surrounding the player's character in a semi-circle. When each trial began the participant's character had 100 health points and enemies would shoot at the player, causing 5 points of damage with each hit. The player would shoot back at the enemies, receiving score points with each shot. Score points would increase as the participant's character's health decreased. Data recorded for each trial included if the participant escaped, health remaining at the end of the trial (zero if they did not escape), and score. Each shot the participant took was also recorded along with if that shot was a hit or miss and, if it did hit an enemy, how many points it was worth.

6.2.3 Procedure

Upon arrival, participants were greeted and the purpose of the experiment was explained. Participants gave informed consent before proceeding.

Participants were then given the following information:

- They would be playing a game level which takes place in a turret setting.
- Their character would be surrounded by enemy soldiers in a semi-circle that would be shooting at them. Their character would be unable to move but could rotate the viewpoint and shoot.
- Once their health was at 20% of maximum health they needed to escape by pressing the escape button.
- They would get points for each enemy that they shot and the point value would increase as their character's health decreased.
- Their overall goal was to get a high score while escaping. Their high score would only update if the score was higher than their previous high score and if they were successfully able to escape before running out of health points.

They were then instructed on the controls and were allowed to begin. A trial ended when either the participant escaped or their health reached zero. Health was not regenerative (i.e., it did not recover over time, as is the case in some FPS games).

Participants completed 20 trials for each of the 12 ammunition displays, completing 240 trials in total. After each trial participants could take a break before continuing. Each trial took approximately 5 seconds. In total, the experiment took approximately 25 minutes. Upon finishing all trials, participants completed a questionnaire about prior experience with FPS games, and soliciting feedback on the level of immersion they experienced and the perceived effectiveness of each health display.

6.2.4 Design

The study employed a 12 $\times$ 20 within-subjects design. The independent variables and levels were:

Health Display: BHB, BHL, BHT, IHB, IHL, IHT, NHB, NHL, NHT, BG, IG, S
Trial: 1, 2, 3, ..., 20

The health display conditions are depicted in Figures 6.1 - 6.5 and were described earlier. The ordering of health display was pseudorandom in order to offset potential learning effects. The dependent variables were percentage of escapes and health when escaped (count, health remaining when the participant successfully escaped before dying).

6.3 Results

6.3.1 Percentage of Escapes

This dependent variable is the average percentage of trials where participants were able to successfully escape the game once their health was below 20% but before it reached 0%. The average percentage of escapes with each health display is depicted in Figure 6.6. A high percentage represents a better performance than a lower percentage, as it implies that participants could see and understand the health display

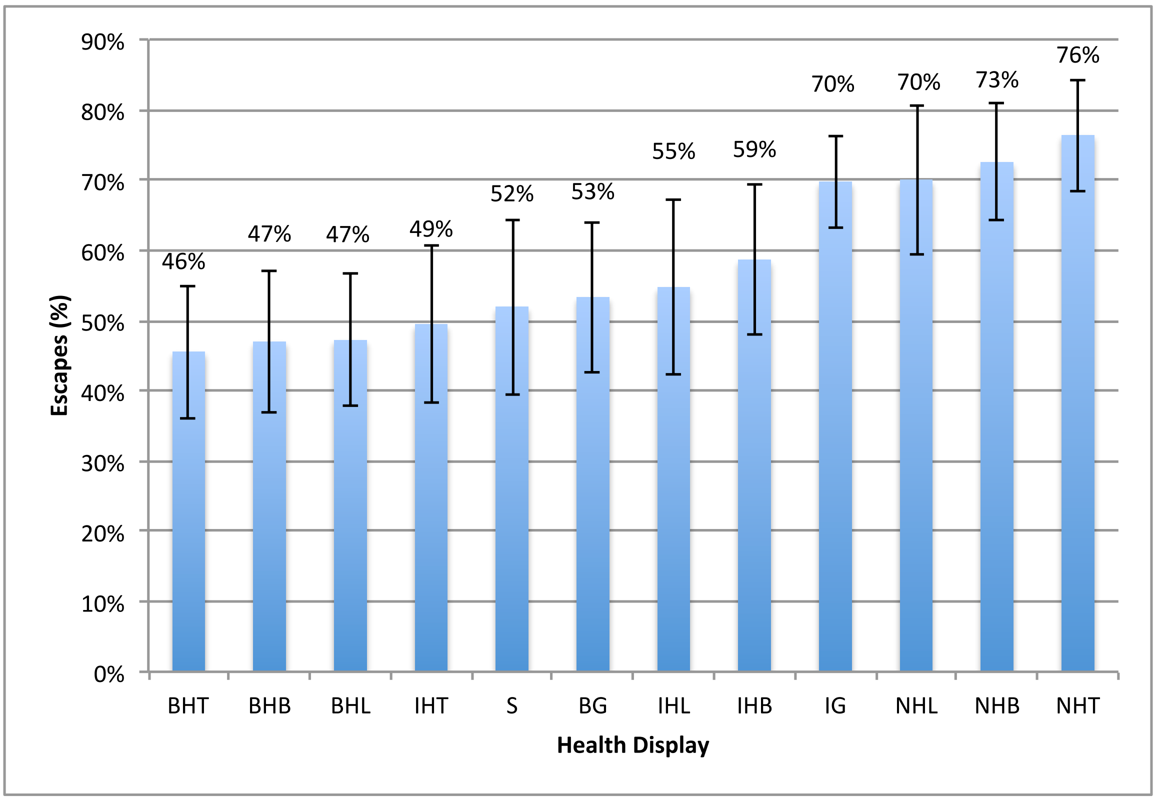


Figure 6.6: Percentage of escapes by health display. Error bars show ±1 SD.

well.

The best performing health display was the number-on-HUD-top (NHT), with 76% escapes. The worst performing display was the bar-on-HUD-top (BHT), with 46% escapes, followed closely by the bar-on-HUD-bottom (BHB) and bar-on-HUD-left (BHL), both with 47% escapes. This was approximately 39% worse than with the number-on-HUD-top (NHT) health display.

There was a significant main effect for health display on percentage of escapes ($F_{11,23} = 12.91$, $p < .0001$). A Fisher LSD analysis revealed the displays which had significantly different results from each other. Figure 6.7, which has the results averaged by health display type, has significance lines joining display types that were significantly different than each other. These lines apply to these results as well (i.e., there was statistical significance between all number on HUD health displays and all bar on HUD health displays). The one addition is that the bar on HUD health display performances were all significantly different than the performance with the icons-on-HUD-bottom (IHB) health display. The complete list of significant differences can be found in Section B.1.

In summary, the number-on-HUD displays (NHB, NHL, and NHT) performed significantly better than all other health displays except for the icons-in-game (IG). The icons-on-HUD-bottom (IHB) performed significantly better than the bar-on-HUD displays.

Figure 6.7 shows the percentage of escapes results when sorted into the health display type (bar, icons, number, bar-in-game (BG), icons-in-game (IG), and splatter). For example, the "bar" display type is an average of the percentage of escapes with the bar-on-HUD-bottom (BHB), bar-on-HUD-left (BHL), and bar-on-HUD-top (BHT)

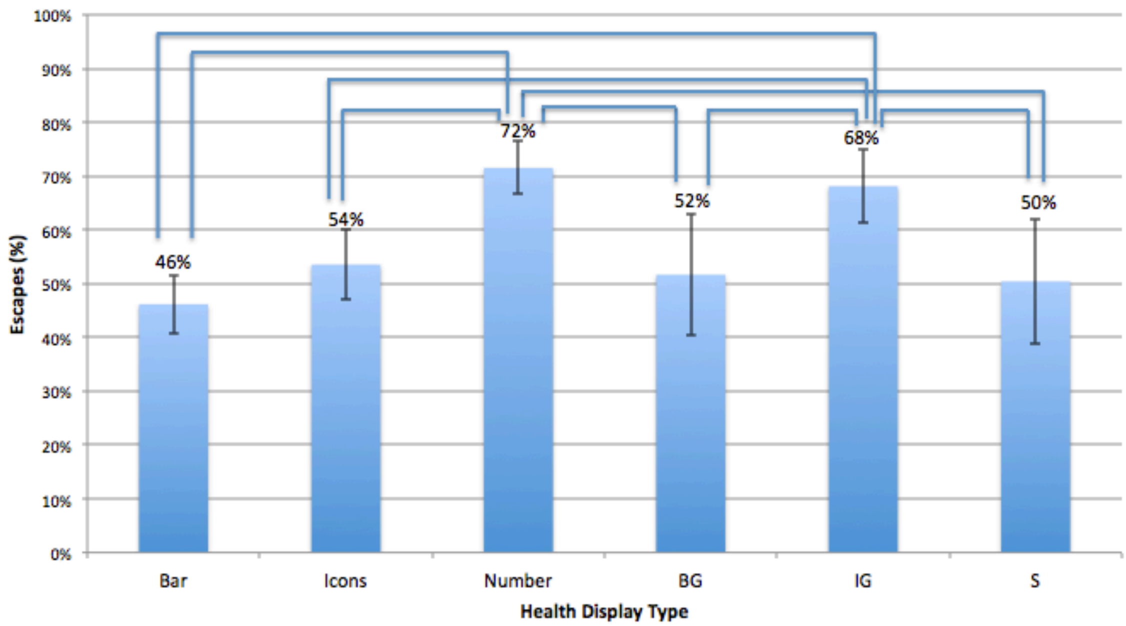


Figure 6.7: Percentage of escapes by health display type. Error bars show ±1 SD.

health displays. Overall the number display type performed the best, with on average 72% escapes. The bar display type performed the worst, with 46% escapes. This is approximately 36% worse than the number display type. There was a significant main effect for health display type on percentage of escapes ($F_{5,23} = 15.17$, $p < .0001$). The figure shows significance lines above the health display types which were found through a Fisher LSD analysis to have a significant difference between them. A list of display types with significant differences can be seen in Section B.1.

To summarize, the number and IG health display types had higher percentages of escapes than all other health display types. Of the remaining health display types, none performed significantly worse than the other (i.e., none had a significantly lower percentage of escapes).

Figure 6.8 shows the percentage of escapes results when sorted by health display location (bottom middle, top left, top middle, arm, and splatter). For example, the

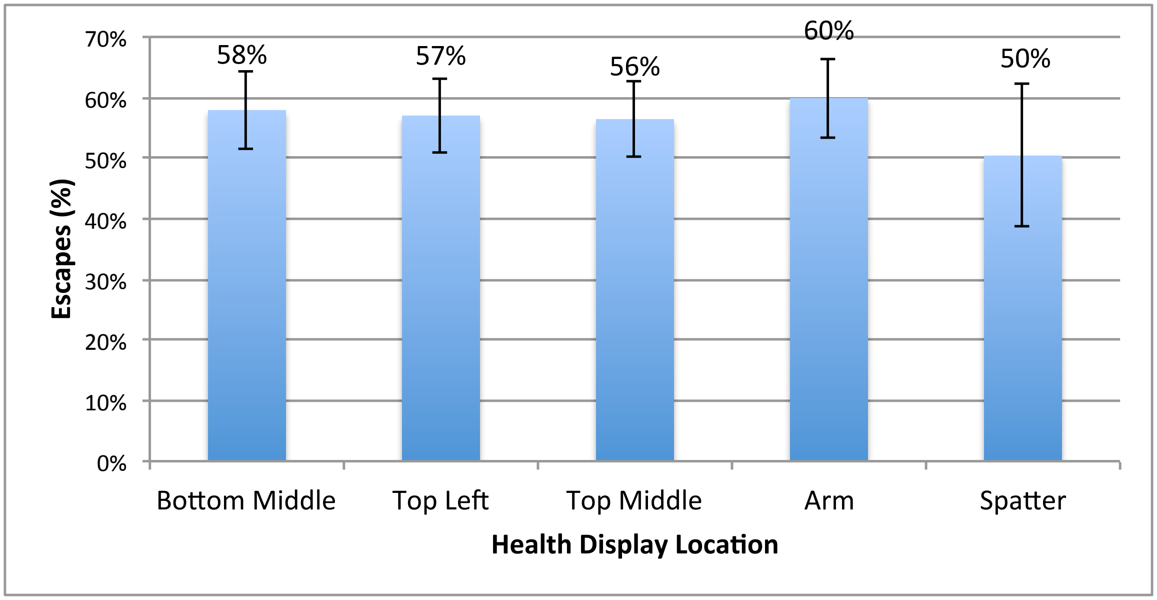


Figure 6.8: Percentage of escapes by health display location. Error bars show ±1 SD.

bottom middle result is an average of the bar-on-HUD-bottom (BHB), icons-on-HUD-bottom (IHB), and number-on-HUD-bottom (NHB) results. Overall the arm position performed best, though not by much, with 60% escapes. The splatter location performed the worst, with 50% escapes. This is approximately 17% worse than with the arm position. There was a significant main effect for health display position on percentage of escapes ($F_{4,23} = 2.63$, $p < .05$). A Fisher LSD analysis indicated that there was a significant difference between the arm and splatter locations. The HUD positions all performed very similarly.

6.3.2 Health when Escaped

This dependent variable is the average health remaining when participants were able to successfully escape after their health was below 20% but before it reached 0%.

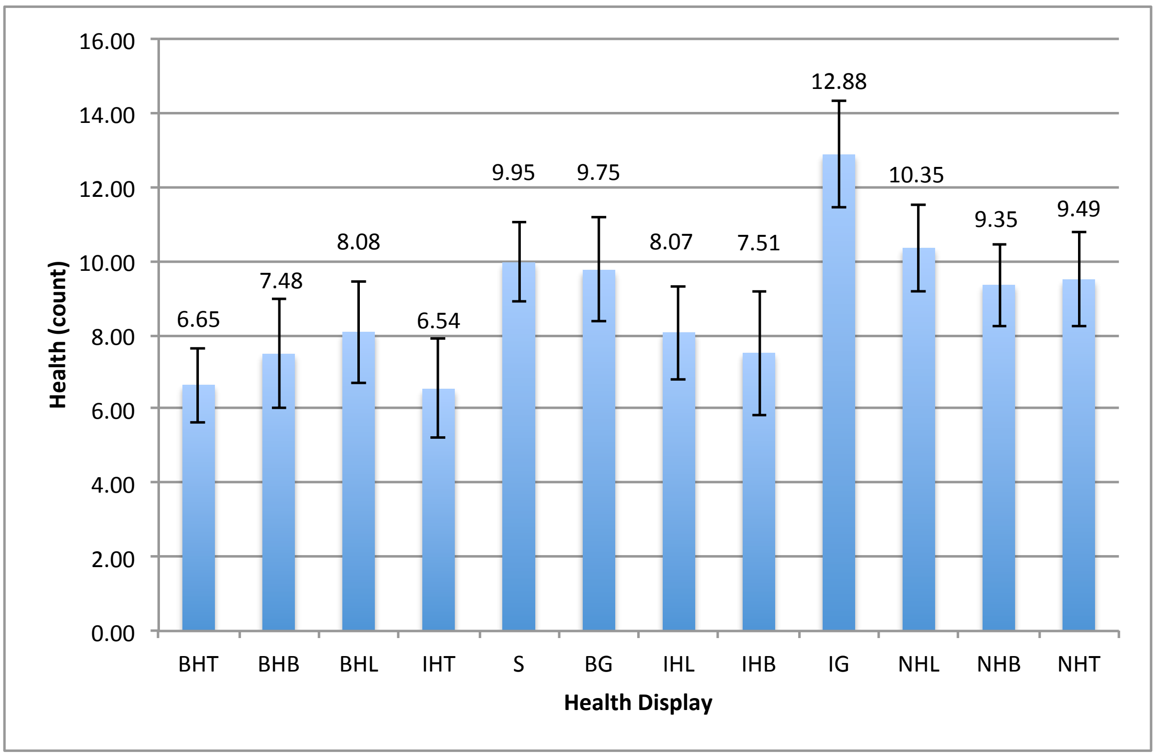


Figure 6.9: Health when escaped by health display. Error bars show ±1 SD.

The average health when escaped for each health display is shown in Figure 6.9. A low value represents a better performance, since this means participants trusted the display enough to communicate how low their health was to them.

The icons-on-HUD-top (IHT) health display performed the best, with an average health when escaped of 6.54. This was followed closely by the bar-on-HUD-top (BHT), with an average health when escaped of 6.65. The icons-in-game (IG) health display performed the worst, with an average health when escaped of 12.88. This was approximately 49% worse than with the icons-on-HUD-top (IHT) health display.

There was a significant main effect for health display on percentage of escapes ($F_{11,23} = 16.01$, $p < .0001$). Figure 6.10, which has the health when escaped averaged by health display type, has significance lines above display types which were significantly different from each other, as revealed in a Fisher LSD analysis. These results are mostly consistent with the results that were significant as individual health displays (i.e., the icons-in-game (IG) health display was significantly different than all bar on HUD health displays). The exception to this is that the bar-on-HUD-left (BHL) health display was only significantly different from the number-on-HUD-left (NHL) and icons-in-game (IG) health displays, and the icons-on-HUD-left (IHL) health display was only significantly different from the number-on-HUD-left (NHL), icons-in-game (IG), and splatter (S) health displays. A complete list of the health displays that had significantly different results from each other can be found in Section B.2.

In summary, the bar and icon displays on the HUD performed significantly better than all other displays, except for when in the top left position. All other health displays performed significantly better than the icons-in-game (IG).

Figure 6.10 shows the health when escaped results when sorted into the health

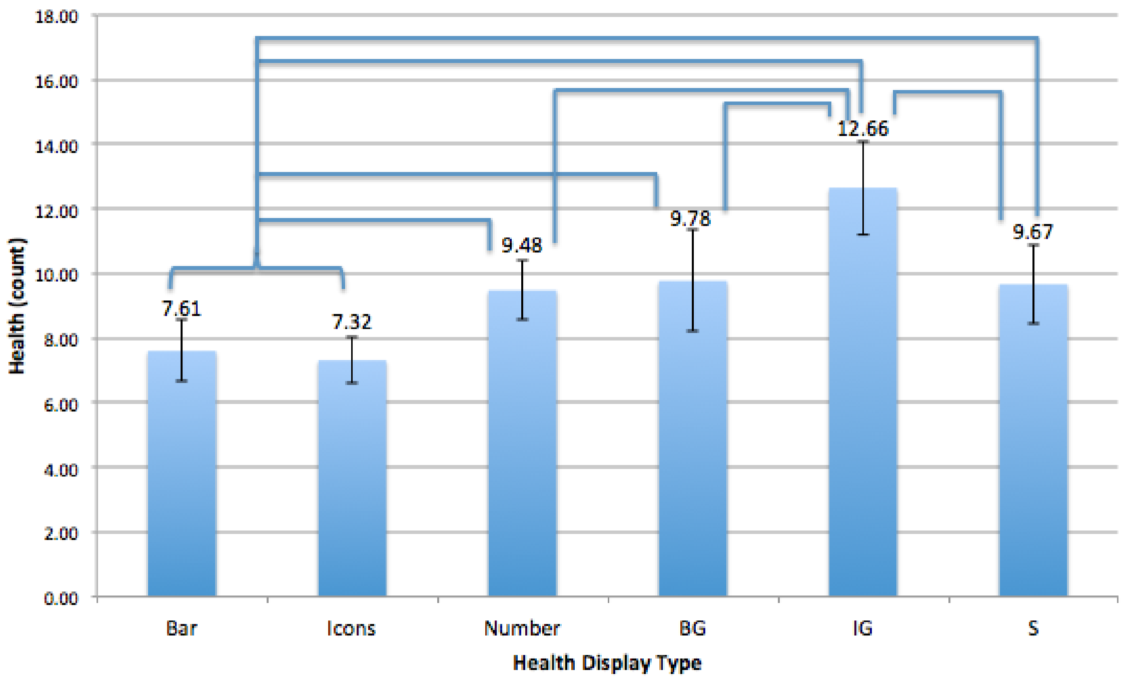


Figure 6.10: Health when escaped by health display type. Error bars show ±1 SD.

display type (bar, icons, number, bar-in-game (BG), icons-in-game (IG), and splatter). For example, the "icons" display type is an average of the health when escaped with the icons-on-HUD-bottom (IHB), icons-on-HUD-left (IHL), and icons-on-HUD-top (IHT) health displays. Overall the icons and bar display types performed best, with health when escaped of 7.32 and 7.61 respectively. The icons-in-game (IG) display type performed worst, with a health when escaped of 12.66. This is approximately 42% worse than with the icons display type. There was a significant main effect for health display type on percentage of escapes ($F_{5,23} = 23.79$, $p < .0001$). The figure shows significance lines above health display types which had significant differences in performance as revealed by a Fisher LSD analysis. A complete list of health display types which were significantly different than each other can be found in Section B.2.

