Stereoscopic Depth Axis Interaction: A Study of Performance and Engagement in Stereoscopic 3D Games

by

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Abstract

Game developers strive to maximize immersion and engagement, to emotionally involve the audience in their material. One technique used to increase engagement is the development of new technologies, such as Stereoscopic 3D. Stereoscopic 3D (S3D) creates the impression of depth (stereopsis) in flat images by providing additional binocular depth cues, such as convergence and binocular disparity. In this thesis, we explore the effects that S3D has on the player experience in an attempt to uncover design methodologies that can help game developers develop more effective content. Three experiments were designed and conducted to examine the effects S3D has on player experience and game design: i) Engagement in Stereoscopic 3D Games, ii) S3D Depth-Axis Interaction for Video Games: Performance and Engagement, iii) Depth Representation and Player Performance with Depth-Axis Interactivity.

We hypothesized that S3D technology would increase immersion and engagement, and new mechanics that exploit the depth axis would be effective.

The results of these studies suggest that S3D does not increase user engagement, and is consistent with prior research that suggest the impact of S3D is dependent on the game. They also demonstrate that developers can design unique experiences in stereoscopic 3D, but there may be additional ways to represent depth. The results suggest developers need to adjust the difficulty of their game when including stereoscopic 3D, depending on the interactions of their game. It is our recommendation that developers continue to explore the affordances offered by stereoscopic 3D to create unique experiences, but its inclusion is dependent on their specific game.

Keywords: Stereoscopic 3D, Depth Cues, Game Design, User Experience, Engagement

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Chapter 1

Introduction

1.1 Motivation

The entertainment industry is constantly looking to provide more immersive and engaging experiences for its audiences. There is no agreed upon definition of engagement, but this thesis uses engagement as a general indicator of involvement in a game [25]. Immersion refers to a deep mental involvement in a game [8], and is related to the game's ability to induce the feeling of being part of the games environment [144].

New technologies are often developed to create more immerisive and engaging experiences. Stereoscopic 3D is one such technology, that enables a viewer to perceive depth on a flat two dimensional display through stereopsis. Stereopsis is the impression of depth produced by the brain when presented visual stimuli [68]. It is often attributed by binocular vision of the human visual system, meaning it requires two images, one from each eye to provide an indication of depth. The brain is able to fuse these two images, that differ only in slight horizontal shifts, to form a three dimension impression of the world(see Figure 1.1). Stereoscopic 3D is a technology or a set of technologies that enable stereopsis on a flat display by allowing two images to be presented to the viewer, giving an impression of depth on an otherwise flat surface.

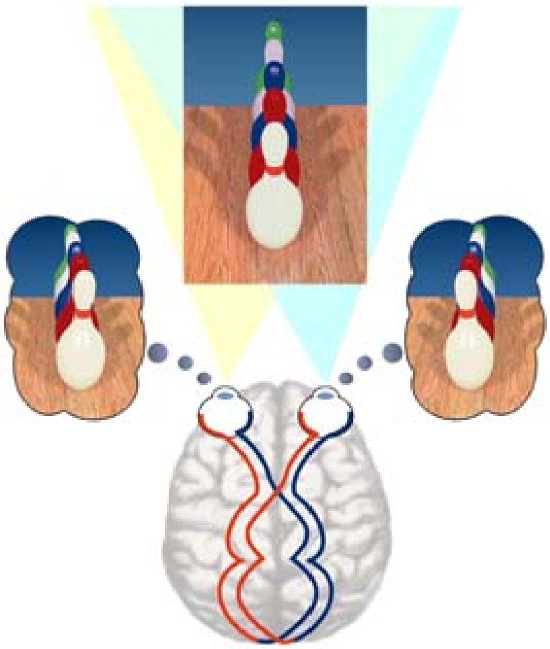

Figure 1.1: Image depicting stereopsis and the mental formation of a three dimensional image from left and right eye's view. [31]

1.2 Stereoscopic 3D (S3D)

Humans don't perceive the world as flat; humans have many different depth cues to help determine how close or far away objects are to them [67]. Most of our depth cues are monocular, in that they only require one eye to make use of them. Examples of these cues are perspective, image size, interposition (occlusion), light and shade, texture, accommodation (eye focusing image onto retina) and in the case of moving objects, motion parallax. There are two other physiological cues called accommodation, that refer how the eye focuses images onto the retina and convergence where the eye rotates to look at a specific point. Stereopsis is a binocular depth cue, meaning it requires two eyes and with two different images to work. Our eyes have a distance between them called the interocular; this separation gives humans two different images from slightly different angles. Our brain using the other depth cues are able to determine depth information from the differences in the two images. Stereoscopic 3D or S3D is a technique to create the illusion of depth in flat images using our stereopsis depth cue, by presenting a different image to each eye [84].

1.2.1 Displaying S3D

Since the discovery of stereopsis in 1838 by Sir Charles Wheatstone, much progress has been made in creating and displaying stereoscopic images [84]. There are many different techniques to display stereoscopic images to a screen, and no standard

Figure 1.2: Images of typically red-blue anaglyph glasses(Left) [4], RealD passive polarized glasses(Top) [129], Nvidia's 3D Vision active shutter glasses(Right) [7]

has emerged. The current most common setups are anaglyph glasses, polarized glasses, and active shutter glasses (see Figure 1.2 for examples). Anaglyph glasses use color filters (usually red-green) to encode the information in a single image. The red filter blocks the red image, letting only the green picture through, and vice versa. This is the cheapest way, but the picture loses color information and can have a strange tint to it. The polarized method works similar to the anaglyph method, except instead of a color filter, the light goes through a sheet-polarizer onto a polarization-conserving screen then back through the viewer's polarized glasses; letting only the light through with a similar polarization. The active glasses method is sometimes referred to as the eclipse method, since the glasses physically block out an eye while allowing the other to see the image. Then both the image and the eye being blocked switch, giving the next eye a different image. At first, this method used mechanical shutters, which physically blocked the alternating eyes. The mechanical shutters were replaced with liquid crystal displays, leading to smaller more conformable glasses. Improving technologies such as liquid crystal displays has lead to an increase in popularity for this method [84].

1.2.2 Capturing S3D

There are also many different techniques to capture or produce stereoscopic 3D images. Creating a stereoscopic image requires two separate images to be presented to the left and right eye. The most common way is to capture two images separated by some fixed distance and their image capture mechanisms are synchronized. This can be done with multiple cameras or a stereoscopic camera that have multiple lens designed to place the images on a single piece of film [84].

A recent technique called stero conversion, creates S3D content from 2D content, meaning a second image is created from the original image. This is typically done by creating a depth map, and offsetting the pixels of the image using the depth map. Problems occur in areas of high amounts of occlusion, where information is missing. The missing information is then filled in using a variety of different algorithms [117]. This method is often criticized for its image quality, while many proponents argue the difference isn't noticeable.

1.2.3 Issues with S3D

There are various issues with stereoscopic 3D viewing, many of which are typically caused by limitations of current technology or due to differences between an S3D image and reality. Stereoscopic 3D isn't a prefect approximation of the human visual system, and differences between other depth cues, such as window violations [128], visual–vestibular conflict [13], and the vergence–accommodation conflict [63] can occur (See section 2.1.2 for more details). All of these issues can lead to visual discomfort, sometimes even resulting in nausea and sickness. Content creators must be aware of these issues, and avoid them if possible. Although techniques and guidelines have been developed or are being researched to reduce the impact these issues have on the visual experience (See section 2.1.2 for more details). Many issues can also be caused by limitations or improper setup of the technology. These include crosstalk [124], misalignment of the images [15], binocular asymmetry [15], and visibility of flicker or motion [15]. Crosstalk is caused when the image for the left-eye leaks into the image of the right; it is particularly noticeable in areas of high contrast. Misalignment of the images refers to images with vertical disparities. Binocular asymmetry is cause by objects only appear in one eye or the other. Both of these can cause visual discomfort including physical pain when viewed. Although as the technologies improve many of these issues are being reduced or eliminated. These issues also lead to visual discomfort, sickness and nausea. Content creators must also be aware that eyewear required to separate the images or inappropriate head orientation from the viewer may also cause visual discomfort [118]. These issues can significantly and negatively impact the experience, and turn an otherwise pleasant one into a painful one.