To summarize, the icons-in-game (IG) had significantly higher health when escaped than all other health display types, while the bar and icons had significantly lower health when escaped than all other health display types.

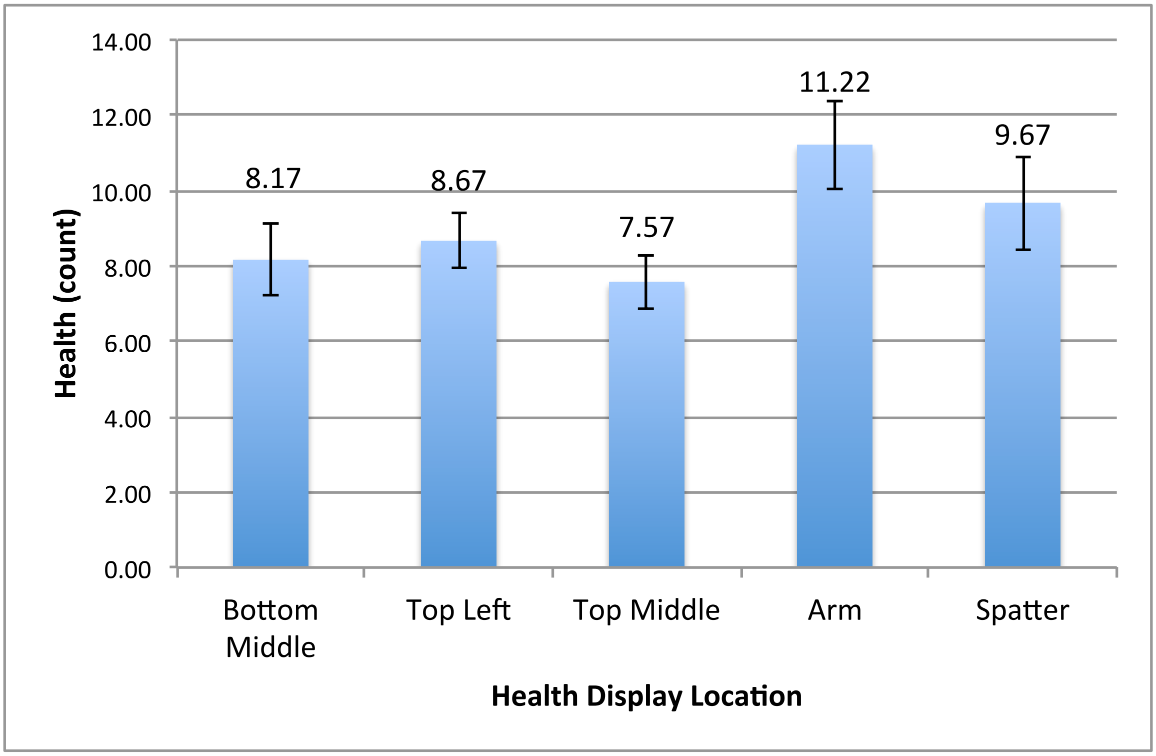


Figure 6.11: Health when escaped by health display location. Error bars show ±1 SD.

Figure 6.11 shows the health when escaped results when sorted by health display location (bottom middle, top left, top middle, arm, and splatter). For example, the top left results is an average of the health when escaped with the bar-on-HUD-left (BHL), icons-on-HUD-left (IHL), and number-on-HUD-left (NHL) health displays. The top middle position performed best, with an average health when escaped of 7.57. The arm position performed worst, with an average health when escaped of 11.22. This was approximately 33% worse than the top middle position. There was a significant main effect for health display type on percentage of escapes ($F_{4,23} = 14.84$,

$p < .0001$). A Fisher LSD analysis indicated that there was a significant difference between the following:

- Bottom Middle and Arm and splatter
- Top Left and Top Middle and Arm
- Top Middle and Arm and splatter
- Arm and splatter

To summarize, the displays on the arm had significantly higher health when escaped than health displays in all other positions, while the displays in the top middle position had significantly lower health when escaped than all other positions except for the bottom middle.

6.3.3 Questionnaire

Participants each completed a questionnaire prior to completing the study, which solicited information about them including gender and age. They completed an additional questionnaire after the study, which gathered feedback on their level of immersion, perception of performance, and overall preference of display.

Immersion

Participants were given a lengthy questionnaire to gauge their immersion level on a 5-point Likert scale (Jennett *et al.*, 2008) which can be seen in Appendix A.

Each participant completed this questionnaire twice. The first time they were asked to think of when they played the game with the HUD health displays (i.e. icon,

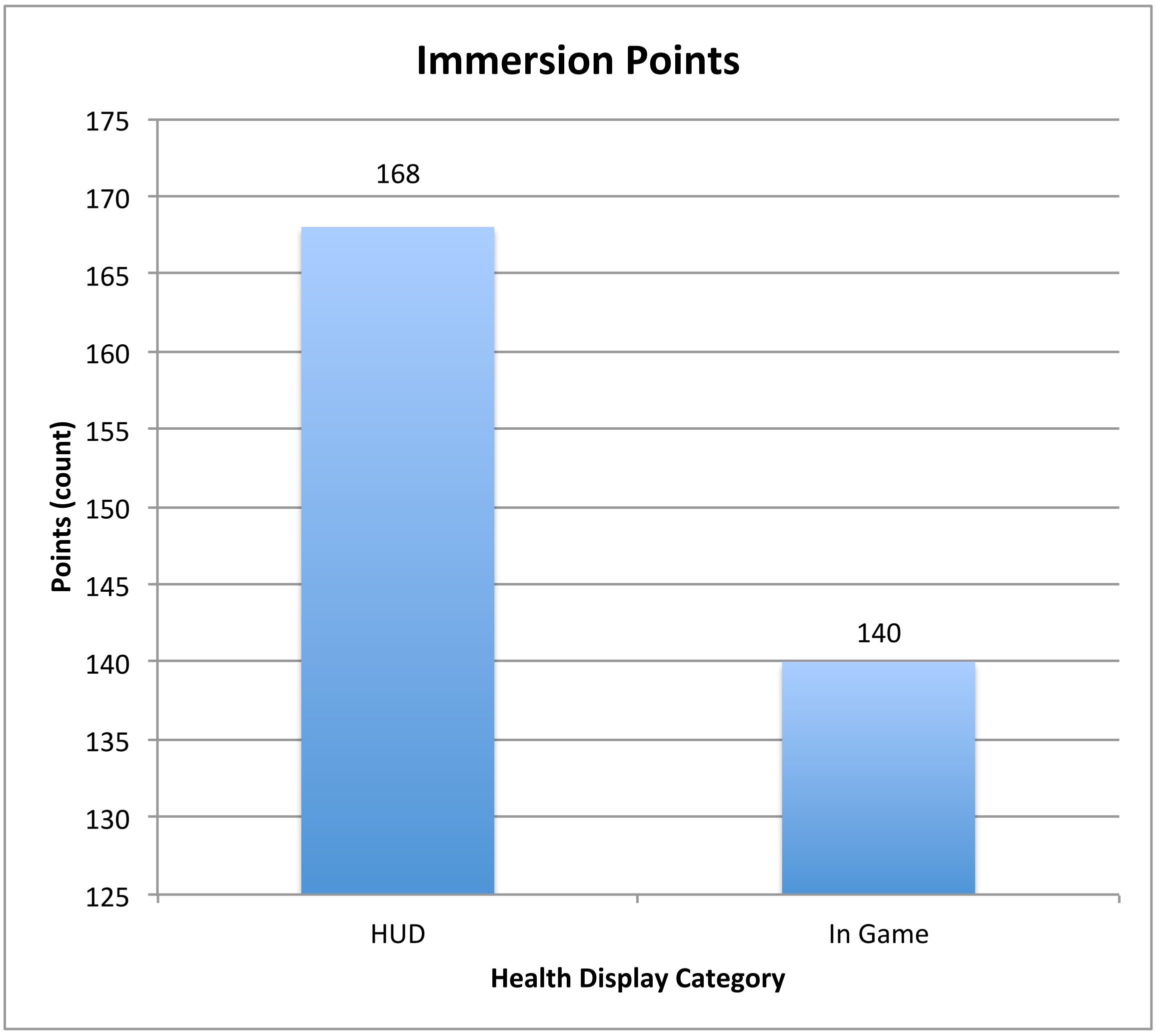
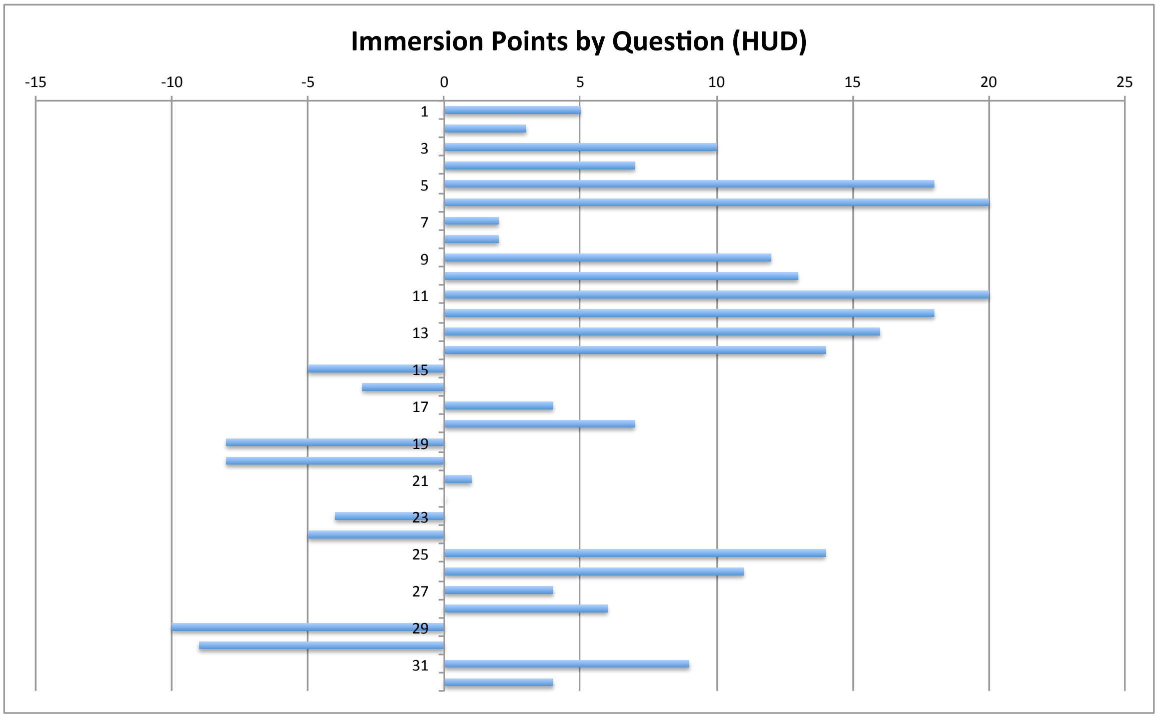
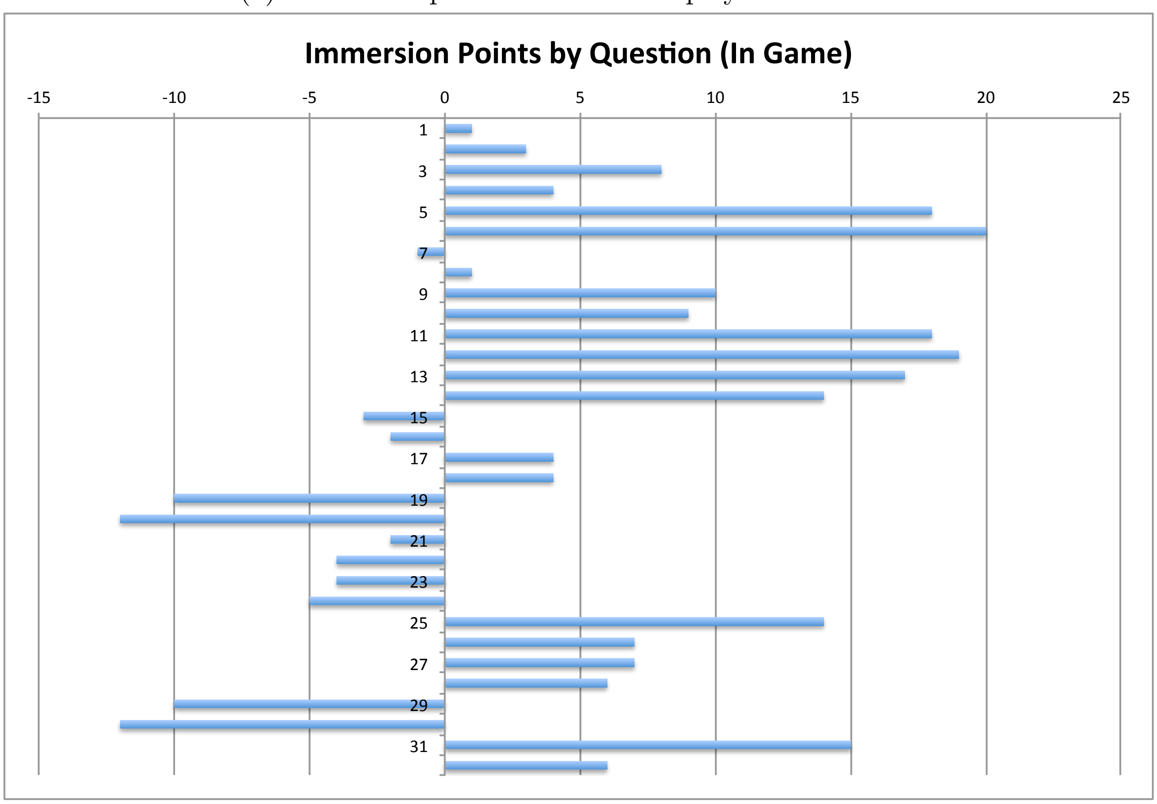


Figure 6.12: Results of Immersion Questionnaire



(a) Immersion points for health displays on the HUD



(b) Immersion points for health displays in the game

Figure 6.13: Immersion points divided by question

number, and bar on HUD displays) when answering. The second time they were asked to think of when they played the game with the in-game displays (bar-in-game (BG), icons-in-game (IG), and splatter (S)). This was done to minimize the number of times they needed to complete this questionnaire, while separating based on if a display is traditionally considered to be less immersive (HUD) or more immersive (diegetic/semi-diegetic).

After completing this questionnaire, they were then asked to rate how immersive they thought the display was from 1-10.

Results of the questionnaire were added, with each response given a point value ("Strongly Agree" = 2, "Agree" = 1, "Neutral" = 0, "Disagree" = -1, "Strongly Disagree" = -2). Questions that supported the display being immersive were added to the total immersion score, while questions that did not support the display being immersive were subtracted. The overall level of immersion results can be seen in Figure 6.12. Figures 7.10a and 7.10b show the responses to each question. Bars to the right indicate that the response supported the display being immersive, while bars to the left indicate that the response to that specific question shows a lack of immersion. Results shows that participants actually felt the HUD health displays to be more immersive overall than the in-game health displays.

Performance and Preference

Participants were asked to rate how much they felt that a display type (bar on display, icons on display, number on display, bar-in-game (BG), icons-in-game (IG), and splatter (S)) helped or hindered their performance on a 5-point Likert scale from "Really Helped" to "Really Hindered". The results can be seen in Figure 6.14. The

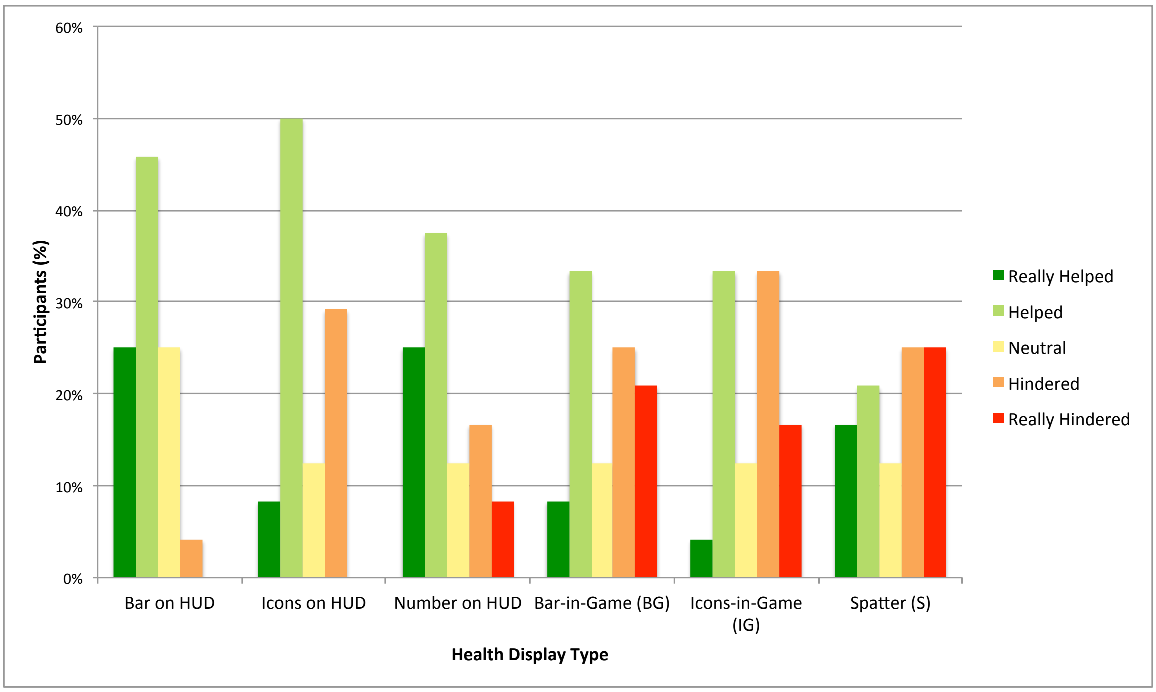


Figure 6.14: Results of having participants rate how much a display type helped or hindered them.

bar on display received mostly positive results, while the other displays had very mixed results. The results were found to be statistically significant using a Friedman non-parametric test ($\chi^2 = 15.134$, $p < .01$, $df = 5$). A post-hoc analysis revealed statistical significance between bar on display and bar-in-game (BG), icons-in-game (IG) and splatter (S), as well as between number on display and bar-in-game (BG), icons-in-game (IG) and splatter (S). This result shows that the the bar and number on display were thought to be much more helpful than the diegetic health displays (bar-in-game (BG), and icons-in-game (IG)) and the splatter (S).

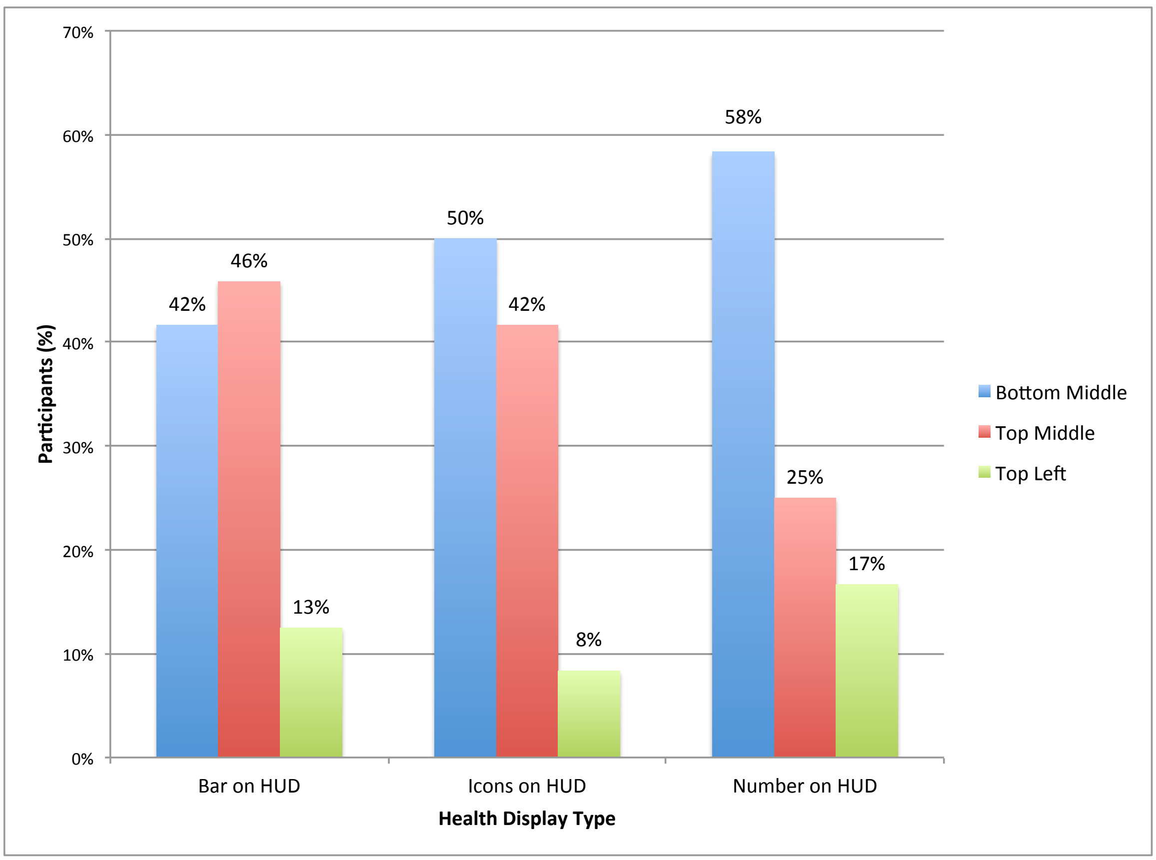


Figure 6.15: Results of asking participants their favourite position for the HUD health displays.

Participants were asked to rank the positions for each HUD health display from most to least favourite. The results can be seen in Figure 6.15. The top left display was the least favoured for all three HUD health display types. For the bar, the top middle position was favoured slightly over the bottom middle, with 46% preferring it. The bottom middle position was preferred by 42% of participants. A Kruskal-Wallis non-parametric test found the results to be statistically significant for the bar ($\chi^2 = 15.901$, $p < .0005$, $df = 2$). For the icons on display, the bottom middle position was favoured by 50% of participants, followed by the top middle position with 42% of participants. A Kruskal-Wallis non-parametric test found the results to be statistically significant for the icons ($\chi^2 = 21.078$, $p < .0001$, $df = 2$). For the number on display, the bottom middle position was favoured by 58% of participants. A Kruskal-Wallis non-parametric test found the results to be statistically significant for the number ($\chi^2 = 15.285$, $p < .0005$, $df = 2$). For all three health display types, a post hoc analysis revealed statistical significance between the bottom middle and top left, and top middle and top left positions.

Participants were asked to order the display types (bar on display, icons on display, number on display, bar in game, icons in game, and splatter) from favourite to least favourite (1 = favourite, 6 = least favourite). The results can be seen in Figure 8.14. As can be seen from the charts, results are very mixed. A Kruskal-Wallis non-parametric test found the results to be statistically significant ($\chi^2 = 13.903$, $p < .05$, $df = 5$). A post-hoc analysis revealed statistical significance between the following:

- Bar on HUD and icons on HUD, BG, IG, and S
- Icons on HUD and BG, and IG
- Number on HUD and BG, IG, and S

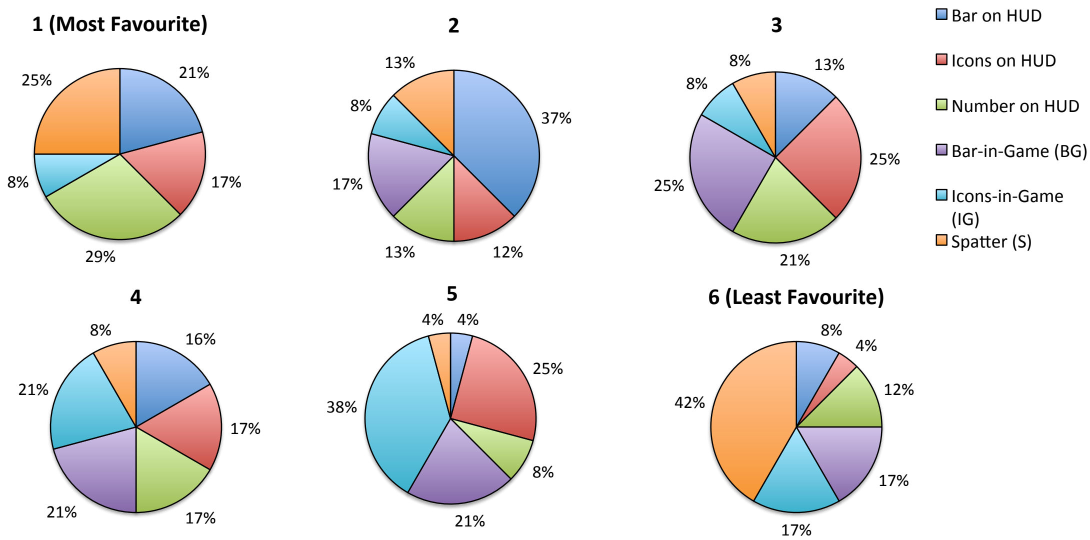


Figure 6.16: Results of having participants rank the health display types from most to least favourite.

These results indicate that the bar and number on HUD displays were preferred over all in-game displays (BG, IG, and S), and the icons on HUD displays were preferred over the diegetic health displays (BG and IG).

6.4 Discussion

The percentage of escapes represents how well a participant is able to use a health display in order to see when their health is low, whereas the health when escaped shows how low a participant would let their health get with a given display before they escape. A good performance with the latter means that participants trust their display enough to let it get low, which would allow them to get the larger point values. Therefore a good health display overall is one that has a high percentage of escapes while having a low health when escaped.

In looking at the results of percentage of escapes, the second best performer, the icons in game (IG) display, had a very high result (70%). It however also had the highest (lowest performing) result with health when escaped (12.88). This would imply that participants did not trust in the display to communicate when their health was low. This appears to be a combination of the effect of using icons and the positioning of the display on the player-character's arm. When looking at the bar-in-game (BG) display, which had an identical position to the icons-in-game (IG) display and also had its health drain towards the bottom of the screen, its result was in the middle for both percentage of escapes and health when escaped. It is therefore not possible to assume that position is the cause of the lack of trust in the icons-in-game (IG) display. When looking at the overall performance with the icon displays (icons-on-HUD-bottom (IHB), icons-on-HUD-top (IHT), and icons-on-HUD-left (IHL)), they had a medium performance with percentage of escapes, and the best performance with health when escaped. The icons overall appear to be a good health display option. It appears as though when the icon display, which had participants performing well when on the HUD, is combined with the arm position, the display actually does very poorly.

6.4.1 Type of Information Display

This groups the HUD methods by bar, icon, BG, IG, and S.

"Percentage of Escapes": The number and IG displays performed much better than the other display types. The bar performed the worst of the displays, but was closely followed by other displays.

“Health when Escaped”: The IG display performed the worst. The icons performed the best, followed closely by the bar.

These results indicate that, depending on the task required for the player, icons and number are both good options, with number performing well for having participants know when their health is low, while icons were good for letting participants take risks. One possibility is because participants were likely to know exactly how low their health was with the number display, participants would escape slightly earlier because of dwindling health. The icons do not report an exact amount of remaining health, and so participants would take more risk with them. Both the number and icon on HUD health displays did well in the questionnaire, with many players indicating that they favoured these displays. This makes either one a good balance of player performance and preference.

6.4.2 Positioning

“Percentage of Escapes”: The arm position performed slightly better overall while the splatter position performed slightly worse. Overall one position was not significantly better than any of the others.

“Health when Escaped”: The arm display performed the worst while the top middle and bottom middle positions performed the best. Of the HUD methods, the top left position performed worst.

These results seem to indicate that while no position is necessarily better for noticing health is low, the middle displays (top middle and bottom middle) are in fact better for knowing more exactly how low health is and allowing players to take more risks. These are also the positions that participants indicated that they prefer, and so they therefore do well in terms of both participant performance and preference.

6.5 Conclusion

Given the mixed performances with different dependent variables, it is not possible to determine the single "best" health display. It is however possible to eliminate certain displays as being good options. Overall, the in game health displays (bar-in-game, icons-in-game, and splatter) did not perform as well as the HUD health displays. It is therefore recommended that if possible, developers choose a HUD health display. If it is necessary for developers to use an in game health display, of the options tested, the bar-in-game (BG) and splatter (S) performed overall much better than the icons-in-game (IG) and so these are more recommended. However, since there is no current standard of diegetic displays, there may be options that were not tested that perform better. It is therefore up to developers to determine these and decide if they will be a good choice for their game.

If it is not required that the game utilize an in game health option, then it is strongly recommended that developers use a HUD health display. The recommendation for position is either the top middle or bottom middle, perhaps slightly leaning towards the top middle. If the game would benefit from the player knowing exactly what their health is, then a number display is recommended, as it had the highest percentage of escapes, most likely due to participants' constant knowledge of exactly what their health was. Participants felt it to be a really helpful display. In a task where it is necessary for players to have a good and fairly exact knowledge of where their health is at, the bar is not recommended. In situations where a vague knowledge of health is necessary rather than a fairly exact one, any of the bar, icons, or number on HUD is recommended. Participants liked these options and also performed well with them.

Chapter 7

Current Weapon Study

7.1 Introduction

This chapter presents a study which compared methods of communicating the player's currently equipped weapon ("current weapon") in FPS games. In current popular FPS games the weapon is always depicted in front of the player character as though they are holding it. In some games, the weapon name and/or an icon representing the weapon is also used. This is placed on the HUD with the remaining ammunition information.

The display methods compared were:

HUD:

1. Name-on-HUD-Right (NHR)

2. Name-on-HUD-Left (NHL)

3. Icon-on-HUD-Right (IHR)

4. Icon-on-HUD-left (IHL)

Diegetic:

5. In-front (IF)
6. Name-on-Gun (NG)

Participants completed a game level where they were required to destroy several groups of enemies. Each group of enemies was a different colour (red, green, blue, or yellow) and the player had 4 weapons available to them (shotgun in red, green, blue or yellow). Participants needed to shoot each enemy with a weapon in the colour that corresponded to the colour of the enemy. The level was complete when all enemies were destroyed.

7.2 Methodology

7.2.1 Participants

24 paid participants (21 male, 3 female) took part in the study. Their ages were from 19 to 53 years (mean 25.42, SD 7.23). All participants were regular gamers, with 58% playing video games for more than 10 hours per week, and 86% playing first-person shooter games for at least 1-10 hours per week. The majority of participants were used for all three studies in Chapters 6 - 8.

7.2.2 Apparatus

Hardware Setup

The system and position were the same as that described in Section 5.2.2. Participants used a Microsoft Xbox One controller to play the game. Viewpoint rotation and aiming was controlled by the right joystick and the participant was unable to move their character. The right trigger button was used to shoot. Each button of the D-Pad on the controller corresponded to switching to a different weapon colour (i.e., up would switch to red, right to green, down to blue, left to yellow). The ordering was so the cycle order was RGB (red, green, blue) then yellow. The D-Pad was used instead of using 1 or 2 buttons to cycle through the weapons in order to prevent a time delay that would occur when participants are cycling and searching.

Software Setup

This study uses the game level discussed in Section 4.3. The software was capable of displaying the player's currently equipped weapon using any of the six displays.. The weapon displays included name-on-HUD-right (NHR, see Figure 7.1), name-on-HUD-left (NHL, see Figure 7.2), icon-on-HUD-right (IHR, see Figure 7.3), icon-on-HUD-left (IHL, see Figure 7.4), in-front (IF) (see Figure 7.5), and name-on-gun (NG, see Figure 7.6). Each presented the same information, but visualized it differently.

The game was set in a warehouse with 4 groups of 5 enemies (each group being coloured in one of 4 colours (red, green, blue, and yellow)) walking towards the participant's character. The groups of enemies were spatially separated. The participant needed to switch to the weapon with the correct colour in order to destroy the enemies. If any enemy was shot while the participant had a different colour weapon equipped,

(a) Overall game with red gun name

(b) Blue gun name

(c) Green gun name

(d) Yellow gun name

Figure 7.1: Overall gameplay with name-on-HUD-right (NHR) displays

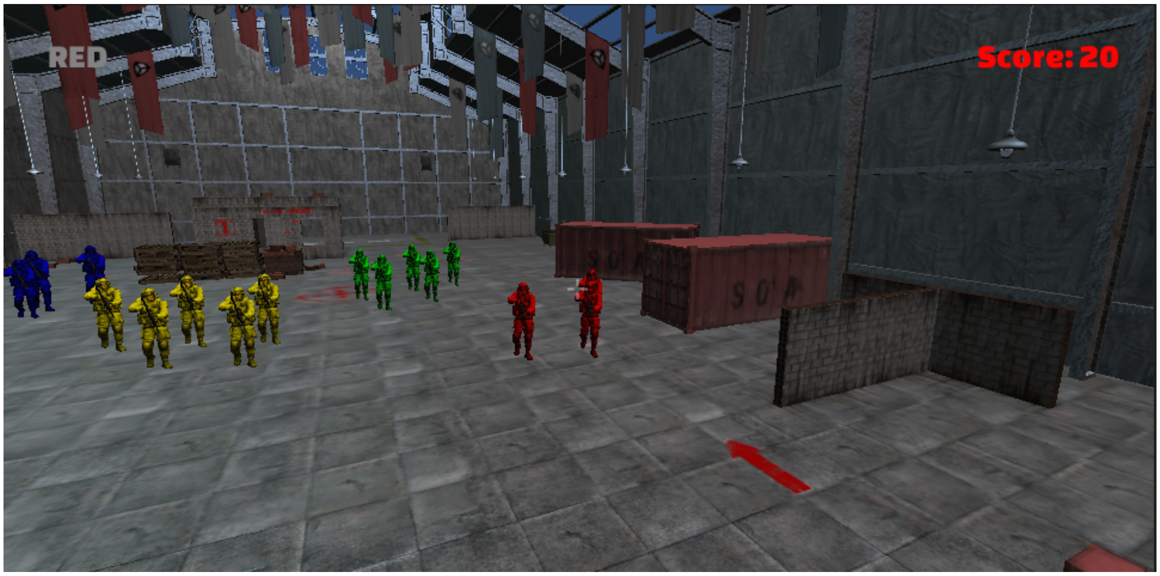
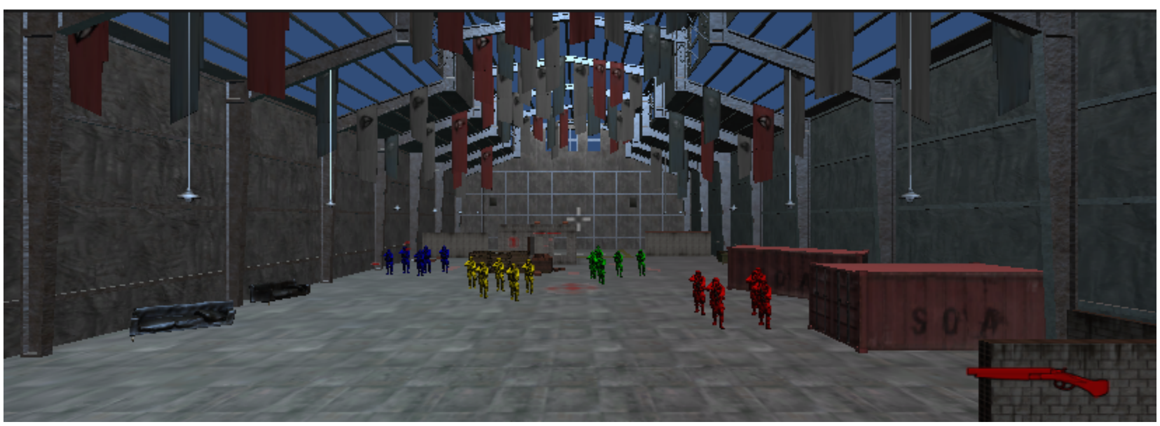


Figure 7.2: Overall gameplay with name-on-HUD-left (NHL) display. Other weapon indicators appear the same as in Figures 7.1b - 7.1d



(a) Overall game with red gun icon

(b) Blue gun icon

(c) Green gun icon

(d) Yellow gun icon

Figure 7.3: Overall gameplay with icon-on-HUD-right (IHR) displays

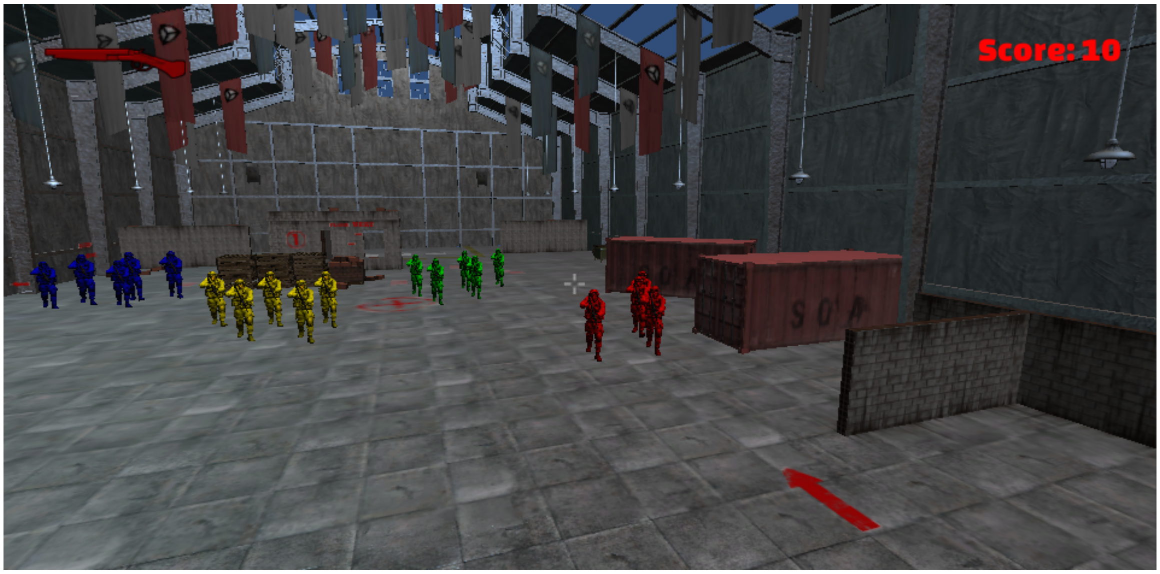


Figure 7.4: Overall gameplay with icons-on-HUD-left (IHL) display. Other weapon indicators appear the same as in Figures 7.3b - 7.3d

the shot would not affect the enemy. The colours of each group changed with each trial based upon a pseudo-random list. A trial was complete when all enemies were destroyed. Data recorded included number of shots with the wrong colour weapon and time to switch to the correct weapon.