1.2.4 S3D in Flims

Since the release of the first stereoscopic 3D film called The Power of Love in 1922 [149], stereoscopic 3D has been re-introduced to the film industry several times. For example in the late 1940's and early 50's cinema attendance was dropping and to bring people back to the theater film studios began to push stereoscopic 3D films. But by 1954, stereoscopic films were already on the decline, mainly due to the low quality of the films [84]. Each of these past attempts failed for various reasons, such as the limited quality content,and expensive technologies.

With the release of Jame's Cameron's Avatar (the top-grossing film of all time [29]) stereoscopic 3D suddenly became relevant again. Audiences were once again excited about the "new" technology. It seemed like everyone needed to go experience it. Other movie studios rushed to capitalize on the sudden popularity of stereoscopic 3D. It seemed like every major movie was releasing a stereoscopic version. However most of these films were not originally intended as stereoscopic 3D films, and had to be converted after production using stereo conversion techniques. While it remains unclear if stereo conversion techniques reduce picture quality, audiences criticized these movies indicating the additional cost to view them in S3D wasn't worth it. The argument from proponents of S3D, is stereoscopic 3D shouldn't be an after thought but part of the production and design of the film [141].

The recent success of stereoscopic 3D films in theaters and the decline of high definition television sales, pressured television manufactures to begin developing and producing stereoscopic 3D enabled televisions. Although there has been limited support from televisions and cable providers, 41.45 million S3D enabled televisions shipped in 2012 compared to 24.14 million in 2011 and 2.26 million in 2010 [6]. With so many S3D enabled televisions being purchased for the home, many including Jeffrey Katzenberg the CEO of Dreamworks Animation felt stereoscopic 3D games were poised to have significant impact on the consumer entertainment market [75].

1.2.5 S3D in Games

The video game industry generates 10.8 billion dollars in revenue, with 67% of US households playing video games [45]. Surprisingly, stereoscopic 3D video games have been around almost as long as video games themselves. The first stereoscopic computer display, nicknamed "Sword of Damocles" was created in 1968 [123]. The display was a large head apparatus that allowed the user to view a wire-frame room. It wasn't until 1982 that the first commercial stereoscopic 3D game was released (Subroc-3D from Sega). Since then, many products have been developed and released such as Sega VR, the Virtual Boy, Atari Jaguar VR and many more with several games playable (see Figure 1.3). While each of these releases might have been met with some optimism, ultimately they faded away, often rather quickly [42]. These attempts usually failed for a number of reasons. More specifically, the technology wasn't available and didn't allow for a good experience, a single company was trying to drive short term sales, or it was marketed as a gimmick [23]. It appears that consumers are not willing to wear bulky, uncomfortable, funny looking things on their head.

Recently, with the push from movie studios and television manufactures, the technology to produce and view stereoscopic 3D content has become cheaper, easier, and produces better results. Industries are thinking longer term, with adoption of standards like the active 3D glasses initiative [120]. There is plenty of content with Nvidia's 3D Vision [96] and DDD's TriDef 3D [34] drivers, which turn existing

Figure 1.3: Images of Nintendo's Virtual Boy(Left) [27], Atari Jaguar VR(Top-right) [3], Sega VR(Bottom-right) [134]

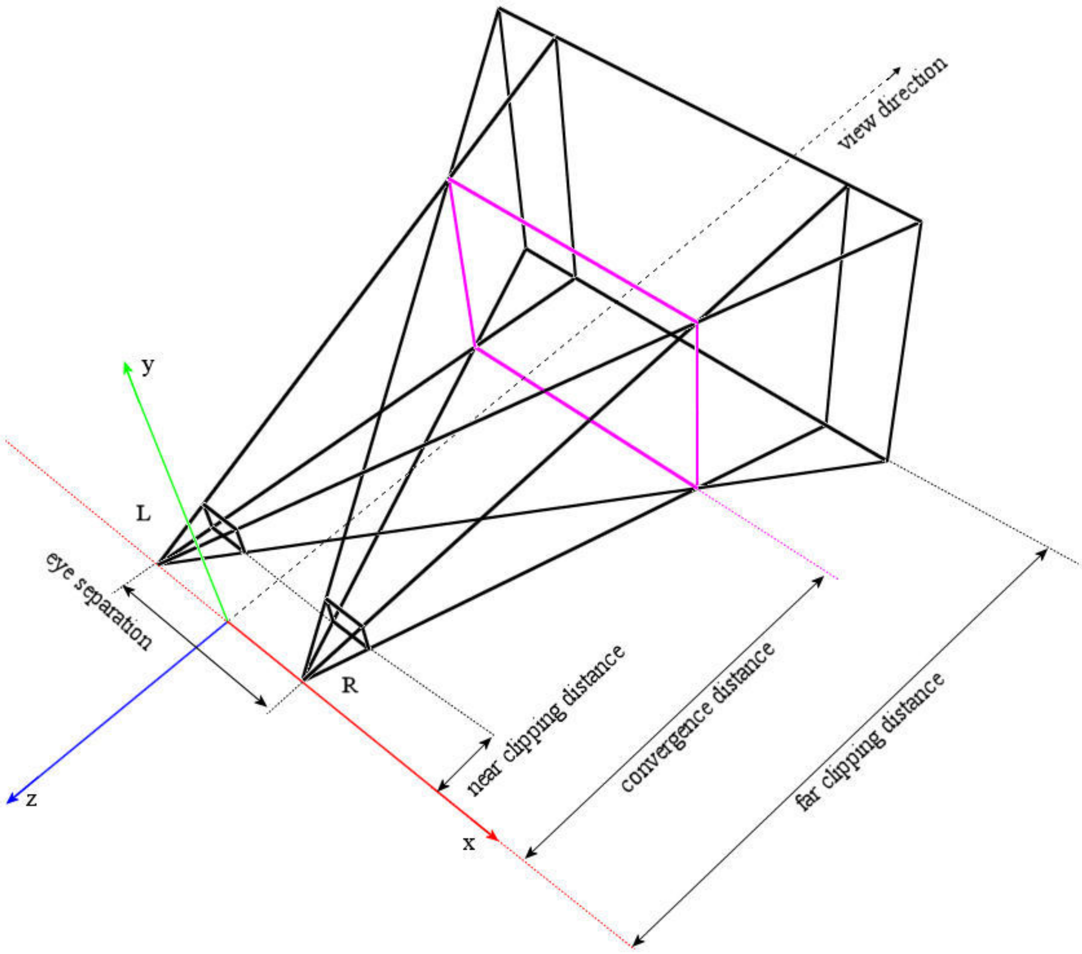

Figure 1.4: Visualization of stereoscopic 3D rendering with two virtual cameras. Eye separation (interaxial) is the distance between the two cameras L and R. The purple rectangle is the convergence plane or zero parallax.

games into stereoscopic 3D games without the need to develop with S3D in mind. It has become very easy for people to experience the content, with a small community developing around it. Larger gaming companies such as Sony and Nintendo have also become involved, both creating long-term S3D plans. Sony is actively developing and pushing their third party studios to produce S3D content for its PlayStation 3 and 4 consoles. Nintendo developed and released the Nintendo 3DS with an autostereoscopic 3D screen, which eliminates the need for any glasses to be worn by the user.

Rendering Stereoscopic 3D Games

It is easy for developers to natively produce the two images needed for a stereoscopic image just by rendering the scene twice, from two viewpoints. To do this, developers simply need to create a second virtual camera, translate it by a fixed amount(referred to as the interaxial) and render an image from both the left and right camera. The convergence plane is where the left and right frustums of the cameras intersect (see Figure 1.4). An object at the convergence plane appears to be located at the screen. Parallax refers to the distance between an object's projected positions in the left and right view. A negative parallax indicates the object is in front of the screen, while a positive parallax indicates the object is behind. The convergence plane can also be referred to as zero parallax. For conformable viewing, objects must be kept within a certain range of positive and negative parallax, with many factors determining that range. When the two cameras are parallel to each other, they will never converge, meaning the convergence plane is located at infinity. Objects at the convergence plane appear on the surface of the screen. Therefore if the convergence plane is at infinity all object will appear in front of the screen, and some will have an extremely large negative parallax and be unconformable to view. To correct this, developers modify the location of the convergence plane by applying a shift along the x coordinate of each projection matrix, bringing the convergence plane towards the cameras.

As mentioned earlier several factors determine the range or amount of parallax a viewer finds comfortable, including the distance from screen, pupil size and the player's general stereoscopic viewing ability. Determining the maximum amount of parallax is rather difficult for a developer. Sony, using the 3D consortium safety guide as a reference believes the maximum parallax should be 1/30th or 3% of the screen width, but that value should never exceeded 6.5 cm. Also they note that players should be given a slider to modify the amount of parallax in a game to make it more comfortable to them [19]. Research done at the University of Ontario Institute of Technology(UOIT) helped determine that there are other interactive ways for the player to determine their personal parallax settings [130].

Using virtual cameras requires the scene to be rendered twice, which requires additional time or processing power. Rendering is a performance intensive operation, and while PCs have the luxury of upgrading the components of the machine, console developers need to optimize their game in order to include a stereoscopic 3D mode. Sony has investigated how to optimize this process for its developers on PlayStation 3. They find games with split screen modes normally have optimizations included; other games can use similar techniques such as turning off certain effects. Or they can use a technique that Sony calls "Re-projection" which creates the second image from a depth map [19]. This eliminates the need to render the scene twice, but doesn't produce a true stereoscopic image. The resulting image has problems with occlusions where large parallax changes occur.

Issues specific to S3D in Games

While many of the issues with stereoscopic viewing are common to other mediums such as film, several issues also arise specific to video games. One such issue is window violations(See section 2.1.2), since the game developer isn't in control of the final image, window violations can occur at any point in time [19]. It is difficult to avoid them and the current solution in films is to use a technique called the "floating window". This technique was modified to work within a game environment and was shown to produce better results at determining depth in a scene [121]. Other solutions to this problem exist like Sony's dynamically adjusted stereoscopic camera parameters [19] or Nvidia's 3D object culling [53].

S3D in Virtual Reality Systems

Outside of the entertainment and consumer products, stereoscopic 3D has always been a large part of virtual reality systems. Virtual reality or VR is all about immersing the player through their senses into a world. S3D plays a large role in mimicking our day to day vision. S3D is almost always included in VR systems, and plenty of research is done on incorporating and improving S3D in such systems [61]. Virtual reality systems usually require the user to wear a head-mounted display, and two screens are presented one for each eye. When developing for head-mount displays, unlike television or movie theater screens,

Unlike television or movie theater screens, developers of head-mount displays don't need to worry about issues with negative parallax since the screens are so close to the user's eyes. Head-mounted displays have never been able to gain traction with the general population. Usually this is due to the cost or quality of the device being sold. However with the soon to be released Oculus Rift, an affordable decent quality head mount display, both virtual reality and stereoscopic gaming could see another push from both developers and consumers [97].

Technical Issue vs. Design Issue

Even with the hardware in the consumers hands, and tools that make it easy to bring software to the consumer, hesitation about S3D still exists from both developers and consumers. Developers support S3D in their games, either natively or through the use of drivers, but very few make it part of the design and development of their game. Similarly to the criticism against stereo converted S3D films, players are expecting a stereoscopic 3D game, not a 2D game that supports stereoscopic 3D viewing. Like the film industry, developers need to explore the benefits S3D can provide a video game including when and where it can add value to their products. Developers are hesitant to do this, due to the high cost associated with developing a game. While research is primarily focused on improving or fixing issues associated with stereoscopic 3D, more work is needed to access the benefits and affordances provided by S3D in games. This is important to help developers understand where S3D can add value to their games, saving them development time and costs.

1.3 Purpose of this Work

Video games are potentially the most interesting, and challenging, artistic medium to develop intriguing narrative experiences. While there has been a considerable amount of experimentation regarding stereoscopic 3D with respect to 3D storytelling in film, the work describing 3D storytelling with respect to video games is sparse given that video game designers and developers have yet to embrace stereoscopy with as much enthusiasm as filmmakers. While much work and research has gone into providing a more comfortable experience in S3D, little work has gone into understanding the impact S3D has on the experience of a game. It is important that issues with the technology are understood and reduced so content developers don't reduce the experience by making it uncomfortable to the user. However, it is becoming equally as important to research how stereoscopic 3D affects the experience itself. Developers have learned how stereoscopic 3D impacts the cost of a game from both a technical and budget perspective. Often citing that including S3D in there game, would require them to exclude other more marketable and useful features [82] However developers don't have all the information, they aren't aware of the trade-off they are making. Developers need to understand how stereoscopic 3D affect the experience of their game, and when they should use it.

Developers treat S3D as a "mode" rather than the primary viewing paradigm, implying that the game must be playable with and without S3D enabled. It is first necessary to see how the visual change of S3D impacts an existing game. However the nature of the gameplay does not take into account the stereoscopic nature of the display. The visuals are the only difference between the experiences. While it is still very important to understand the impact this visual change has, it is also important for us to investigate and question how S3D may modify the interactive experience of a game. Interactive experiences unlike passive viewing experiences require the player to complete tasks, meaning players may perform differently when playing the game. If the player has a significant performance boost in S3D then developers must be aware so the game isn't too easy. The visual component may have an effect on the performance of a player within a game or S3D may only affect specific tasks. Additionally there may be tasks that are only possible when using S3D, and non-S3D games may be avoiding these tasks. It is not possible to effectively investigate these questions, when only studying the effects of stereoscopic 3D on games designed and developed for traditional 2D displays. Further investigation on games designed specifically for stereoscopic 3D viewing is needed. To accomplish this, both researchers and designers need to investigate the design of an S3D game by examining the affrodances offered by S3D. If the affrodances offered by S3D are significant enough, it may indicate game developers can create games with different mechanics, and ultimately create more compelling stereoscopic 3D experiences. It is also important to study the effects of engagement when the tasks or mechanics are specifically designed for S3D. There are many important questions that developers need answers for:

1. Does stereoscopic 3D affect engagement in video games?

2. Does stereoscopic 3D affect performance in video games?

3. Is it possible to make a Stereoscopic 3D only game? If so are there any depth cues that can replace stereoscopic 3D?

4. Do certain interactions coupled with stereoscopic 3D increase engagement?

Engagement is important to study because it is related to the emotional involvement of the player with the material. Just as a writer wishes their audience to become emotionally engaged in their stories, game developers also wish emotional engagement in their stories or gameplay. It is a popular (and logical) belief that consumer engagement increases sales, which is the reason for consumer loyalty programs, achievement systems, and the use of other forms of media to engage the consumer at different levels. Game developers are constantly looking to increase engagement through the use of technology.

This thesis explores the usefulness of stereoscopic 3D in increasing the engagement of video games. The author of this thesis performed three separate studies: i) Engagement in stereoscopic 3D, ii) Interactions along the depth-axis and their performance in stereoscopic 3D, iii) Different depth representation and their performance with interactions along the depth-axis.

The first study investigates the effect of stereoscopic 3D on user engagement in an existing game. The study compared engagement when the same game was played on traditional displays and in stereoscopic 3D. The study was conducted by the author of this thesis and two additional colleagues in [64].

The second study examined the performance of stereoscopic 3D with tasks perpendicular to the screen plane and its effects on engagement. The study developed a game which required the user to interact perpendicular to the screen plane. The study compared engagement and performance when the game was played on traditional displays and in stereoscopic 3D. The study and game was developed and conducted by the author of this thesis.