7.2.3 Procedure

Upon arrival, participants were greeted and the purpose of the experiment was explained. Participants gave informed consent before proceeding.

Participants were given the following instructions:

- Their character would be positioned in a warehouse setting with a small group of enemies walking towards them. Their character would be unable to move but could look around and shoot.

(a) Overall game with red gun in front

(b) Blue gun in front

(c) Green gun in front

(d) Yellow gun in front

Figure 7.5: Overall gameplay with in-front (IF) displays

(a) Overall game with red name on gun

(b) Blue name on gun

(c) Green name on gun

(d) Yellow name on gun

Figure 7.6: Overall gameplay with name-on-gun (NG) displays

- They needed to kill the enemies as quickly as possible, and once they killed one small group a new group would appear.
- Enemies would be either red, blue, green, or yellow and needed to be killed with a gun of the same colour. They would therefore need to change their gun to be the correct colour.
- Each enemy is destroyed with one hit
- They (the participant) would have unlimited ammunition
- If they got on a "kill streak" where they killed multiple enemies within 750 ms of the first enemy of the streak being killed, they would receive more points.
- Their overall goal was to get the highest score possible.

They were then instructed on the controls and were allowed to begin. The high score goal was implemented to ensure that players attempted to complete the level quickly, and so weapon display would become more critical than if they were able to think through their weapon selection more slowly.

Participants completed 8 trials for each of the six ammunition displays, completing 48 trials in total. After each trial participants could take a break before continuing. Each trial took approximately 25 seconds. In total, the experiment took approximately 25 minutes. Upon finishing all trials, participants completed a questionnaire about prior experience with games, and soliciting feedback on a 5-point Likert scale on the level of immersion they experienced and the perceived effectiveness of each weapon display.

7.2.4 Design

The study employed a 6 × 8 within-subjects design. The independent variables and levels were:

Weapon Display: NHR, NHL, IHR, IHL, IF, NG

Trial: 1, 2, 3, ..., 8

The weapon display conditions are depicted in Figures 7.1 - 7.6 and were described earlier. The ordering of weapon display was counterbalanced according to a Latin square. The dependent variables were shots with wrong weapon (count), and time to switch to correct weapon (seconds).

7.3 Results

7.3.1 Shots with Wrong Weapon

This dependent variable is the number of shots at an enemy of a colour different than that of the equipped weapon. A lower value means that participants performed better with that weapon display. The results can be seen in Figure 7.7.

The icons-on-HUD-right (IHR) display performed the best, with 2.12% of shots with the wrong weapon. This was closely followed by the weapon in-front (IF) display, with 2.20%. The name-on-gun (NG) display performed the worst, with 2.93% of shots with the wrong weapon.

There was not a significant main effect for weapon display on shots with wrong weapon ($F_{5,23} = 1.74$, ns). The main effect for trial was significant ($F_{7,23} = 2.44$, $p <$

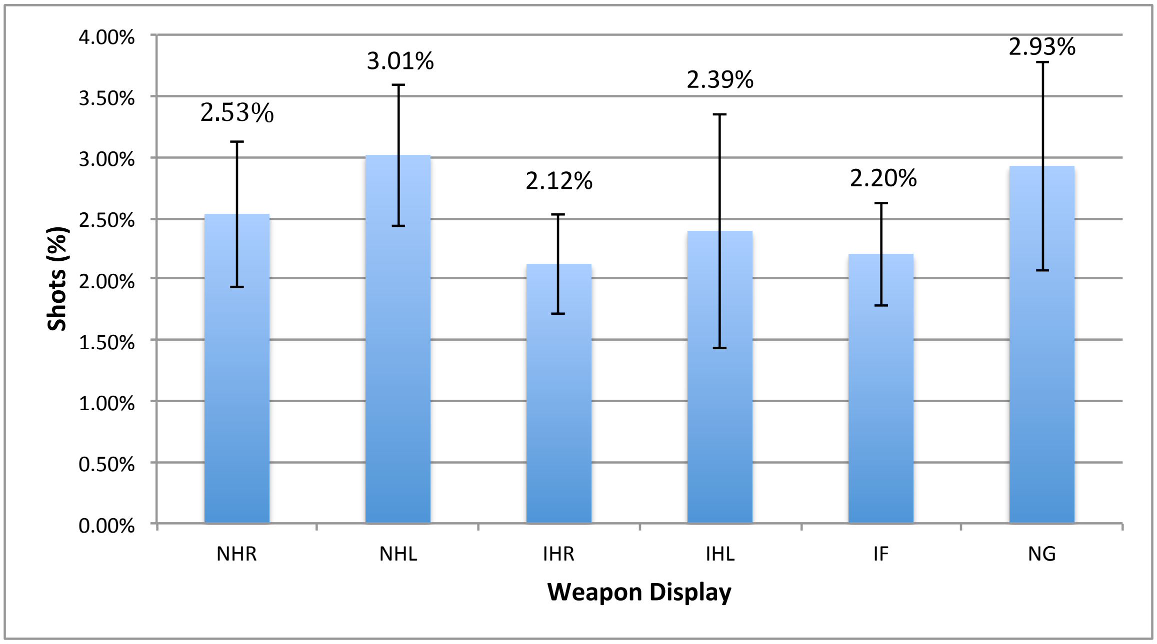


Figure 7.7: Shots with wrong weapon by weapon display. Error bars showing ±1 SD

.05). The interaction between weapon display and trial was not significant ($F_{35,23} = 0.82$, ns).

7.3.2 Time to Switch to Correct Weapon

This dependent variable is the time, in seconds, to switch from a weapon that is not the colour of the currently approaching enemies to the weapon that is the colour of the currently approaching enemies. A lower time represents better performance. The results can be seen in Figure 7.8.

The icon-on-HUD-right (IHR) again performed the best, with an average of 1.01 seconds to switch to the correct weapon. This was closely followed by the name-on-HUD-left (NHL), in-front (IF), and name-on-HUD-right (NHR) weapon displays. The name-on-gun (NG) weapon display performed the worst, with an average of 1.16 seconds to switch

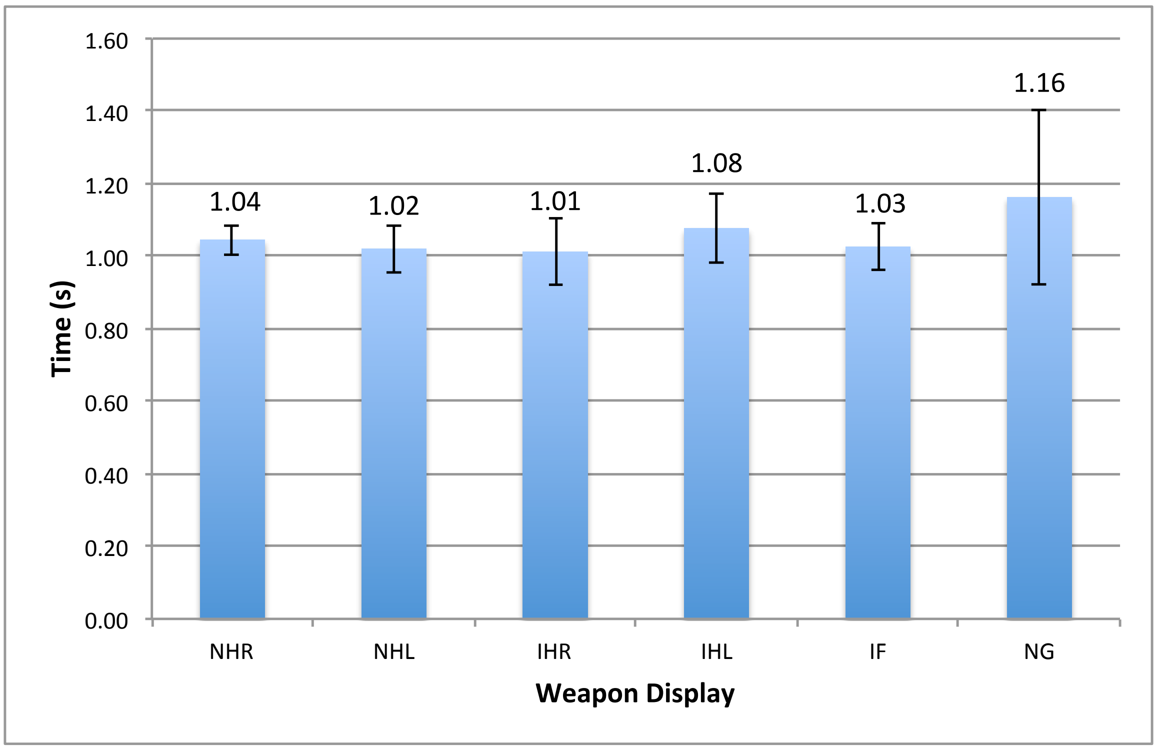


Figure 7.8: Time to switch to correct weapon by weapon display. Error bars show ±1 SD

to the correct weapon. This was approximately 11% worse than with the icons-on-HUD-right (IHR) display.

There was not a significant main effect for weapon display on time to switch to correct weapon ($F_{5,23}$ = 2.03, ns). The main effect for trial was significant ($F_{7,23}$ = 17.33, p < .0001). The interaction between weapon display and trial was also significant ($F_{35,23}$ = 1.73, p < .01). A Fisher LSD post-hoc analysis revealed the significance to be between the majority of trials and NHR trial 1, IHR trial 1, and NG trial 1.

7.3.3 Questionnaire

Participants each completed one questionnaire prior to completing the study, which solicited information about them including gender and age. They also completed one questionnaire after the study, which gathered feedback on their level of immersion, feelings on performance with each display, and overall preference of display.

Immersion

Participants were given a lengthy questionnaire to gauge their immersion level on a 5-point Likert scale (Jennett *et al.*, 2008) which can be seen in Appendix A.

Each participant completed this questionnaire twice. The first time they were asked to think of when they played the game with the HUD weapon displays (i.e. icon and name on HUD) when answering. The second time they were asked to think of when they played the game with the diegetic displays (in-game (IG) and name-on-gun (NG)). This was done to minimize the number of times they needed to complete this questionnaire, while separating based on if a display is traditionally

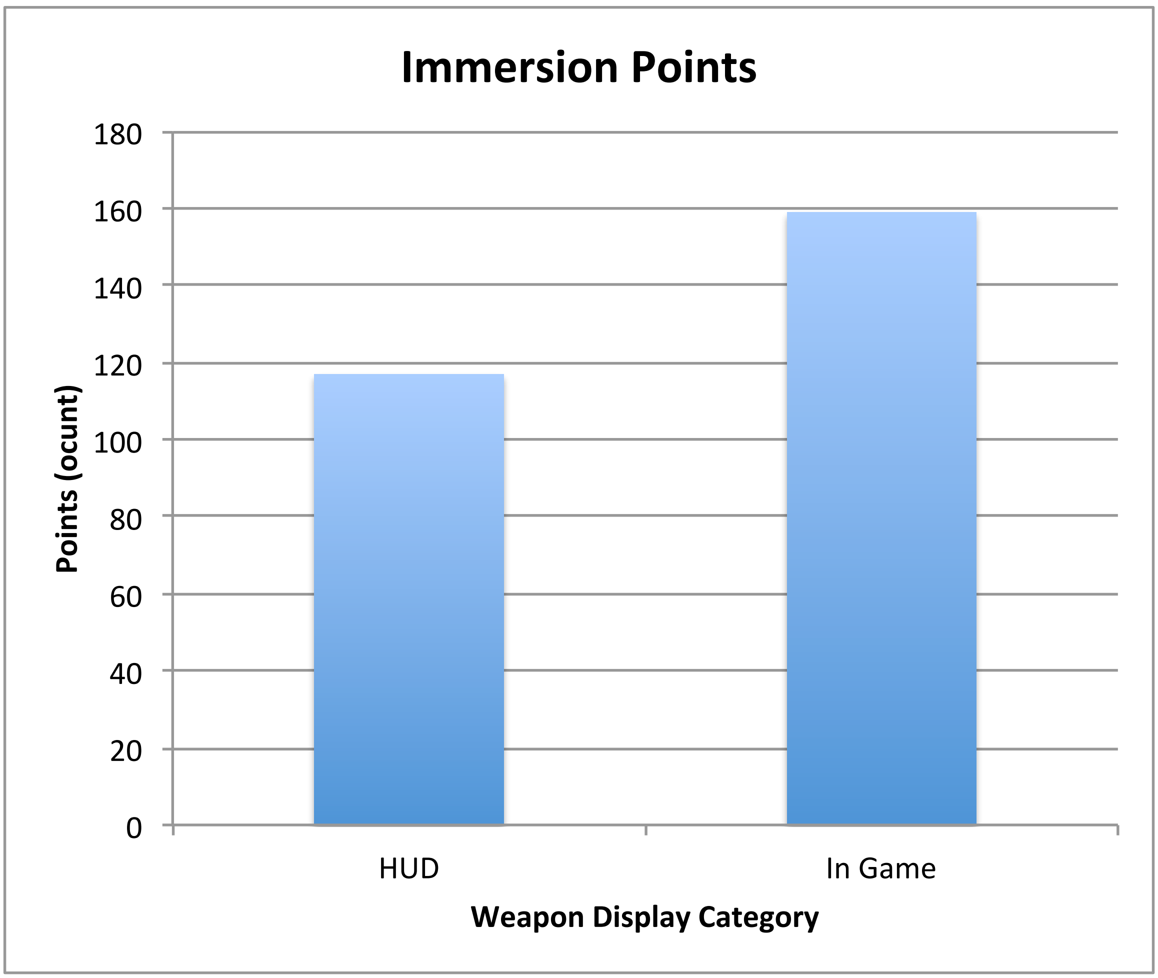
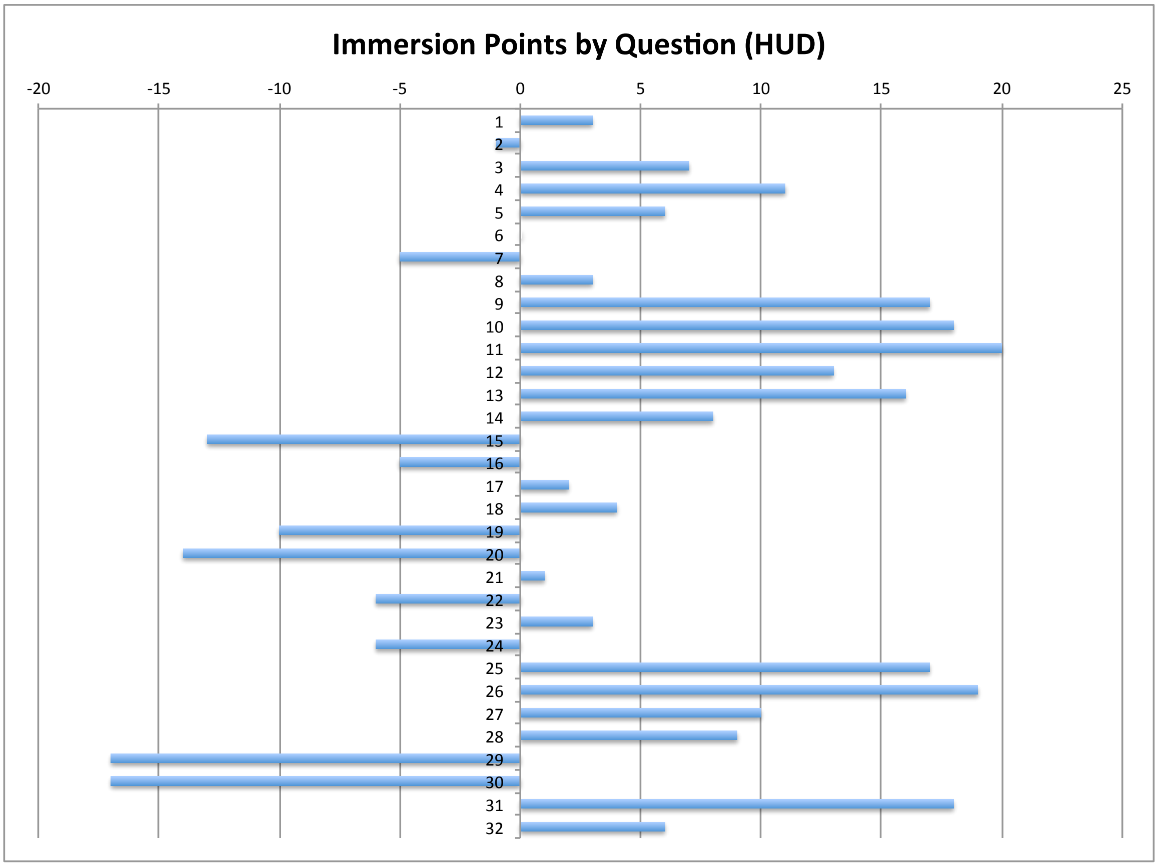
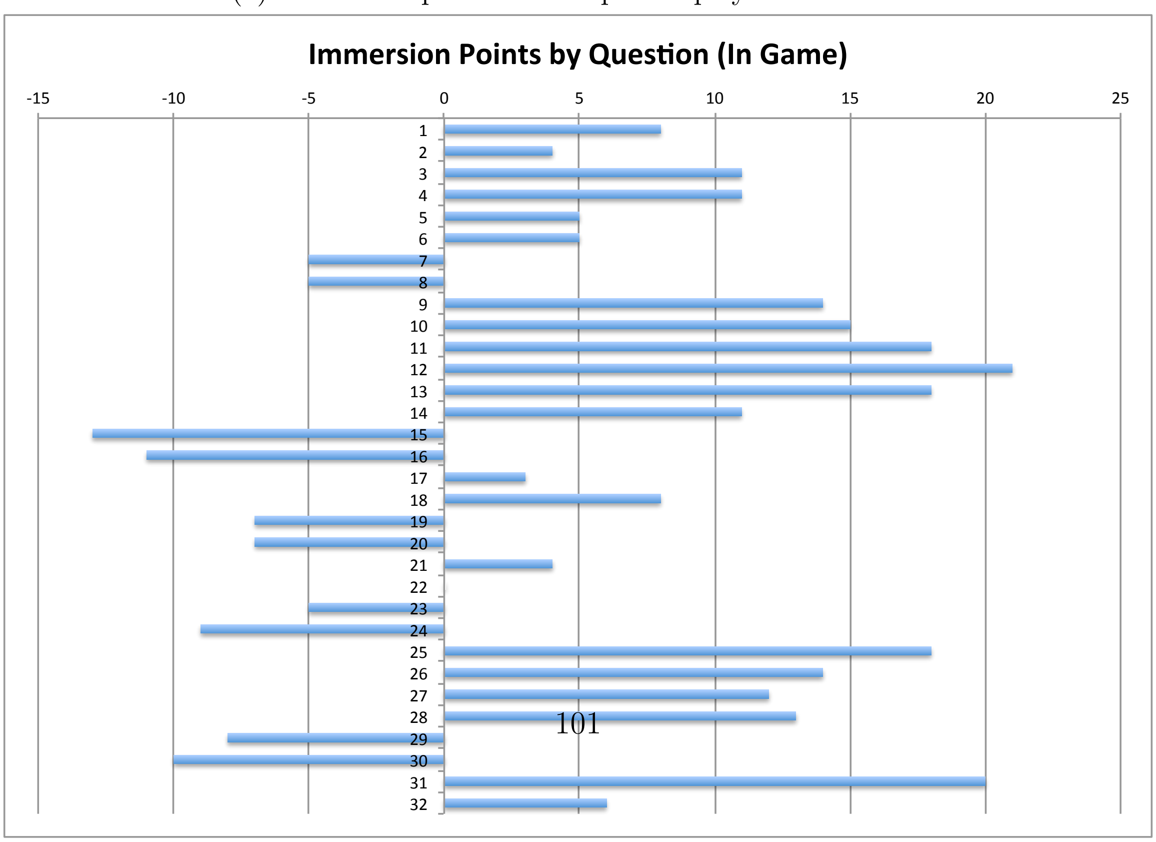


Figure 7.9: Results of immersion survey



(a) Immersion points for weapon displays on the HUD



(b) Immersion points for weapon displays in the game considered to be less immersive (HUD) or more immersive (diegetic).