The third study examined the affect different depth cues had on performance and engagement when the task was perpendicular to the screen plane. The study expanded upon the second study and used a modified version of the game. The study and game was developed and conducted by author of this paper.

The three studies were developed and performed over the course of two years at the University Of Ontario Institute Of Technology(UOIT). All three experiments abided by the University of Ontario Institute of Technology Research Ethics Review process (REB #11-004, Title: Multi-modal interactions and video games: defining user experience with stereoscopic 3d vision, auditory, and haptic cues). This thesis is part of a larger project called iGO3D, which brings together academic and game industry partners to investigate human factors in stereoscopic 3D games. The goals of iGO3D are to provide developers with a knowledge base on the effect S3D will have on their game, with regard to work-flow, financial implications, design choices, and player experience. The specific questions asked in this thesis is whether stereoscopic 3D viewing affects player experience or does interaction and gameplay override any change S3D would have on engagement.

1.3.1 Hypothesis

It is the hypothesis of this thesis that stereoscopic 3D will have a positive impact on engagement when material or game is specifically designed to make use of stereoscopic 3D. It is also hypothesised that stereoscopic 3D will have a significant advantage in performance when the task is designed around stereoscopic 3D.

Studies two and three, in particular should demonstrate that stereoscopic 3D has both better performance and is more engaging when the task is perpendicular to the screen plane.

1.3.2 Thesis Structure

The remainder of this thesis is organized as follows. In Chapter 2, a background and literature review of stereoscopic 3D and user experience is provided. A overview of the human visual system system, stereopsis, stereoscopic 3D, issues with S3D, and the impact S3D has on the viewing experience in films is provided. The chapter also provides details on rendering and optimizing S3D for games, creating comfortable S3D in games, and designing S3D games. A literature review on measuring user experience in games and the effect S3D has on it provides the necessary information to understand the studies presented in this thesis. Chapter 3 describes the first experiment conducted which investigates the effect stereoscopic 3D has on user experience compared to traditional 2D viewing. Chapter 4 describes the second experiment conducted which investigates the performance and engagement when interacting along the depth axis with stereoscopic 3D verses without. Chapter 5 describes the third and final experiment which compares the performance and engagement of different depth cues (stereoscopic 3D, HUD, shadow and none) when interacting along the depth of stereoscopic 3D. The results and their implications along with future work are discussed in Chapter 6.

Chapter 2

Related Work

This chapter provides background information and a literature review of stereoscopic 3D and user experience in games. The fist section introduces the human visual system, stereopsis, stereoscopic 3D and its issues and impact in film. The second section focuses on research being conducted on S3D games, including rendering and optimizing techniques for S3D images, creating comfortable stereoscopic 3D experiences for games, and the impact S3D has on user experience in games.

2.1 Stereopsis and other Depth Cues

There has been a considerable effort placed in the understanding of how humans perceive depth in the world around them. Depth perception is only possible thanks to a number of different depth cues, which are usually classified into two categories: monocular and binocular cues. Monocular cues refer to depth cues seen with a single eye, while binocular cues refer to depth cues that require two eyes. Monocular cues consist of perspective [98], image size [62], interposition (occlusion) [99], light and shade [84], texture [14], aerial perspective [100], accommodation [127] and motion parallax [47]. Binocular cues include stereopsis [84], and convergence [109]. Linear perspective is what causes parallel lines to merge or converge together in the distance. Size of objects can also determine distance with objects appearing smaller the further they are away. Most surfaces have texture to them, as the distance to the surface increases the texture becomes smoother as it loses detail. Texture and linear perspective are often consider related depth cues [51]. Aerial perspective results from objects that are far away, needing to be viewed through more atmosphere [100]. Shadows can provide depth information with both with static object and objects in motion [86], it is particularly useful in determining

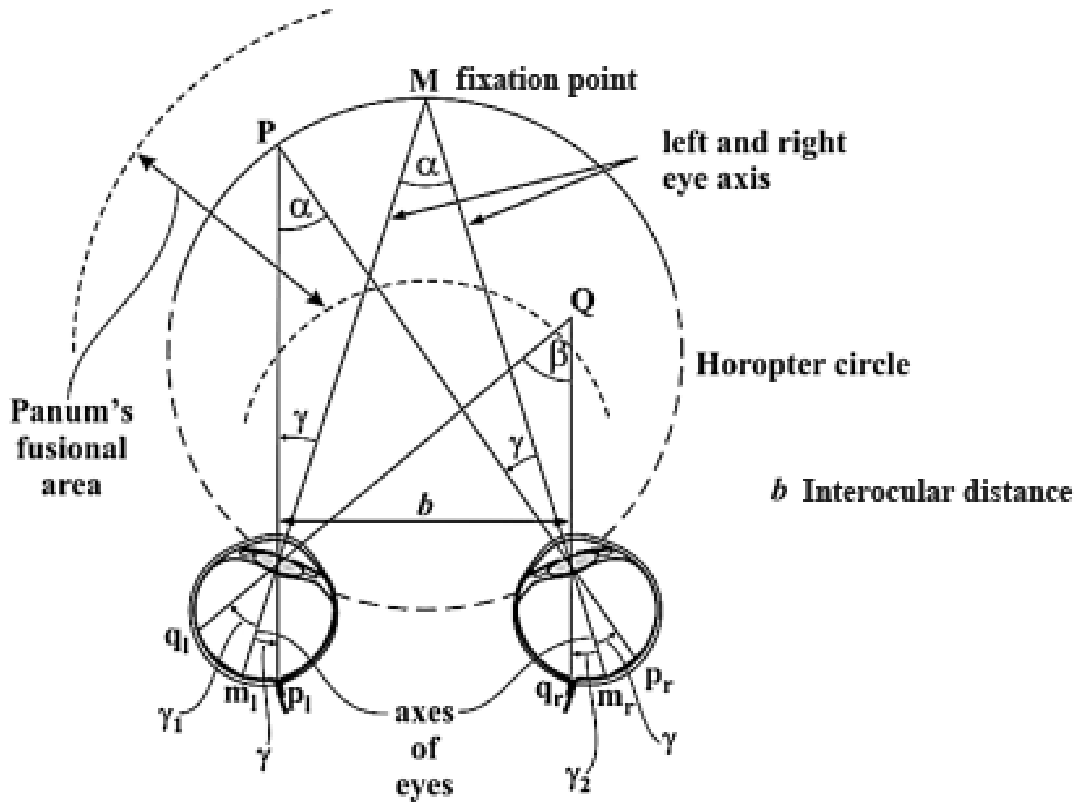

Figure 2.1: Diagram of binocular disparity [85]. The interocular distance, fixation point, horopter, and "Panum's fusional area" are labeled. Points M, and P are on the theoretical horopter, while point Q will have some disparity between the images.

the relative distance between the object and the surface with which the shadow falls on [86]. Occlusion, occurs when an object overlaps another; we can determine which one is closer because it will be fully visible, while the other is occluded [99]. Accommodation is a control mechanism of the eye [127], which focuses the image onto our retina, allowing us to view objects that are close or far away [50]. The final monocular cue, motion parallax is the apparent movement of a static object, during an observers change of position [54]. Convergence is a binocular cue, meaning both eyes converge or rotate to focus on an object [84]. Some depth cues can provide a highly quantitative impression of depth, such as motion parallax, while others can only provide coarse depth information [38].

Stereopsis is the mental formation of a three dimensional impression of the world. It is a qualitative visual phenomenon often considered a byproduct of binocular vision, however research suggest stereopsis can be induced during monoscopic viewing or when viewing a two-dimensional picture [138]. Binocular vision refers to vision that incorporates information form both eyes simultaneously. Binocular vision is responsible for convergence, a depth cue referred to above, and binocular disparity. Binocular disparity is often confused with stereopsis. Binocular disparity refers to an additional depth cue, while stereopsis is a the impression of depth. Stereoscopic 3D is a technique to provide both convergence and binocular disparity depth cues to induce stereopsis in the viewer. Binocular disparities (see Figure 2.1) are caused by the separation or distance between the eyes referred to as the interocular distance [84]. This separation causes disparities or small positional differences of objects and features in each image [38](see Figure 2.2). The amount of disparity depends on the depth of the object or feature compared to the fixation point of the viewer, therefore differences in disparity provide an indication of the objects depth. It is still not completely understood how our brain understands depth from these disparities, but a lot of work has been done on mapping out the neurons responsible for it [38]. The horoptor is an imagery surface where single vision occurs [67], meaning an object that lies on the horoptor has zero disparity. The fixation point, or point of convergence lies on the horoptor. Any object behind or in front of the horoptor will have disparities between the two images; the amount of disparity is dependent on how far the objects is from the horoptor. Binocular fusion is the process of merging the slightly different images caused by the disparities into a single stereoscopic perception. There is a limit to the amount of disparity that can be fused, which is defined by "Panum's fusional area" [106]. If the disparity is larger, then double vision or diplopia can occur.

While binocular disparity has been researched extensively, further investigation into the matching process [55] is still needed. The matching process refers to the process the brain uses to recognize the same object in each picture. There are several ideas about this process, it may be a surface recovery problem where our brains match contours in the images [95], or may be the unpaired components of an image play a decisive role [55]. It is also a bit unclear what role other depth cues have in this process. This is most clear when these depth cues are ambiguous, causing us to be unable to fuse the image properly and retinal rivalry occurs [132]. Retinal rivalry refers to the alternating visual perception of an image when the brain isn't able to correctly fuse the images presented to each eye. While stereopsis occurs naturally in the majority of the population, about 2.7% of the population is completely stereoblind [108]. Depth perception can be affected by disorders such as amblyopia and strabismus [83]. Stereoacuity, or full stereoscopic vision, can be measured or tested via stereograms. Random-Dot (Figure 2.3) stereograms consist of a pattern of random elements, that are duplicated. Then a selected region is shifted in equal and opposite directions. This should cause the selected region to float above the other dots, when viewed stereoscopically [143].

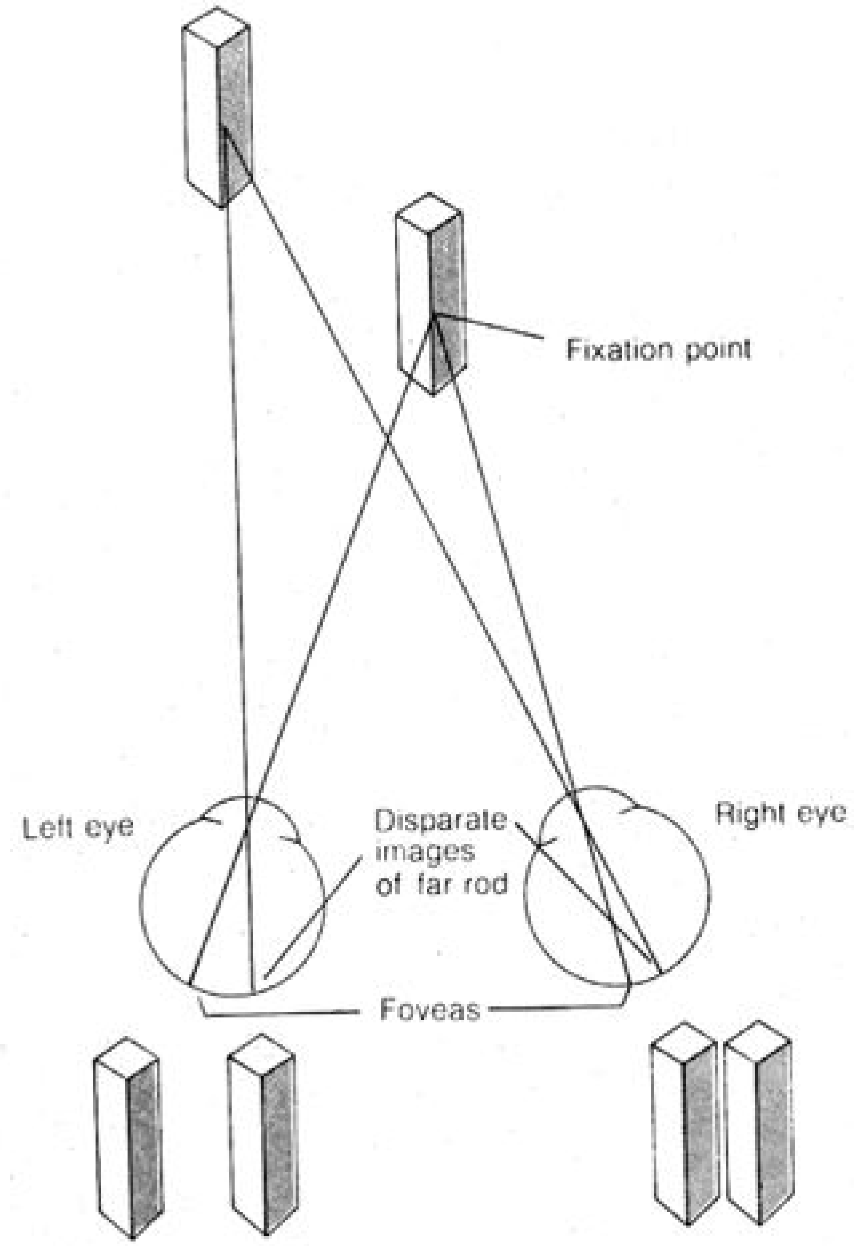

Figure 2.2: Visualization of binocular disparity, showing the two images from either eye's viewpoint [60].

Figure 2.3: Image of a Randot stereogram[1].

Depths cues have been extensively studied independently of each other, but to understand our visual system completely, investigation into how these systems work together is needed. When multiple depth cues are present in a single location within a scene, our visual system attempts to combine them [79]. There is no standard theory on how the visual system combines the depth cues, but three models exists, although there is no consensus on which is more accurate. The three models are: i) vetoing theory, ii) weak fusion , and iii) strong fusion [72]. The vetoing theory model is the idea that a strong cue will override a weaker cue, meaning the strong cue is used and the weaker cue is ignored. Bulthoff and Mallot's work supports this model, their experiment demonstrates stereoscopic 3D vision overriding shading [28]. Weak fusion is the theory that each depth cue is processed separately and then the estimates are linearly combined. This model is also referred to as the linear combination model and is well supported with studies from Dosher et al. [40] and Cutting and Burno [32]. Strong fusion is the most complex, it states that depth cues cooperate before individual estimates, meaning if a depth cue is incomplete another depth cue will provide it with the information necessary for it to make an estimate. While this method doesn't have as much support, possibly due to it being more complex then the other two, some studies like Rosas et al show support for the model [110]. Not understanding how the combination of depth cues affect depth perception, can sometimes lead to distortions in perceived distance [142].

2.1.1 Stereoscopic 3D

Stereoscopic 3D or S3D is a technique to create the illusions of depth in an image or flat display by presenting a left and right perspective to each eye in an attempt to mimic stereoscopic vision [84]. While it is easy to represent monocular cues on a flat surface, binoculars cues can't be displayed on flat surfaces in a single image, because they require two images. We need to present a left and right image to the appropriate eye, this requires specialized displays and technologies that have been developed over the last hundred years. While the concept of stereoscopic 3D is quite simple, producing and displaying proper images has proved difficult.