After completing this questionnaire, they were then asked to rate how immersive they thought the display was from 1-10.

Results of the questionnaire were added, with each response given a point value ("Strongly Agree" = 2, "Agree" = 1, "Neutral" = 0, "Disagree" = -1, "Strongly Disagree" = -2). Questions that supported the display being immersive were added to the total immersion score, while questions that did not support the display being immersive were subtracted. The overall level of immersion results can be seen in Figure 7.9. Figures 7.10a and 7.10b show the responses to each question. Bars to the right indicate that the response supported the display being immersive, while bars to the left indicate that the display was not immersive.

Performance and Preference

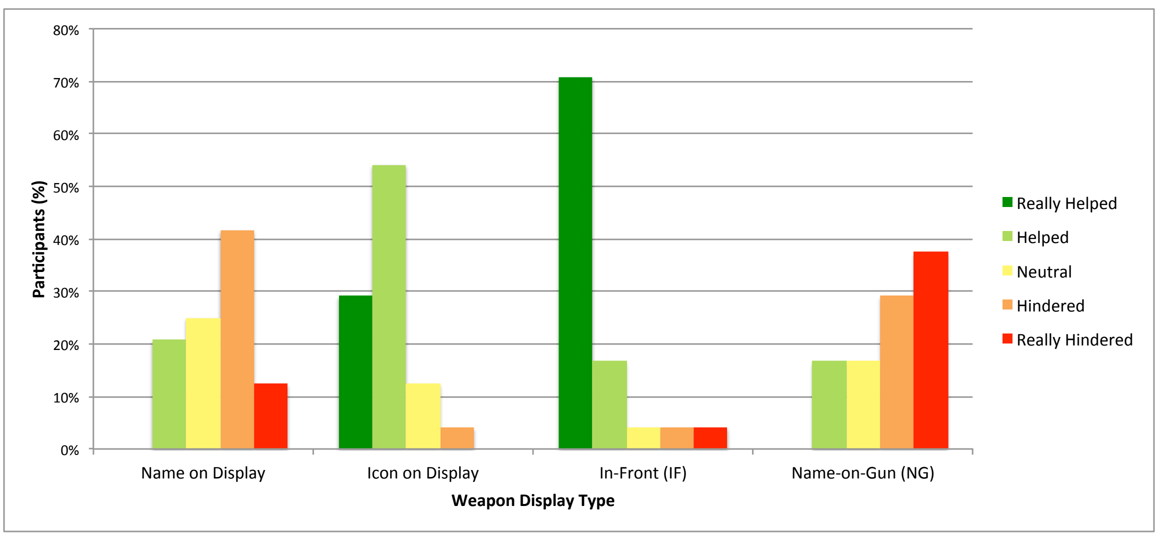


Figure 7.11: Results of having participants rate how much a display type helped or hindered them.

Participants were asked to rate how much a display type (name on display, icons on display, in-front, and name-on-gun) helped or hindered their performance on a 5-point Likert scale from "Really Helped" to "Really Hindered". The results can be seen in Figure 7.11. The weapon in-front (IF) display received mostly very positive results, while the icon on display weapon display type (icon-on-HUD-left (IHL) and icon-on-HUD-right (IHR)) also received mostly positive results. The name on display weapon display type (name-on-HUD-left (NHL) and name-on-HUD-right (NHR)) results were mixed. The results for name-on-gun (NG) lean more negatively. The results were found to be statistically significant using a Friedman non-parametric test ($\chi^2 = 40.854$, $p < .00005$, $df = 3$). A post-hoc analysis revealed the results to be significant between all pairs except for the name on display and name-on-gun (NG).

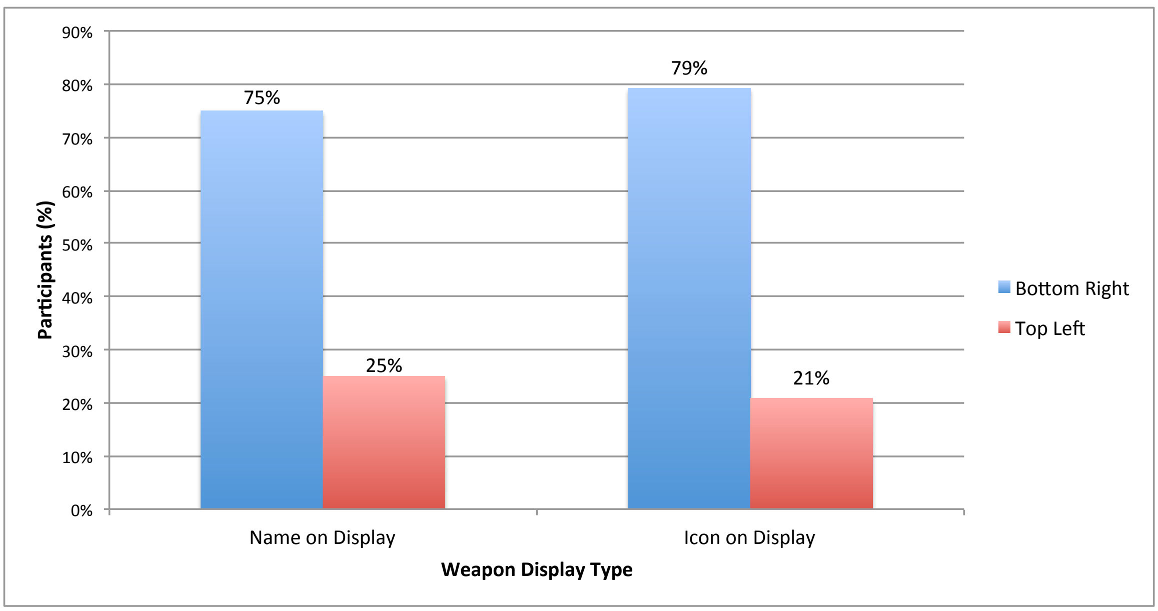


Figure 7.12: Results of asking participants their favourite position for the HUD weapon displays.

Participants were asked to select their favourite position for the icon and name HUD displays. The results can be seen in Figure 7.12. The bottom right position was preferred for both, with 75% preferring it for the name and 79% preferring it for the icon.

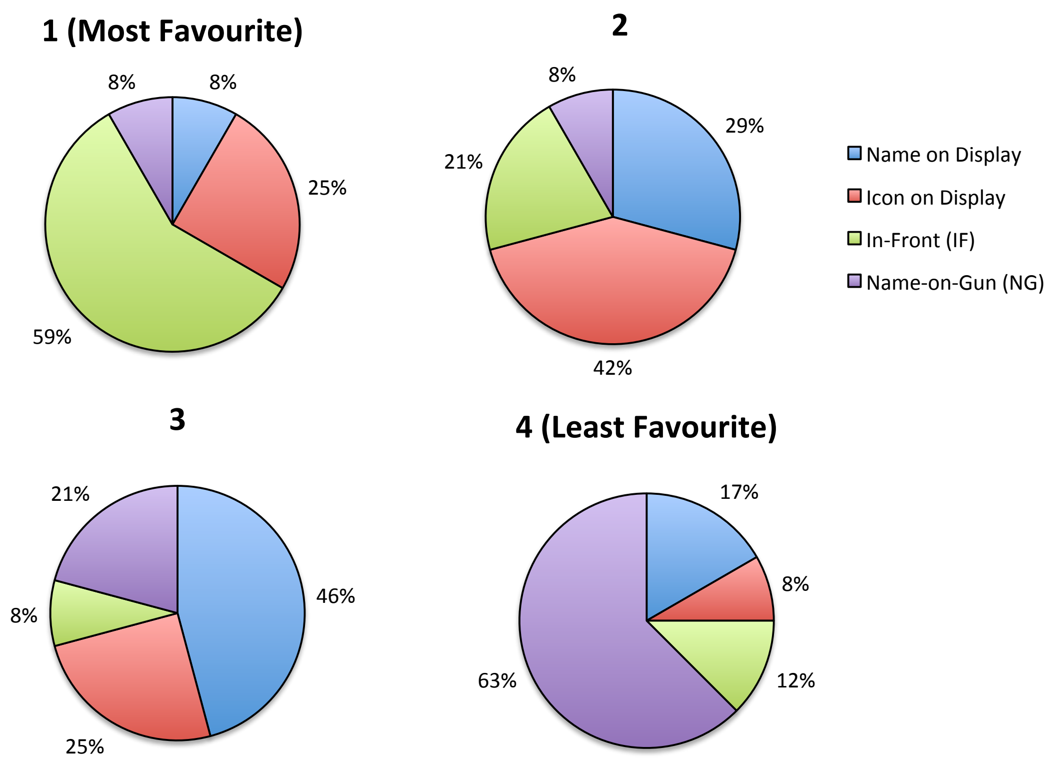


Figure 7.13: Results of having participants rank the display types from most to least favourite.

Participants were asked to order the display types (name on display, icons on display, in-front, and name-on-gun) from favourite to least favourite (1 = favourite, 4 = least favourite). The results can be seen in Figure 7.13. 59% of participants put the weapon in-front (IF) display as their favourite, while 63% of participants put the name-on-gun (NG) as their least favourite. The icon displays dominate as the second favourite and the name on display as third. A Kruskal-Wallis non-parametric test found the results to be statistically significant ($\chi^2 = 28.170$, $p < .00005$, $df = 3$). A post-hoc analysis revealed statistical significance between all pairs except for icon on display and weapon in-front (IF).

7.4 Discussion

7.4.1 Display Type

"Shots with Wrong Weapon": The icon on the HUD and weapon in front displays did the best with this variable. The name-on-gun (NG) weapon display performed the worst.

"Time to Switch to Correct Weapon": All display types performed similarly, except for the name-on-gun (NG) which performed the worst.

Questionnaire: The in-game displays were preferred in terms of immersion. The weapon in front (IF) did the best in terms of performance and preference, with participants stating that it is really helpful and the majority ranking it as their most favourite.

These results suggest that the icon on the HUD and weapon in front displays are the best choices for display type. The icon on the HUD displays did the best overall in terms of performance. The weapon in front (IF) was the most preferred, and often performed well. This suggests that these are both good options for use in FPS games and also could be good in combination with each other, since they both had strengths in different areas. The other diegetic option tested, name-on-gun (NG) did not perform well and was the least favourite option of participants. This suggests that it is either a bad option, or another implementation would be necessary in order for it to be more favourable. However, at this time there are better and more recommendable options. The name-on-HUD displays performed mediocrely and so it is not recommended, especially since the icon is a similarly sized and positioned option that performs much better.

7.4.2 Display Position

"Shots with Wrong Weapon": For both the name and icon on HUD displays, the right position performed better for this variable.

"Time to Switch to Correct Weapon": The right position performed better with the icons on HUD, while the left position performed just slightly better with the name on HUD.

Questionnaire: The bottom right position was much more preferred to the top left position.

Overall, the bottom right position is the one that these results suggest to be better. This position performed significantly better in terms of preference, and mostly performed better in terms of actual performance. However, the fact that the top left performed better for two of the three dependent variables for only the name on HUD weapon display is interesting.

7.5 Conclusion

Overall, it is recommended to use the icon and/or weapon in front for weapon display in FPS games. It is potentially advisable to use both in order to achieve optimal performance and player satisfaction, but this depends upon HUD availability and game style. Both of these displays performed very well with most dependent variables, and also did well in the survey. The weapon in front was by far the preferred choice of participants, but the icon-on-HUD-right (IHR) overall performed the best. This is why both are advisable choices. The bottom right position is also recommended over the top left position. This was very much the preference of participants and also the position that overall performed better. This positive result for the bottom right position could be because it has been found that humans are better at discriminating stimuli presented in the lower visual field (Skrandies, 1987). This was also the position where weapon information was most often seen in the games analysis when it was visible on the HUD. This suggests that participants may be more used to looking in the bottom right corner for weapon information rather than in the top left corner.

Chapter 8

Navigational Aid Study

8.1 Introduction

This chapter presents a study into the navigational aid used in FPS games. This includes displays both on the HUD and within the game (diegetic and geometric elements). The navigation displays were selected based upon the results of the games analysis presented in Chapter 2 and specifically discussed in Section 2.5.

The navigation displays (and their short-hand names) are:

HUD:

1. Mini-map still (MMS)

2. Mini-map rotate (MMR)

Geometric Element:

3. Wayfinding arrow (WA)

Diegetic:

4. Light Pillar (LP)

5. Compass (C)

6. Navigation Line (NL)

This study involved participants completing a maze level in a custom FPS game. A maze was selected as the task because of its reliance on good navigation to improve performance, as well as because it has been used in past wayfinding research (Lin *et al.*, 2012).

8.2 Methodology

8.2.1 Participants

24 paid participants (22 male, 2 female) took part in the study. Their ages ranged from 19 to 53 years (mean 25.29, SD 7.30). All participants were regular gamers, with 46% reporting they play video games more than 10 hours per week. 95% of participants reported playing FPS games every week. 21% reported that their preferred system was a console, and 54% reported that they preferred a PC for gaming. The majority of participants were used for all three studies in Chapters 6 - 8.

8.2.2 Apparatus

Hardware Setup

The system and position were the same as that described in Section 5.2.2. Participants used a Microsoft Xbox One controller to play the game. Viewpoint rotation was controlled by the right joystick. Movement was controlled by the left joystick.

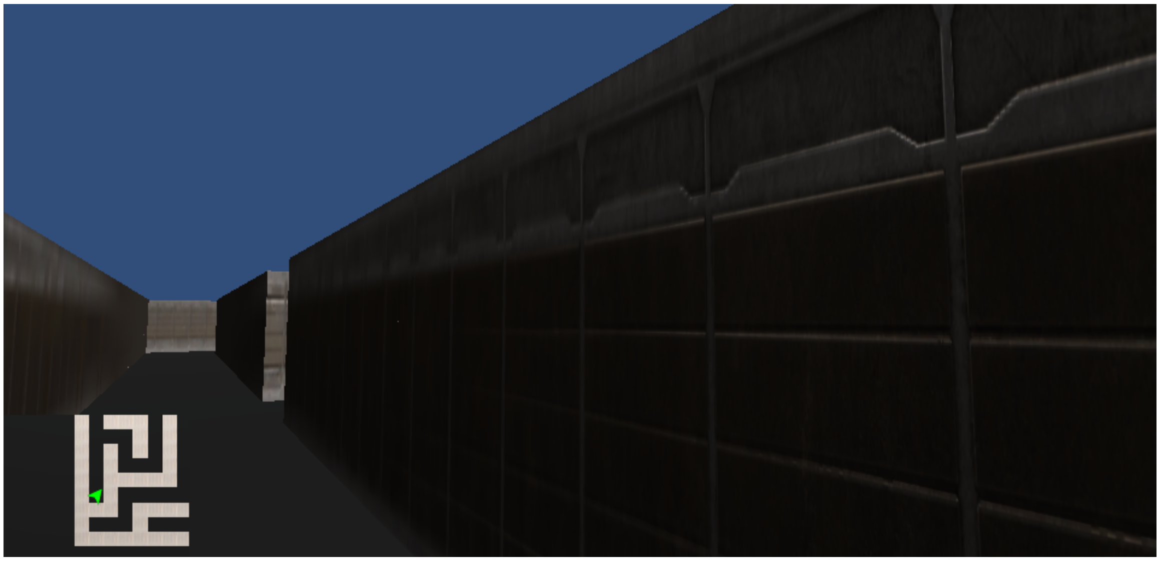


Figure 8.1: Gameplay with mini-map still (MMS) navigational aid

Software Setup

This study uses the game level discussed in Section 4.4. The navigational aid displays, as described earlier, included mini-map still (MMS, see Figure 8.1), mini-map rotate (MMR, see Figure 8.2), wayfinding arrow (WA, see Figure 8.3), light pillar (LP, see Figure 8.4), compass (C, see Figure 8.5), and navigation line (NL, see Figure 8.6). Each presented the same information, but visualized it differently.