Capture

Before a stereoscopic 3D image can be displayed, a stereoscopic 3D images needs to be captured or created. Two types of camera systems exist to capture the left and right images needed for stereoscopic 3D. The first method is to simply use two monocular cameras to capture the images at the same time. The second method is to use a single S3D camera where the lens directs two different images onto a single piece of film [84]. One of the unique aspects to shooting two images, especially with two cameras, is both can move independently of each other. This allows the artist to experiment with the amount of distance between cameras, as well as rotating the cameras. The distance between the two cameras is referred to as the interaxial, and it relates to our interocular distance (distance between our eyes) [84]. This distance between the two cameras creates disparities between the two images, similar to the disparities caused by the distance between our eyes. The disparities in the images provide an additional depth cue when displayed to each eye. Typically, these disparities between the images are referred to as parallax. If an object has negative parallax it is seen in front of the scene, while if the parallax is positive, the object appears behind the screen. An object with zero parallax will appear on the screen plane. In the early days of stereoscopic cinema there was debate over whether the interaxial should be fixed at 3.5in or whether a variable interaxial should be used [84]. A variable interaxial is widely used today, it allows control over the amount of parallax or disparity of a shot which usually varies over the course of a movie [80]. Separating the cameras also allows the cameras to be rotated toward each other, a technique is referred to as toe-in. The idea was to converge on an object in a similar way to our eyes. Generally this technique is to be avoided [111], although it does allow filmmakers to modify the convergence point, determining where the location of zero parallax plane. Leaving the cameras

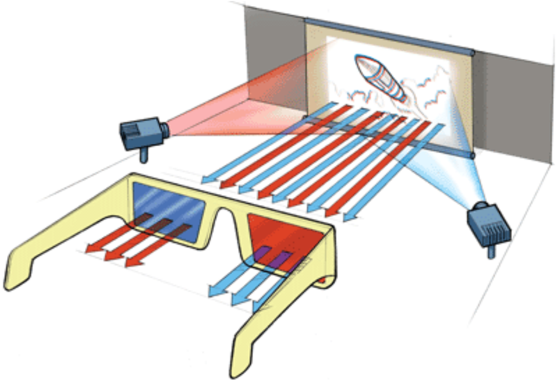

Figure 2.4: Image depicting stereoscopic 3D seen through anaglyph glasses [24]

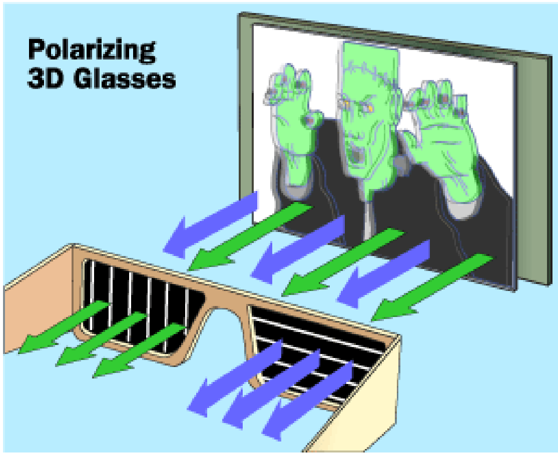

Figure 2.5: Image depicting stereoscopic 3D seen through polarized glasses [24]

parallel produces a better picture, toe-in leads to keystone distortions by creating unwanted vertical disparities increasing eyestrain [148]. A better approach to setting convergence is to shift the film or sensor [148].

Recently, there has been considerable work done on converting 2D films to create S3D films. The dominant technique is to create a depth map for each frame of the movie [56]. There are many different techniques to acquire the depth map, such as Battiato at al [16] and Harman at al [56]. The depth map is used to offset the pixels in the image [117]. One of the main issues with this method is the parallax effect, the second eye should see around objects that the first eye can't, meaning information is missing in the other eye. Sometimes this information is created by an artist or an algorithm. This method is often criticized for its image quality, while many proponents argue the difference isn't noticeable.

Display

To display a stereoscopic image we need to present the left and right images to the appropriate eye. Many techniques have been developed, the first being the stereoscope. The stereoscope was invented by Sir Charles Wheatstone in 1838 as a device to present a static stereoscopic image to the user, his version used a pair

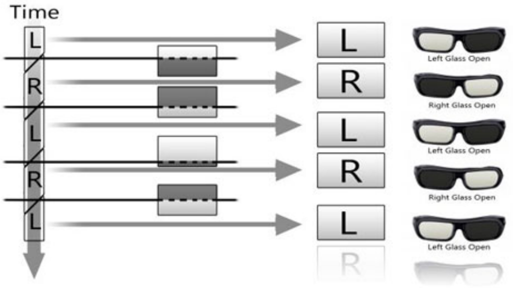

Figure 2.6: Image depicting stereoscopic 3D seen through active shutter glasses [9]

of mirrors to reflect images at the side to the viewers left and right eye, but other versions exist [66]. Today our stereoscopic 3D content is typical presented through anaglyph(Figure 2.4), polarized(Figure 2.5), or active shutter glasses(Figure 2.6). Anaglyph glasses are inexpensive and work with any flat display, by multiplexing the left and right perspective into complementary color channels [145]. Anaglyph glasses are particularly susceptible to cross-talk or ghosting [145]. Polarized glasses work similar to anaglyph glasses, except instead of encoding the data in color, it uses different polarizations. The method works by filtering light through a sheet-polarizer onto a polarization-conserving screen then back through the viewer's polarized glasses; letting only the light through with a similar polarization [84]. Filters for LCD screens have been developed and are common. Polarized glasses suffer from light loss, requiring bright projectors and screens [43]. Also unlike anaglyph, the polarized method requires a light source within the system (Projector or back-light). Active shutter glasses, also referred to as the eclipse method, requires the user to wear glasses which physically blocks the display from an eye, both the display and eye switch in sync. In the past this was done using mechanical glasses, but with the invention of liquid crystal displays the glasses have become electronic [84]. Many other types of displays exist each with there own advantages and drawbacks, like Parallax Barrier, Lenticular Sheets, Head Mounted Displays and others [87].

When displaying S3D on a screen such as a movie theater or television screen we have positive and negative space. Space in front of the screen is negative space caused by negative parallax, while space behind the scene is referred to as positive space and is made up of positive parallax [89]. To make for a comfortable viewing for the audience, creators must consider these spaces. Too much disparity in either direction can cause discomfort, as well as sustained imagery or focusing at extremes can cause fatigue [128]. For positive parallax, avoid disparities larger then the viewers interocular width, defined by the average interpupillary distance in the sweet spot, anymore causes divergence [128]. Some film makers go up to twice that width for short periods of time [89]. Negative parallax is equal to positive parallax, but is relative to screen distance, screen size and is also time sensitive, meaning

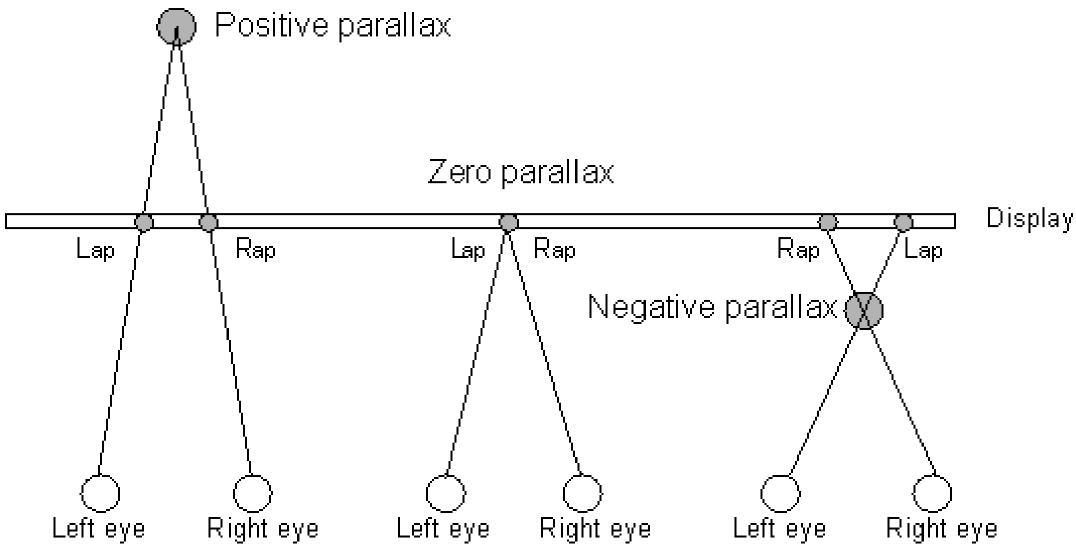

Figure 2.7: Image depicting positive and negative parallax, in front of and behind the screen [2].

the further out the less time the object should stay there [89]. For these reasons modern films, change the interaxial and convergence points throughout the film, providing more depth during intense scenes [80]. Filmmakers are beginning to explore how stereoscopic 3D can be used to support the storytelling.

2.1.2 Issues with stereoscopic 3D

As mentioned above, much of the current research into stereoscopic 3D is concerned with how to reduce or remove issues with stereoscopic 3D. Creating an enjoyable experience for users is extremely important. Issues with stereoscopic 3D do not only create negative experiences, but they can also be quite painful to the user. A few common and important issues that still remain are i) the vergence-accommodation conflict, ii)window violations and iii)crosstalk.

The vergence-accommodation conflict is the conflict between the convergence cue and the accommodation cue. When viewing an S3D film, our eyes converge on the virtual object that maybe in front or behind the screen, but the image is displayed on a flat screen where the eye accommodates [63]. The difference between these two depth cues confuses the brain causing eye fatigue. It is recommended to keep the viewers attention close to the screen plane, by changing the interaxial and convergence point of the scene.

Window violations are caused by a conflict between convergence and occlusions, when an object that is supposed to be in front of the frame or window disappears off screen. This conflict can be jarring and unconformable for a viewer [128]. It is also quite common when trying to perform a classic over the shoulder shot for a scene. A technique referred to as the floating window, helps viewers sort out the conflict allowing them to view the scene comfortably [128]. The floating window technique places a very narrow bar at the edge of the screen in one eye to extend the frame in that eye. The disparty between the actual frame edge and the virtual frame edge cause the frame to appear closer to the viewer then the conflicting object, allowing the brain to make sense of the image and remove the conflict.

Crosstalk or ghosting occurs when the image for the left eye leaks into and is seen by the right eye, or vice-versa. In a crosstalk free system, the left eye only sees the left image and the right eye only see the right image. Crosstalk reduces the perceived depth and quality of a stereoscopic 3D image [135]. It is also a factor in causing simulator sickness and nausea. Much research is done in evaluating and reducing crosstalk within the display systems [101], with the goal to eliminate crosstalk from the display system [124].

2.1.3 Impact of S3D on Viewing Experience in Films

The user experience that stereoscopic 3D films create continue to improve as researchers gain a better understanding of how our visual system works, and issues with the technology are resolved. It is important to provide a comfortable, issue-free experience, because eyestrain and nausea can be induced by uncomfortable settings. Eyestrain or visual fatigue, including symptoms such as tiredness, headaches, and soreness of the eyes, are caused by demands on focusing and converging [137]. Visual fatigue can occur in everyday life, if eyes are used for long periods of time. Vergence-accommodation conflict, causes visual fatigue faster, especially as the conflict grows farther apart [137]. Issues with stereoscopic 3D, such as binocular rivalry can also lead to nausea and sickness for the viewer [21].

The impact S3D has on films is also being investigated. Stereoscopic 3D is expected to enhance the viewing experience for the audience by providing a more natural viewing experience. Research has examined viewing experience from both a quantitative and subjective viewpoints. Seuntiëns et al. [116] examined the viewing experience and naturalness of 2D and 3D images, and argue this is a better measure than image quality and would better reflect the added value of 3D. In their experiment, they added visual distortions (noise) to 2D and 3D images and asked participants whether the images provided a bad, poor, good or excellent viewing experience. They repeated this procedure replacing bad, poor, good or excellent with levels of naturalness. Their study concluded that 3D added value over 2D, when the same noise level was applied [116]. Pölönen et al. [104] investigated how stereoscopic 3D affects films of different genres. The study asked questions related to sickness, visual strain, stereoscopic image quality, and sense of presence to participants after watching the film avatar, which they compared to previous results for the film U2 3D. Their results showed that genre has a significant effect on the viewers sense of presence, with Avatar (an action, adventure, and sci-fi) film being more immersive. Participants when questioned in both studies indicated they were immersed, focused, and absorbed in the film. They also reported previous experience with S3D significantly reduced eye strain [104]. Pölönen et al. compared stereoscopic 3D experiences between adults and children; both groups found it funny, exciting and impressive but children were more enthusiastic about it. Results showed that 80 percent of children would choose S3D over 2D compared to 26 percent of adults [103].

2.2 S3D and Video Games

There are many similarities between S3D in film and games, but there are a few differences that need to be addressed. There are three main areas of research in stereoscopic 3D games: i) Rendering and optimizing stereoscopic 3D images, ii) Creating a comfortable experience in stereoscopic 3D games, iii) And the impact stereoscopic 3D has on the experience of a video game. Video games must be studied independently to assess the affect interaction has on the effect of stereoscopic 3D on the viewing experience. It is also important to study video games independently to investigate the effects stereoscopic 3D has on interactions.

2.2.1 Rendering and Optimizations of S3D for Games

Rendering stereoscopic 3D images is similar to creating and capturing stereoscopic images for films. A left and right image are still required to produce an S3D image. Computers generate or create 2D images of 3D scenes from a process called rendering. The process of rendering, also refereed to as the rendering pipeline function, is to produce a 2D image given a virtual camera, geometry or models, light sources, shading, and texture information. The pipeline is broken into three stages: Application, Geometry, and Rasterizer [12] (see Figure 2.8). The application stage is where the developer updates the scene, reacting to the users input. The geometery stage is responsible for the majority of per-polyon and per-vertex operations. It takes a 3D scene and converts it to a 2D image. This stage is broken into several

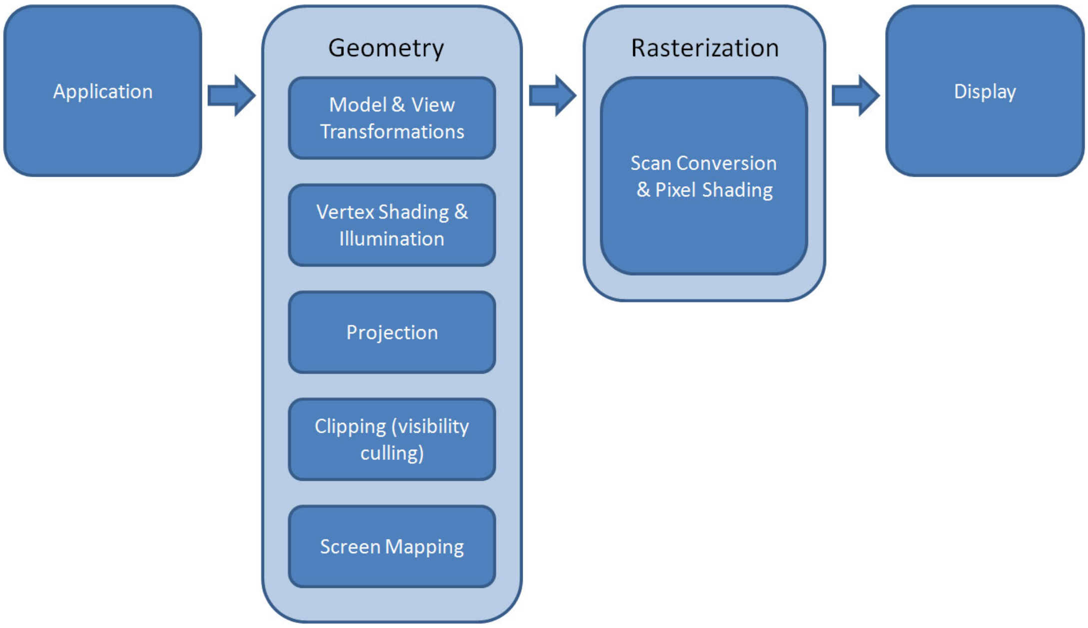

Figure 2.8: Diagram of the three stages of the rendering pipeline before the image is displayed. [131]

sub-stages: Model and view transform, vertex shading, projection, clipping and screen mapping. The third stage is the rasterizer stage, takes the information given from the geometry stage and computes a color for each pixel [12]. Basic stereoscopic 3D rendering requires two complete passes of the rendering pipeline to produce the two required images.