The game was set in an outdoor maze. The same maze was used for all trials. For the first trial, participants would complete the maze in one direction, and in the second trial, participants would complete the maze in the reverse direction. This was done so that the complexity and distance were equal in both directions for experimental consistency. It also avoids learning affects that could occur by using the same maze in the same direction in both trials. There were 4 waypoints (represented by large red spheres) located in the maze, all separated by equidistant paths. The next waypoint would appear and be accessible after the previous waypoint was reached. Participants

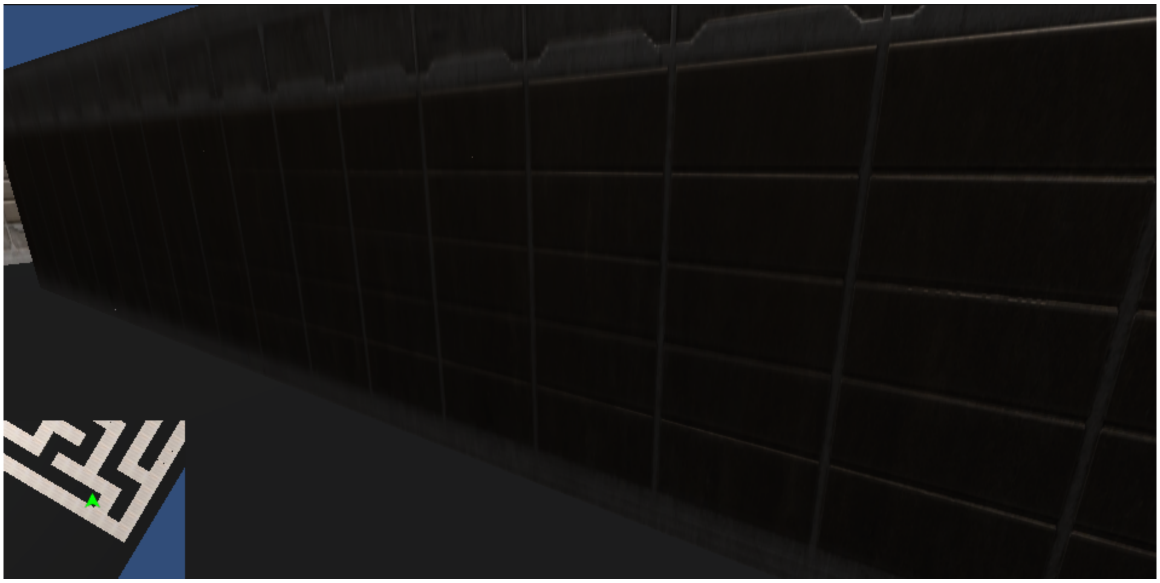


Figure 8.2: Gameplay with mini-map rotate (MMR) navigational aid

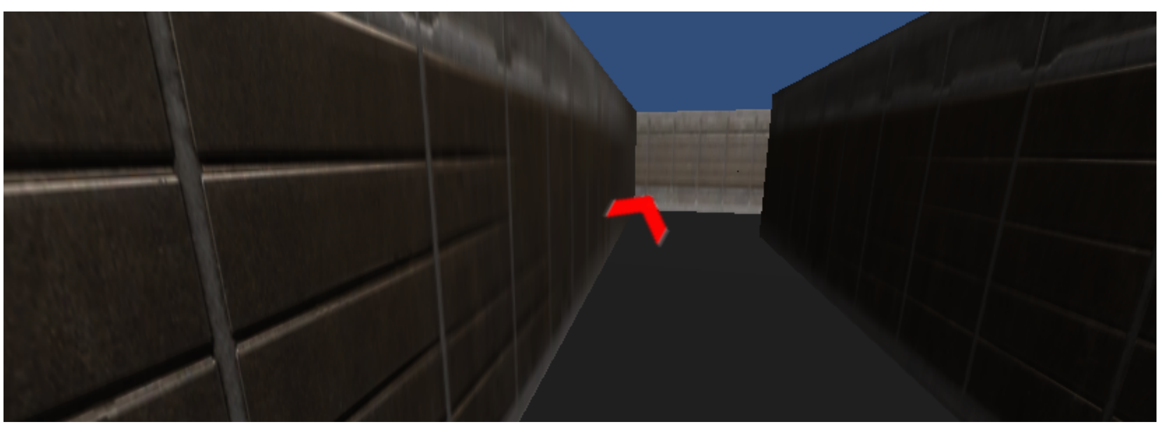


Figure 8.3: Gameplay with wayfinding arrow (WA) navigational aid

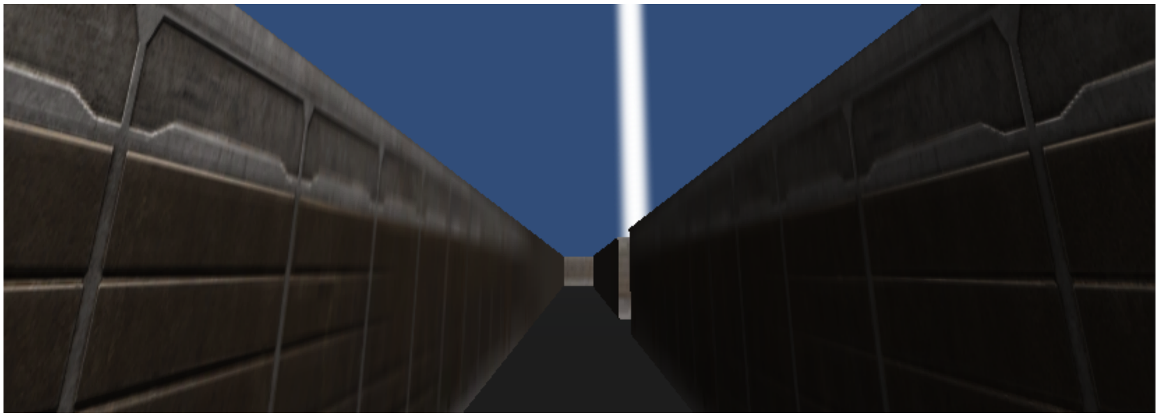


Figure 8.4: Gameplay with light pillar (LP) navigational aid

Figure 8.5: Gameplay with compass (C) navigational aid

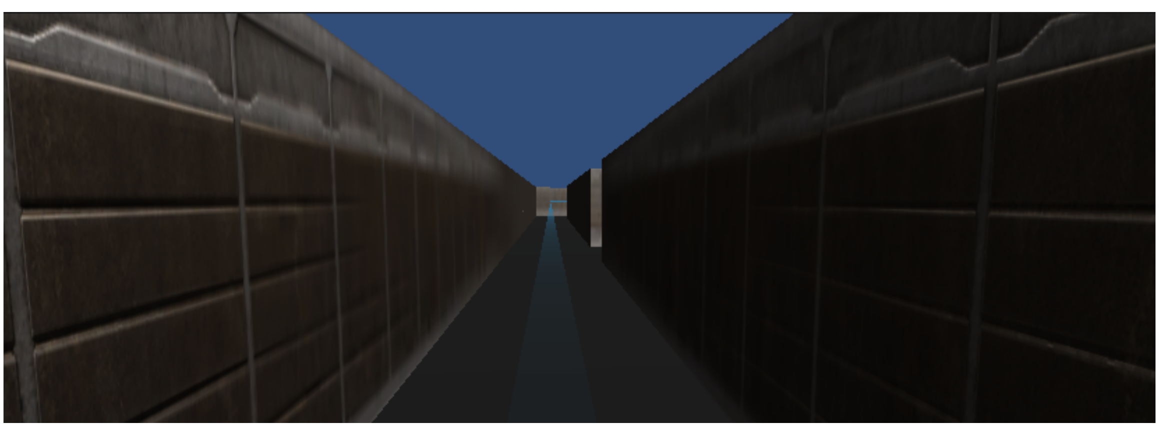


Figure 8.6: Gameplay with navigation line (NL) navigational aid

needed to reach all 4 waypoints for a trial to be complete. The software recorded number of tiles stepped on to get to the waypoint and time to get to each waypoint from either the start or the previous waypoint. If a participant did not find all 4 waypoints within 6 minutes, then the trial would end.

8.2.3 Procedure

Upon arrival, participants were greeted and the purpose of the experiment was explained. Participants gave informed consent before proceeding.
Participants were then given the following instructions:

- They were to navigate a maze as quickly and accurately (meaning to minimize wrong turns and wandering into unnecessary parts of the maze) as possible.
- Throughout the maze there were 4 waypoints, represented by large red spheres. Their goal was to reach all of them.
- Only one waypoint would be visible and reachable at a time. Once they reached one waypoint, the next would appear and be reachable, until all 4 were reached and the trial would end.

They were then instructed on the controls and were allowed to begin.

Participants completed 2 trials for each of the six navigation displays, completing 12 trials in total. After each trial participants could take a break before continuing. Each trial took approximately 3 minutes. In total the experiment took approximately 36 minutes. A trial would end after 6 minutes if the participant was unable to solve the maze by this point and that would be recorded. Upon finishing all trials, participants completed a questionnaire about prior experience with FPS games, and soliciting feedback on a 5-point Likert scale on the level of immersion they experienced and the perceived effectiveness of each navigation display.

8.2.4 Design

The study employed a 6 $\times$ 2 within-subjects design. The independent variables and levels were as follows:

Navigation Display: MMS, MMR, WA, LP, C, NL

Trial: 1, 2

The navigation display conditions are depicted in Figures 8.1 - 8.6 and were described in Section 2.5. The ordering of navigation display was counterbalanced according to a Latin square. The dependent variables were step error rate (the average number of tiles used to get to each waypoint divided by the actual number of tiles, 60), time (in seconds, the average time that participants took to find a waypoint), and incomplete trials (the percentage of trials where all waypoints were not able to be found before the trial timed out).

8.3 Results

8.3.1 Time

When analyzing the average time, in seconds, to find a waypoint, a lower time indicates a better performance than a higher time. The results can be seen in Figure 8.7.

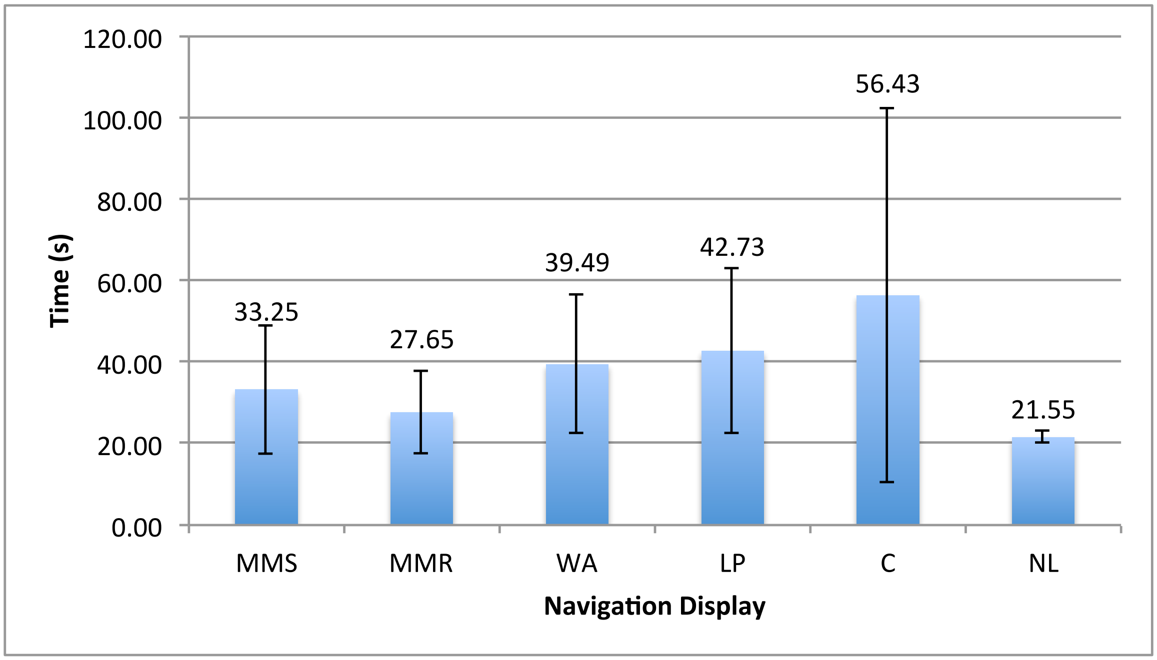


Figure 8.7: Average time to reach a waypoint by navigation display. Error bars show ±1 SD.

The navigation line (NL) display performed the best, with an average time of 21.55 s to reach each waypoint. The compass (C) performed the worst, with an average time of 56.43 s to reach each waypoint. This was about 62% worse than with the navigation line (NL). These results only consider when a trial was completed, so as not to include times when a waypoint was not actually found.

There was a significant main effect for navigation display on time ($F_{5,23} = 26.77$, $p < .0001$). A Fisher LSD post-hoc analysis indicated statistical significance between the following:

- MMS and WA, LP, and C
- MMR and WA, LP, and C
- WA and MMS, MMR, LP, C, and NL

- LP and MMS, MMR, WA, C and NL
- C and MMS, MMR, WA, LP, and NL
- NL and WA, LP, and C

This result indicates that participating using the mini-map displays (MMR and MMS) and the navigation line (NL) resulted in significantly lower average waypoint finding times than the wayfinding arrow (WA), light pillar (LP), and compass (C).

The main effect for trial was significant ($F_{1,23} = 47.06$, $p < .0001$), as was the interaction between navigation display and trial ($F_{5,23} = 9.90$, $p < .0001$). Participants overall took less time to complete trial 1 than trial 2. Despite being the same map, participants often found the reverse map much more difficult than the trial 1 map.

8.3.2 Step Error Rate

The best possible result for step error rate - the average number of tiles stepped on to reach a waypoint divided by 60 (total number of tiles) - is 1, with results higher than this indicating worse performance. The results can be seen in Figure 8.8.

The results for step error rate are very similar to the time results. The navigation line (NL) display performed the best, with an average step error rate of 1.03 to reach each waypoint. The compass (C) again performed the worst, with an average step error rate of 2.43 to reach each waypoint. This was about 58% worse than with the navigation line (NL).

There was a significant main effect for navigation display on step error rate ($F_{5,23}$ = 36.32, $p < .0001$). A Fisher LSD post-hoc analysis found statistical significance between the following:

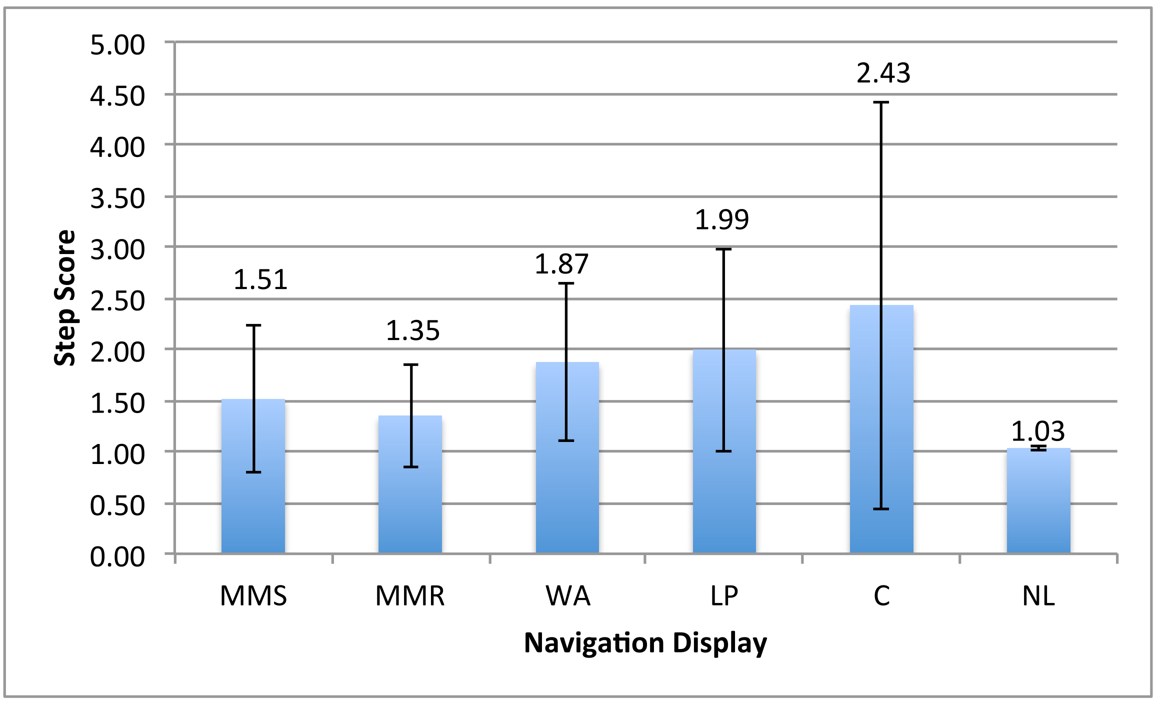


Figure 8.8: Average steps to reach a waypoint by navigation display. Error bars show ±1 SD.

- MMS and WA, LP, C, and NL
- MMR and WA, LP, and C
- WA and MMS, MMR, and NL
- LP and MMS, MMR, C and NL
- C and MMS, MMR, LP, and NL
- NL and MMS, WA, LP, and C

In summary, the navigation line (NL) navigation display had a significantly lower step error rate than all other navigation displays except for the mini-map rotate (MMR). The compass (C) had a significantly higher step error rate than all other navigation displays except for the wayfinding arrow (WA).

The main effect for trial was significant ($F_{1,23} = 132.24$, $p < .0001$), as was the interaction between navigation display and trial ($F_{5,23} = 5.27$, $p < .0005$). As mentioned with time, participants in general performed worse with trial 2 than trial 1.

8.3.3 Incomplete Trials

Trials were incomplete if a participant took longer than 6 minutes to find all 4 waypoints. The results can be seen in Figure 8.9. A lower percentage indicates a better performance than a higher percentage.

The navigation line (NL) navigation display performed the best, with 2% of trials incomplete. The compass performed the worst, with 42% of trials incomplete. This was about 95% worse than with the navigation line (NL).

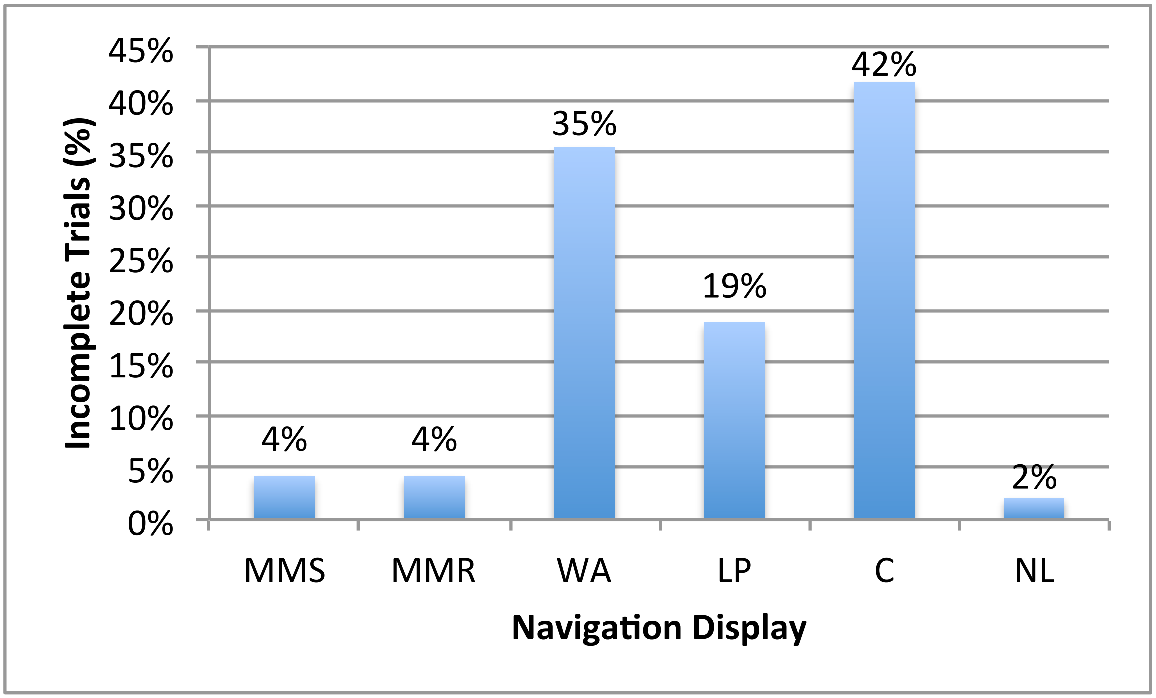


Figure 8.9: Percentage of incomplete trials by navigation display.

There was a significant main effect for navigation display on incomplete trials ($F_{5,23} = 18.29$, $p < .0001$). A Fisher LSD post-hoc analysis indicated statistical significance between the following:

- MMS and WA, LP, and C
- MMR and WA, LP, and C
- WA and MMS, MMR, LP and NL
- LP and MMS, MMR, C and NL
- C and MMS, MMR, LP and NL
- NL and WA, LP, and C

This result indicates that the mini-maps (MMS and MMR) and the navigation line (NL) all performed significantly better at navigating participants through the entire maze than the wayfinding arrow (WA), light pillar (LP), and compass (C). The wayfinding arrow (WA) and compass (C) both performed significantly worse than all other navigation displays at navigating participants through the entire maze.

8.3.4 Questionnaire

Participants each completed one questionnaire prior to completing the study, which solicited information about them including gender and age. They then completed one questionnaire after the study, which gathered feedback on their level of immersion, feelings on performance with each display, and overall preference of navigation display.

Immersion

Participants were given a lengthy questionnaire to gauge their immersion level on a 5-point Likert scale (Jennett *et al.*, 2008) which can be seen in Appendix A.

Each participant completed this questionnaire twice. The first time they were asked to recall when they played the game with the HUD health displays (i.e. mini-map still (MMS), and mini-map rotate (MMR)) when answering. The second time they were asked to recall when they played the game with the in game navigation displays (wayfinding arrow (WA), light pillar (LP), compass (C), and navigation line (NL)). This was done to minimize the number of times they needed to complete this questionnaire, while separating based on if a display is considered to be less immersive (HUD) or more immersive (diegetic/semi-diegetic).

Results of the questionnaire were added, with each response given a point value

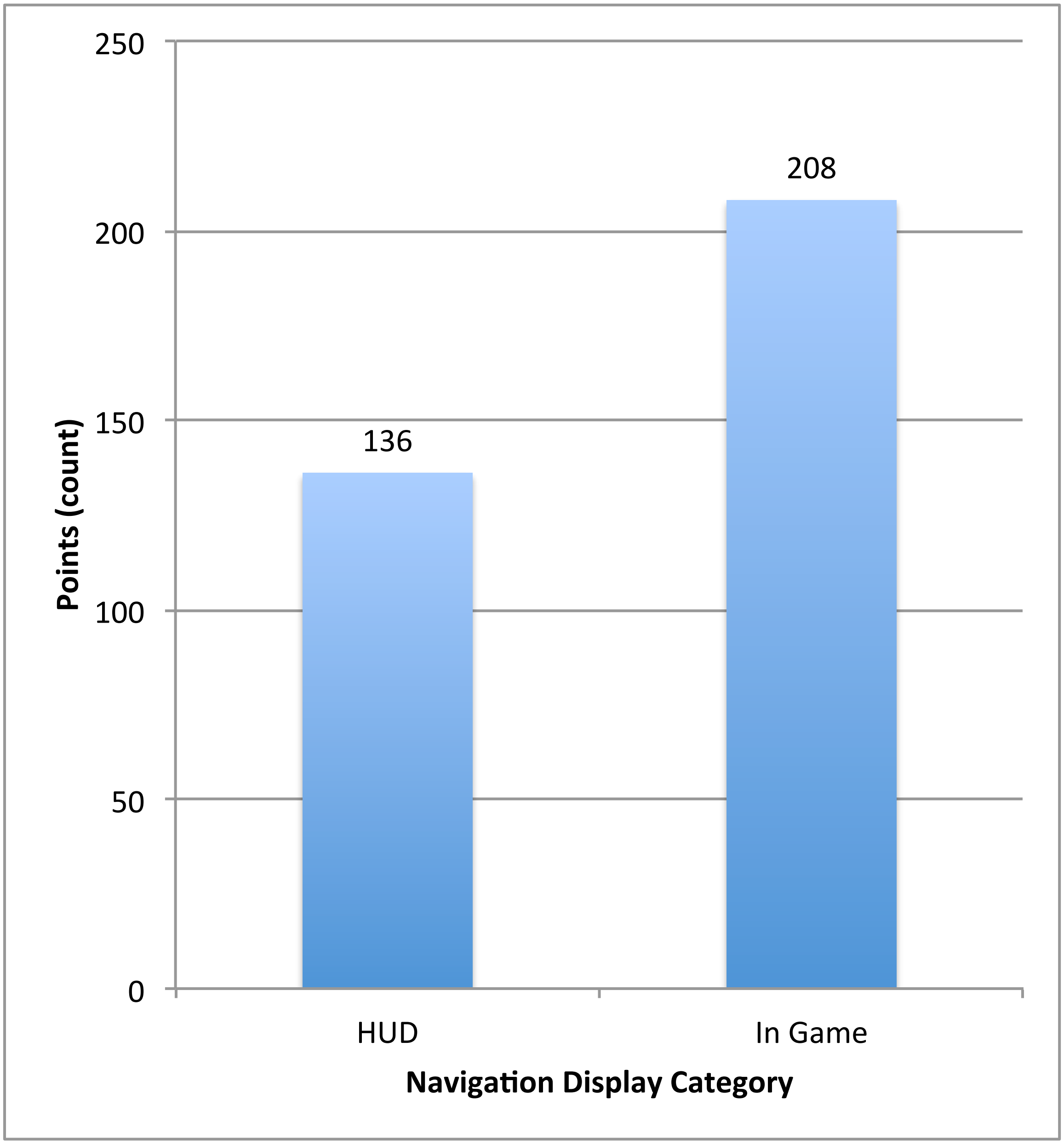
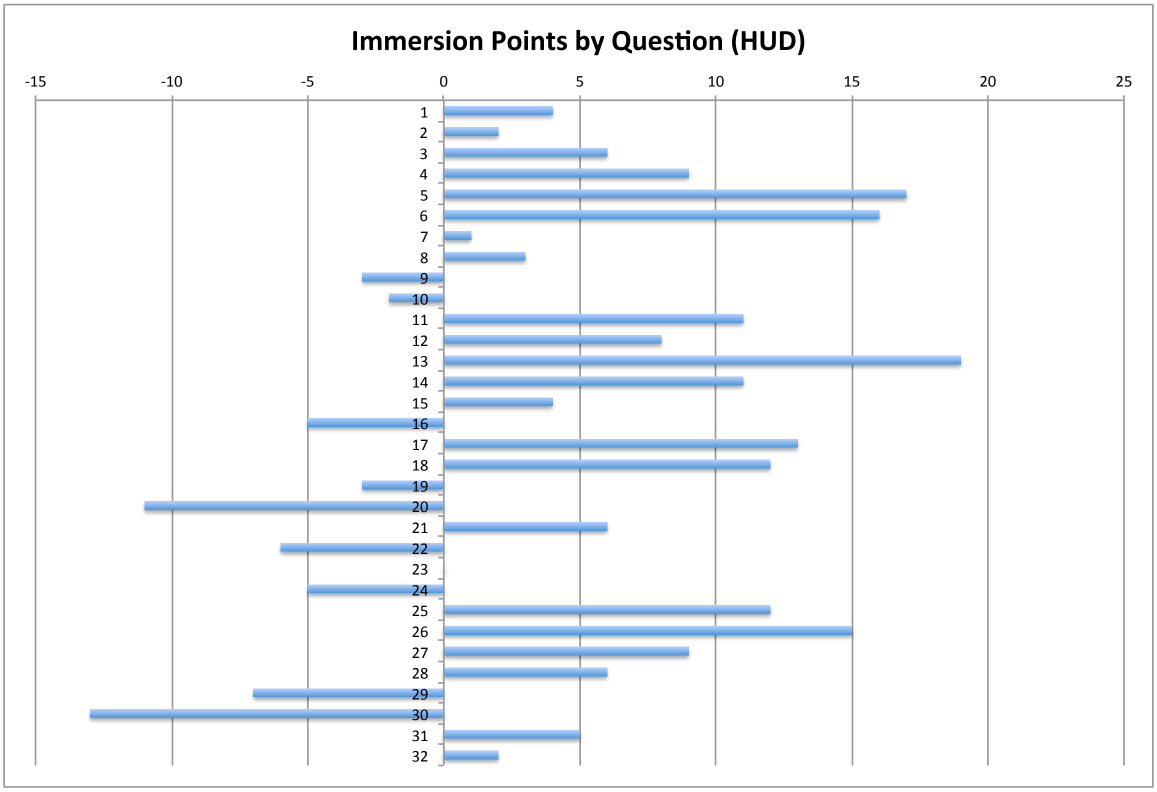
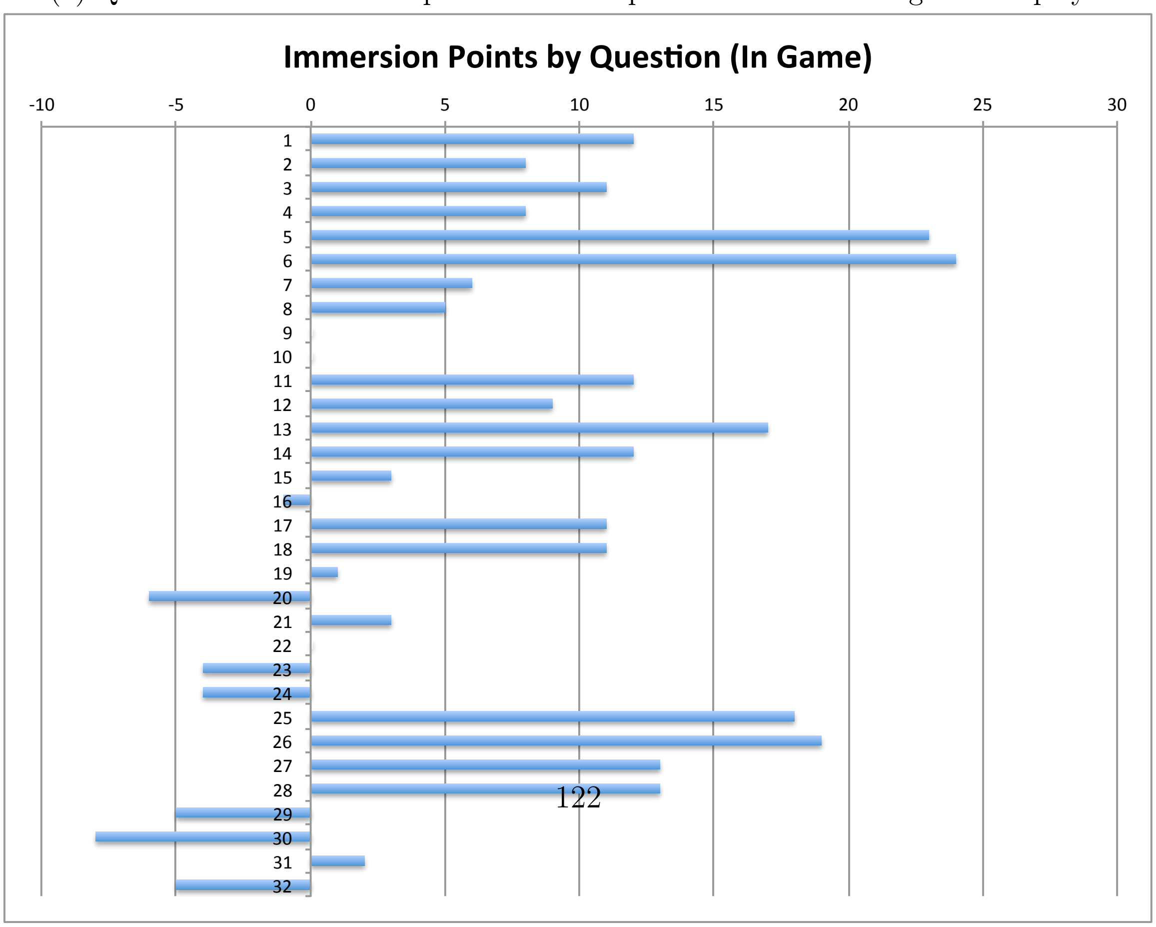


Figure 8.10: Questionnaire points by Navigation display type.



(a) Questionnaire immersion points for each question for HUD navigation displays.



(b) Questionnaire immersion points for each question for In Game navigation displays.

("Strongly Agree" = 2, "Agree" = 1, "Neutral" = 0, "Disagree" = -1, "Strongly Disagree" = -2). Questions that supported the display being immersive were added to the total immersion score, while questions that did not support the display being immersive were subtracted. After completing this questionnaire, they were then asked to rate how immersive they thought the display (HUD and in game) was from 1-10. The overall level of immersion results can be seen in Figure 8.10. Figures 8.11a and 8.11b show the responses to each question. Bars to the right indicate that the response supported the display being immersive, while bars to the left indicate that the display was not immersive.

The results of this show that the participants felt the in game displays to overall be more immersive. The positive result with the HUD navigation displays indicates that participants felt that these displays were also immersive.

For the in game displays, participants were also asked to rank the displays most to least immersive from 1-4 (1=most immersive, 4=least immersive). The results can be seen in Figure 8.12.

The navigation line (NL) was thought to be the most immersive of the in game displays by 42% of participants. The wayfinding arrow (WA) was thought to be the least immersive in game display by 38% of participants. A Kruskal-Wallis non-parametric test found the results to be statistically significant ($\chi^2 = 19.20$, $p < .0005$, $df = 3$). A post-hoc analysis revealed statistical significance between the wayfinding arrow (WA) and all 3 other navigation displays, as well as between the compass (C) and light pillar (LP). This shows that the wayfinding arrow (WA) was thought to be significantly less immersive than other displays.

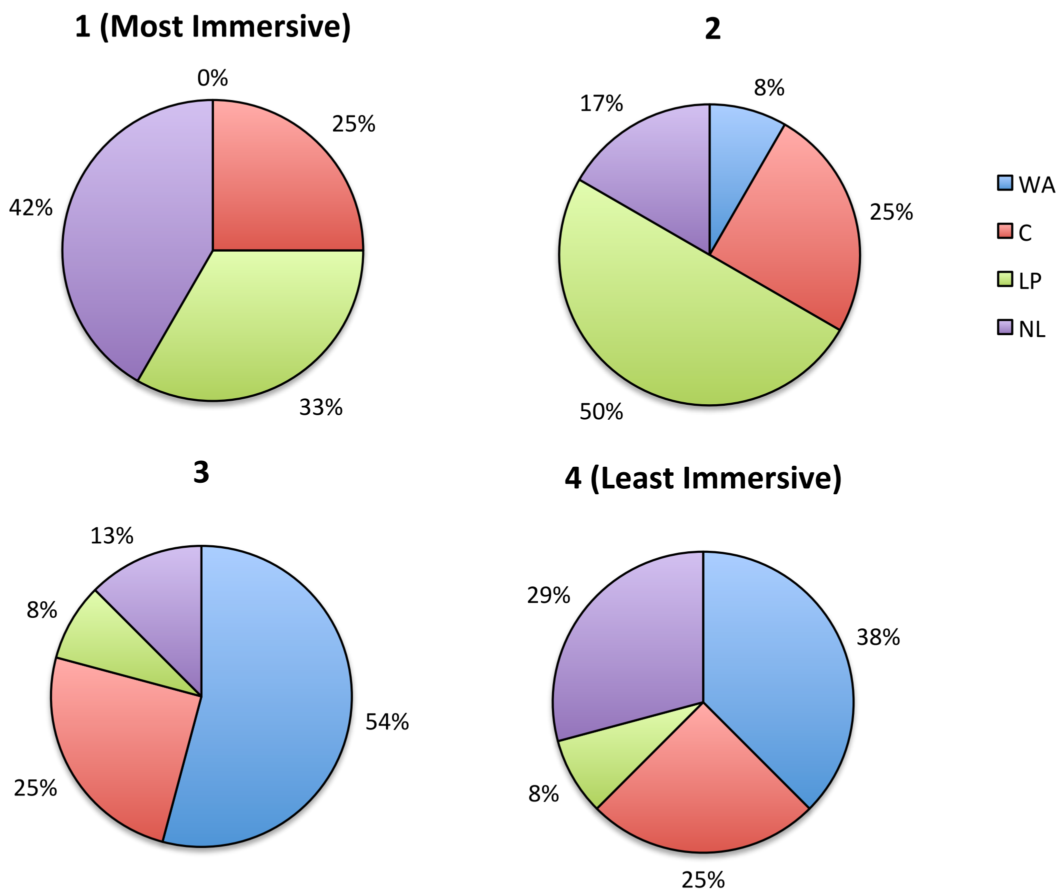


Figure 8.12: Results of participants ranking the in game navigation displays in terms of how immersive they were.

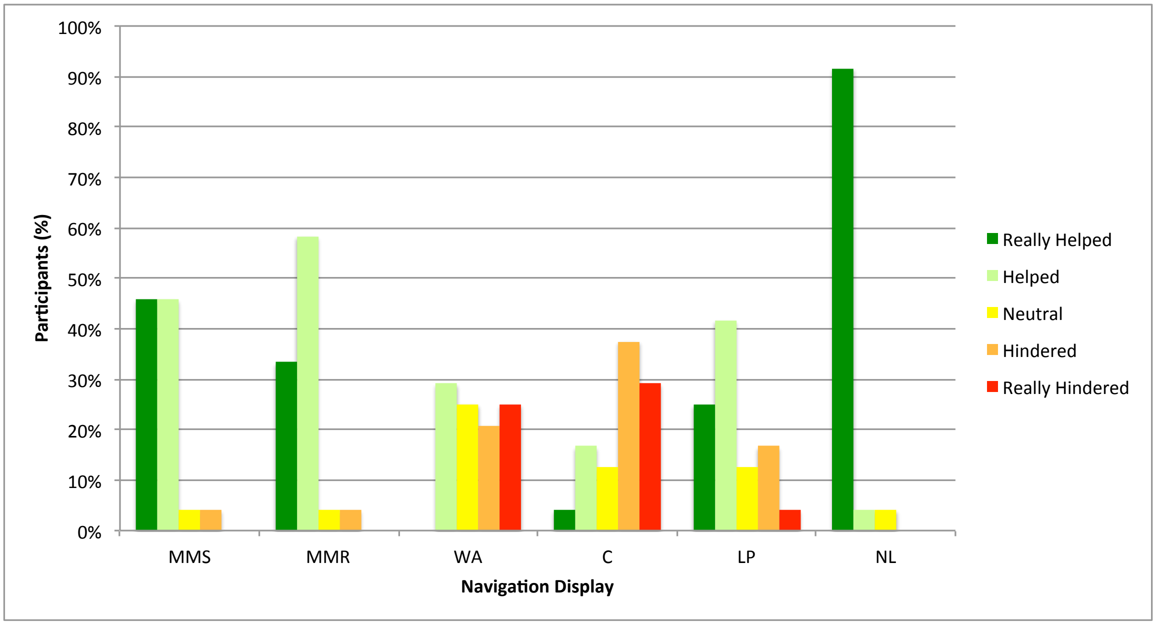


Figure 8.13: Percentage of participants who felt a display helped or hindered their performance by Navigation display.

Performance and Preference

Participants were asked to rate how much a display helped or hindered their performance on a 5-point Likert scale from "Really Helped" to "Really Hindered". The results can be seen in Figure 8.13. A Friedman non-parametric test found the results to be statistically significant ($\chi^2 = 71.94$, $p < .0001$, $df = 5$). A post-hoc analysis revealed the significance to be between the following:

- MMS and WA, C, LP, and NL
- MMR and WA, C, and NL
- WA and MMS, MMR, LP and NL
- C and MMS, MMR, LP and NL

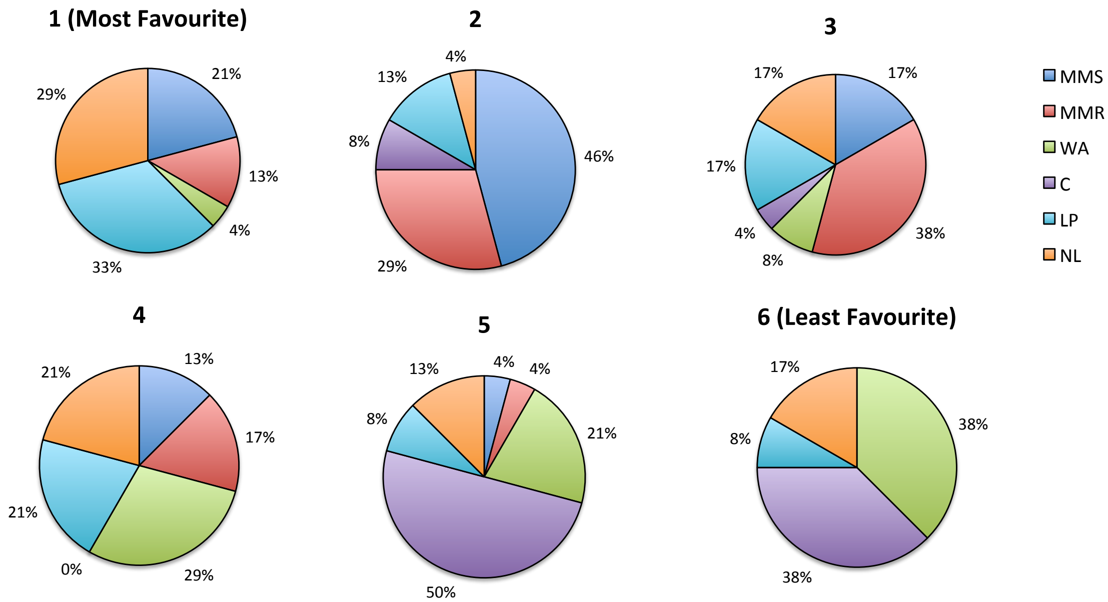


Figure 8.14: Percentage of participants who ranked each display as their favourite to least favourite.

- LP and MMS, WA, C, NL
- NL and MMS, MMR, WA, C, and LP

This result indicates that the navigation line (NL) received significantly a more positive result than any of the other navigation displays. They also indicate that the mini-maps (MMS and MMR) received statistically similar results, and that mini-map rotate (MMR) and light pillar (LP) also received statistically similar results. The wayfinding arrow (WA) and compass (C) received statistically similar mixed results.

Participants were asked to order the navigation displays from favourite to least favourite (1 = favourite, 6 = least favourite). The results can be seen in Figure 8.14. The results were mixed. The light pillar (LP) received the most participants ranking it as their most favourite, with 33% of participants. The wayfinding arrow (WA) and compass (C) were both the least favourite, with 38% ranking each at 6.

A Kruskal-Wallis non-parametric test found the results to be statistically significant ($\chi^2 = 52.29$, $p < .0001$, $df = 5$). A post-hoc analysis found that the significance was between the following:

- MMS and WA, C, and NL
- MMR and WA, C, and NL
- WA and MMS, MMR, LP and NL
- C and MMS, MMR, LP and NL
- LP and WA and C
- NL and MMS, MMR, WA, and C

These results emphasize that the wayfinding arrow (WA) and compass (C) received significantly more negative results than the mini-maps (MMS and MMR), but also show that the light pillar (LP) and navigation line (NL) received statistically similar results.

8.4 Discussion

This discussion is separated by display type, sorted from best to worst result in this study. Both preference and performance are considered, and quite often these coincide.

It is important to note that these navigation displays were all compared in a maze. This is not necessarily the best gameplay setting for all of these displays, as will be discussed. A large amount of information is needed to be communicated through the navigation display in order for players to perform well. This information includes path, direction, and distance. Path arguably affects the performance the most, since knowing the path allows players to find the target easiest. Path information can include direction, though not always. Directional information is of more use when the gameplay setting is an open world where path is not as important. Distance information is the least useful on its own in the map setting, and is often combined with path and/or direction in navigation displays.

8.4.1 Navigation Line

The navigation line (NL) overall did the best in this study, performing the best with all 3 dependent variables (time, step error rate, and incomplete trials), and doing well in the questionnaire. It was thought to be the most immersive display (when compared with the wayfinding arrow (WA), compass (C), and light pillar (LP)). Participants also thought it was really helpful, though were mixed on if it was their overall favourite.

The navigation line (NL) provides path information, which makes it very useful for a maze. It does not, however, provide direction information, and so if players were to get turned around then the lack of direction information would affect their performance.

If considering the navigation line (NL) for use in an FPS game, developers need to consider performance, preference, as well as game theming and difficulty. Though the navigation line (NL) is both liked and helps players to perform well, it only fits the theming of futuristic games. It also makes game situations very easy. Developers could create a variant to use if their game is not futuristic. Overall, the navigation line (NL) is most suitable if developers are interested in communicating path to their players and are creating a game with a futuristic setting.

8.4.2 Mini-Maps

The mini-maps both did reasonably well in this study. They both performed well in terms of the dependent variables (time, step error rate, and incomplete trials). The mini-map rotate (MMR) performed slightly better for time and step error rate. Performance of the mini-maps was second to that of the navigation line (NL) with all dependent variables. In terms of the questionnaire, the overall favourite was the mini-map still (MMS). This could be caused by participants not liking the rotation aspect of the mini-map rotate (MMR).

Mini-maps provide path, direction, and distance information. These are all to a lesser degree than with other displays that primarily display these pieces of information. These pieces of information are only known to the player when they are able to see the target on the mini-map. In some games, direction is provided on a mini-map through the use of an arrow on the map.

The mini-map navigation display, which is very common in video games of many genres, is overall a good navigation option when used properly. It can be used with a variety of theming. However, some gamers like the mini-map to be optional, as it can cause a game to be too easy or cause them to only look at the map rather than the game space. Several participants commented during the study when using mini-map displays (MMS and/or MMR) that they were no longer looking at the gameplay area, but were instead just looking at the mini-map. Game developers should keep the difficulty level they'd like to have in mind when selecting a navigation display, especially when considering a mini-map.

8.4.3 Light Pillar

The light pillar (LP) had a mediocre to positive result in this study mostly due to participant preference rather than performance. Overall it had very similar performance to that with the wayfinding arrow (WA). Though the wayfinding arrow (WA) resulted in slightly better performance for time and step error rate, the light pillar (LP) had much better performance with incomplete trials. The light pillar (LP) was also much more preferred than the wayfinding arrow (WA). One participant commented "I don't know why I like this better than [the arrow], but I do, even though it seems to give me less information". However, this participant is incorrect since the light pillar gives information about how much distance is remaining. The majority of participants ranked the light pillar (LP) as one of their top 2 choices for most immersive of the in game navigation displays. Participants were mixed when asked if it really helped or hindered their performance, though the results leaned towards positive (helped). The light pillar (LP) was overall thought to be the most favourite navigation display by 33% of participants (the highest result).

The light pillar (LP) provides direction and distance information, though this distance information is not total path distance but rather direct distance.

Again, use of the light pillar (LP) in video games is situational. It is used more in open area situations, where it would be much more useful than in a maze, since directional information would be more useful and path information would be less necessary. It does demonstrate that it has medium performance and is somewhat likeable, and so when appropriate its use would be recommended.

8.4.4 Wayfinding Arrow

The wayfinding arrow overall did poorly in this study. When looking at performance in terms of all 3 dependent variables (time, step error rate, and incomplete trials), its performance was poor. It resulted in a slightly better performance than the light pillar (LP) for time and step error rate, but a much worse performance for incomplete trials, where it performed close to the compass (C). Participants did not think it was particularly immersive, with it receiving mostly ranks of 3 and 4 when asked to rank the in game displays. It received very mixed results from participants when asked if it helped or hindered performance. Overall it also received negative results when participants were asked to rank their favourite to least favourite navigation displays, receiving mostly 4, 5, and 6.

The wayfinding arrow (WA) provides only direction information, which could be useful in some settings, but in a maze is not enough information to have to perform well.

Overall, this suggests that it is not necessarily a recommended navigation display, especially not for gameplay which involves a maze. This is unless frustrating players is the goal of the game. This poor performance could be situational; perhaps it would perform better or be more liked in a different situation, such as an open world rather than one that requires more specific directional information.

8.4.5 Compass

The compass is the worst display in this study, performing badly in both performance and preference. It had the worst results for all three dependent variables, and participants did not appear to like it. They were very mixed on if it was immersive, with 25% of participants placing it in each rank from most to least immersive when compared to the other in game displays. Its results when participants were asked if it helped or hindered performance leaned towards hindered and really hindered. When participants were asked to rank the navigation displays from favourite to least favourite, it received low ranks of mostly 5 and 6.

As with the wayfinding arrow (WA), the compass provides only direction information. This hindered performance in the maze setting, where it is more useful to know path than direction. One participant suggested that the reason performance was worse with the compass than the wayfinding arrow (WA) despite their identical information was that participants had to pay more attention to the compass when using it than the wayfinding arrow (WA). This could also be what led participants to rank it higher than the wayfinding arrow (WA) for level of immersion.

Overall it is not recommended to use the compass in a maze situation, where gamers may need more information than just the direction of the goal in order to perform well. It is possible that it would perform well in an open world setting, but future work would need to be done in order to determine if this is the case.

8.5 Conclusion

As with health and remaining ammunition, the theming of the game is very important when selecting a navigation display. Also crucial with navigation display selection is the situation in which it is being used. As mentioned in the discussion, some displays worked very well in a maze situation (e.g., navigation line (NL), and mini-maps (MMS, MMR)), while others performed terribly (e.g., wayfinding arrow (WA) and compass (C)). However, the displays that performed terribly may perform very well in an open world setting. Further work and testing would need to be done in order to determine if this is the case. A developer must decide given the situation (maze, open world, etc.), what information do they want the player to have. From there they can select an appropriate display that fits with the theming of their game.

Chapter 9

Conclusion

This thesis work has presented multiple studies aimed at informing game developers of best options when communicating critical game status information in first-person shooter games. Each of the studies compared traditional HUD communication methods along with fairly new diegetic methods. However, this work is not about whether or not diegetic is better or more immersive than HUD methods, but rather what display allows the player to perform at their best.

When evaluating the remaining ammunition display methods, the option that was both most preferred and allowed participants to perform the best was in fact the diegetic method, the number-in-game (NG). With remaining ammunition, it is a small piece of information when communicated as a number that is relatively easy to place on a weapon, and thus in the centre of the player's view. The central location may in fact be what was the best about the number in front, and future work should look more at how position effects performance.

With the health display study, the results were not nearly as conclusive, and in fact the HUD health display performed better than the diegetic method in this case. Diegetic displays that placed health near the centre of the screen were used, but they performed mediocrely. As discussed in Chapter 6, each of the HUD health displays has its pros and cons, but overall they performed better than the diegetic and splatter displays. Participants also liked them better. Both the top and bottom middle positions performed very well, with top middle performing just slightly better.

The current weapon results also indicate that a HUD weapon display is a good choice. The icon on HUD weapon display, positioned in the bottom right corner, did very well in this study, performing the best of all displays. The weapon in front, one of the diegetic displays tested, also performed well, and was the clear preference of participants. This suggests that these two options could work well together, bringing performance and preference to optimal levels. It also suggests that the bottom right corner is best for displaying weapon information on the HUD. Testing combinations of weapon displays would be a good opportunity for future work. The second diegetic display, the name on the gun, did not perform well and participants did not like it. This could be due to the angle that the name needed to be at in order to be on the weapon, requiring participants to quickly read at an angle in a fast-paced situation.

The navigational aid study was not as concerned with HUD vs. diegetic displays, but rather testing performance and preference of several different navigation displays. The navigation display that did the best in the study - the navigation line (NL) - happened to be diegetic, but it allowed participants to perform the best because of the information that it provided, not because it was in the game. The worst performing navigation display - the compass (C) - was also diegetic. This suggests there is no relationship (at least for navigational aid) between diegetic displays and performance/preference. Performance and preference are determined by how well an option suits a given situation. In this study, the navigation line (NL) was the best display for a maze. In future work, it is possible a different display will perform better for a different situation.

All this suggests that it is not in fact diegetic vs. non-diegetic that is important, but rather individual display types (i.e. word, icon, number, bar, etc.) as well as position (in-game, bottom middle, top left, etc.). It is necessary to know the best method to use to display a piece of information and then the best place to put it. Despite design guidelines in other papers mentioning using diegetic displays where theming allows (Fagerholt and Lorentzon, 2009), the results of this research actually shows that the diegetic displays are not always the best options when considering player performance and preference. The game world and tasks that the player must complete should be the key factors to selection of information display method, and not immersion or following the current information display trends. As prior research has suggested, it is not the fact that a display is diegetic that keeps players immersed, but if the display allows them to perform well. This is likely a contributing reason why, in some cases, participants cited the HUD display methods as more immersive than the in-game display methods. In general, the displays that participants preferred in the studies were also the displays that let them perform at their best.

9.1 Future Work

This work is only the beginning in learning optimal critical game information displays for video games. Within the short-term, good options for future work are finding optimal positions for information on HUDs, as well as testing other displays. An additional possibility is testing the navigation displays in different situations in order to see if what is best changes depending on the situation. Once the best display methods for these pieces of critical game information are determined individually, it is then possible to test combinations (i.e., combine a health, weapon, ammunition, and navigation display) to learn how different displays combined affect performance. Different display sizes can then be tested to learn how screen size affects performance and preference. After this, other genres can be explored. There are many possibilities for future work stemming from this thesis.

Appendix A

Immersion Questionnaire

Please rate how far you would agree with the statements below when playing the game with the [health/weapon/navigation] displays on [the HEADS UP DISPLAY/IN THE GAME].

SD = strongly disagree; D = disagree; N = neutral; A = agree; SA = strongly agree.

I felt that I really empathised/felt for with the game.

SD D N A SA

I did not feel any emotional attachment to the game.

SD D N A SA

I was interested in seeing how the game?s events would progress.

SD D N A SA

It did not interest me to know what would happen next in the game.

SD D N A SA

I was in suspense about whether I would win or lose the game.

SD D N A SA

I was not concerned about whether I would win or lose the game.

SD D N A SA

I sometimes found myself to become so involved with the game that I wanted to speak to the game directly.

SD D N A SA

I did not find myself to become so caught up with the game that I wanted to speak to directly to the game.

SD D N A SA

I enjoyed the graphics and imagery of the game.

SD D N A SA

I did not like the graphics and imagery of the game.

SD D N A SA

I enjoyed playing the game.

SD D N A SA

Playing the game was not fun.

SD D N A SA

The controls were not easy to pick up.

SD D N A SA

There were not any particularly frustrating aspects of the controls to get the hang of.

SD D N A SA

I became unaware that I was even using any controls.

SD D N A SA

The controls were not invisible to me.

SD D N A SA

I felt myself to be directly travelling through the game according to my own volition.

SD D N A SA

I did not feel as if I was moving through the game according to my own will.

SD D N A SA

It was as if I could interact with the world of the game as if I was in the real world.

SD D N A SA

Interacting with the world of the game did not feel as real to me as it would be in the real world.

SD D N A SA

I was unaware of what was happening around me.

SD D N A SA

I was aware of surroundings.

SD D N A SA

I felt detached from the outside world.

SD D N A SA

I still felt attached to the real world.

SD D N A SA

At the time the game was my only concern.

SD D N A SA

Everyday thoughts and concerns were still very much on my mind.

SD D N A SA

I did not feel the urge at any point to stop playing and see what was going on around me.

SD D N A SA

I was interested to know what might be happening around me.

SD D N A SA

I did not feel like I was in the real world but the game world.

SD D N A SA

I still felt as if I was in the real world whilst playing.

SD D N A SA

To me it felt like only a very short amount of time had passed.

SD D N A SA

When playing the game time appeared to go by very slowly.

SD D N A SA

How immersed did you feel? (10 = very immersed; 0 = not at all immersed)

1 2 3 4 5 6 7 8 9 10

Appendix B

Health Study Significance Results

B.1 Percentage of Escapes

There was a significant main effect for health display on percentage of escapes ($F_{11,23}$ = 12.91, $p < .0001$). A Fisher LSD analysis indicated that there was a significant difference between the following:

- BHB and IHB, NHB, NHL, NHT, and IG
- BHL and IHB, NHB, NHL, NHT, and IG
- BHT and IHB, NHB, NHL, NHT, and IG
- IHB and BHB, BHL, BHT, NHB, NHL, NHT, and IG
- IHL and NHB, NHL, NHT, and IG
- IHT and NHB, NHL, NHT, and IG
- NHB and BHB, BHL, BHT, IHB, IHL, IHT, BG and S

- NHL and BHB, BHL, BHT, IHB, IHL, IHT, BG and S
- NHT and BHB, BHL, BHT, IHB, IHL, IHT, BG and S
- BG and NHB, NHL, NHT, and IG
- IG and BHB, BHL, BHT, IHB, IHL, IHT, and S
- S and NHB, NHL, NHT, and IG

B.1.1 Averaged by Display Type

There was a significant main effect for health display type on percentage of escapes ($F_{5,23} = 15.17$, $p < .0001$). A Fisher LSD analysis indicated that there was a significant difference between the following:

- Bar and number, and IG
- Icons and number, and IG
- Number and bar, icons, BG, and S
- BG and number and IG
- IG and bar, icons, BG, and S

B.2 Health when Escaped

There was a significant main effect for health display on percentage of escapes ($F_{11,23} = 16.01$, $p < .0001$). A Fisher LSD analysis indicated that there was a significant difference between the following:

- BHB and NHB, NHL, NHT, BG, IG, and S
- BHL and NHL and IG
- BHT and NHB, NHL, NHT, BG, IG, and S
- IHB and NHB, NHL, NHT, BG, IG, and S
- IHL and NHL, IG and S
- IHT and NHB, NHL, NHT, BG, IG, and S
- NHB and BHB, BHT, IHB, IHT, and IG
- NHL and BHB, BHL, BHT, IHB, IHL, IHT, and IG
- NHT and BHB, BHT, IHB, IHT, and IG
- BG and BHB, BHT, IHB, IHT, and IG
- IG and BHB, BHL, BHT, IHB, IHL, IHT, NHB, NHL, NHT, BG, and S
- S and BHB, BHT, IHB, IHL, IHT, and IG

B.2.1 Averaged by Display Type

There was a significant main effect for health display type on percentage of escapes ($F_{5,23} = 23.79$, $p < .0001$). A Fisher LSD analysis indicated that there was a significant difference between the following:

- Bar and number, BG, IG, and S
- Icons and number, BG, IG, and S

- Number and bar, number, and IG
- BG and bar, icons, and IG
- IG and bar, icons, number, BG, and S
- S and bar, icons, and IG

B.3 Score

There was a significant main effect for health display on score ($F_{11,23} = 3.54$, $p < .0005$). A Fisher LSD analysis indicated that there was a significant difference between the following:

- BHB and IG
- BHL and IG, NHL and NHT
- BHT and IG, NHL, and NHT
- IHB and IG, NHL, and NHT
- IHL and IG
- IHT and IG, NHL, and NHT
- NHL and BHL, BHT, IHB, and IHT
- NHT and BHL, BHT, IHB, IHT
- IG and BHB, BHL, BHT, IHB, IHL, IHT, and S

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