In the geometry stage of the rendering pipeline, model geometry such as vertices undergo transformations from model space to world space to camera space and finally to screen space [12]. Rendering stereoscopic 3D images requires two different virtual cameras, therefore we must have two different camera spaces. Since rendering is a pipeline operation, modifying the camera requires the scene to be rendered a second time using a second pass of the pipeline, requiring twice as long as a single two dimension image [37]. Similar to real cameras used in films, the distance between the two virtual camera is also called the interaxial distance, and just like the setup of real cameras, we need a way to set the convergence plane. The toe-in method from film is a possible solution, but the same problems of vertical parallax are introduce with virtual cameras. One of the most used methods for generating comfortable stereoscopic pairs is described by Bourke [22] and called "off-axis". It describes a method were viewpoints share the same image plane and use an asymmetric projection volume. This method shifts the selected image plane(defined by the convergence depth) of each eye to the left or right depending on which view is being shifted(opposite shift: right view shifts to the left). The applied shift should

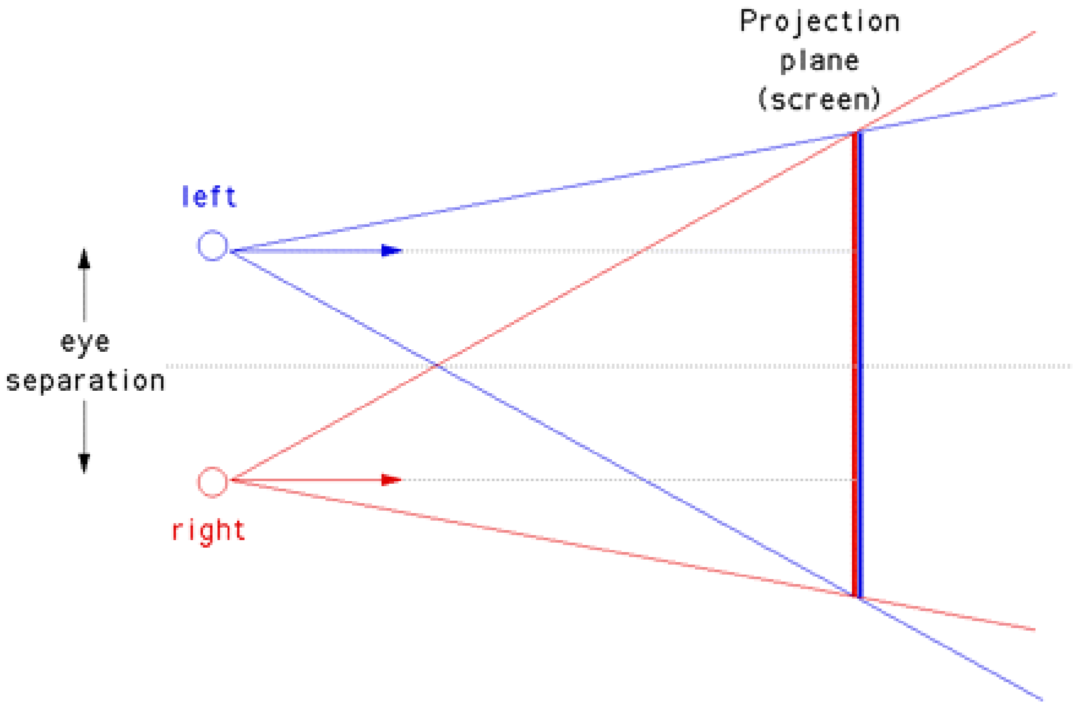

Figure 2.9: Diagram of sheared projections, shifting the image planes to the convergences plane [22]

position the image planes of each eye at the exact same location and orientation, this shared image plane is the convergence plane (see Figure 2.9). This operation is performed by applying a shear to the projection matrix. The projection matrix is used to convert from camera space to screen space. Below is the standard 3D perspective projection matrix, defined by a top, bottom, left, right, near, and far plane.

$$P_{persp} = \begin{bmatrix} \frac{2(near)}{right-left} & 0 & \frac{right+left}{right-left} & 0 \\ 0 & \frac{2(near)}{top-bottom} & \frac{top+bottom}{top-bottom} & 0 \\ 0 & 0 & -\frac{far+near}{far-near} & -\frac{2(far)(near)}{far-near} \\ 0 & 0 & -1 & 0 \end{bmatrix}$$

Applying a shear to the original projection using a convergence transformation, we provide the correct projection matrix(see below). A positive translation is used for the left eye, and a negitive translation is applied to the right eye. The interaxial is the distance between the two virtual cameras. Convergence is the depth of the zero parallax barrier relative to the camera.

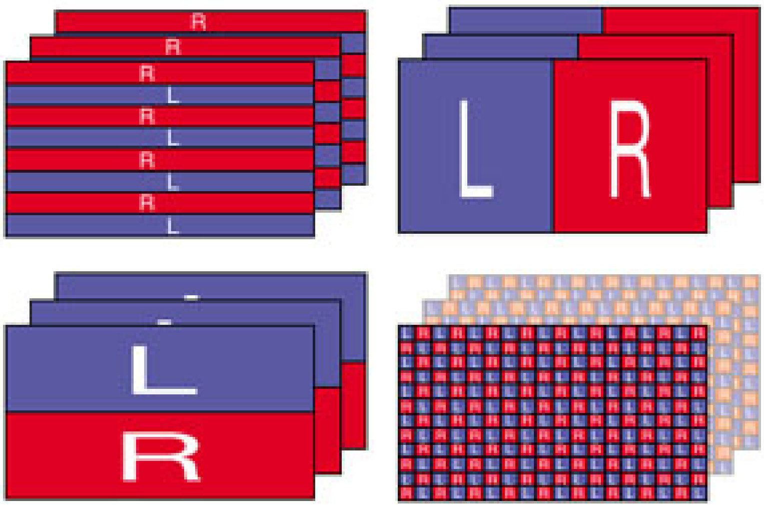

Figure 2.10: Image depicting display formats, including interlaced(top-left), side-by-side(top-right), top-down(bottom-right), and checkerboard(bottom-left) [10].

$$P_{persp_{stereo}} = \begin{bmatrix} \frac{2n}{r-l} & 0 & \frac{r+l}{r-l} & 0 \\ 0 & \frac{2n}{t-b} & \frac{t+b}{t-b} & 0 \\ 0 & 0 & -\frac{f+n}{f-n} & -\frac{2fn}{f-n} \\ 0 & 0 & -1 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 & \pm\frac{interaxial}{2(convergence)} & \pm\frac{interaxial}{2} \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The Rasterizer stage is important because the final images must be in a specific output format for stereoscopic displays to understand the information [20]. The High-Definition Multimedia Interface(HDMI) [58] and Digital Visual Interface(DVI) both have different specifications for transmitting a stereoscopic signal. HDMI allows two stereoscopic video formats: i) 1920×1080 for each eye at 24 frames per second ii) and 1280x720 for each eye at 60 frames per second. The second allows transmission of real-time images important to game development, while the first is used for film. Developers should implement by creating a single 1280x1470 image buffer, which contains two 1280x720 images in top/bottom format. The extra 30 pixels goes in between the two images, and is used for video timing purposes [19]. This method of transmitting images is referred to as frame sequential. There are a number of additional formats that arrange both the left and right view into a single frame, including side-by-side, top-down, interlaced, and checkerboard (see Figure 2.10).

In the worst case, stereoscopic 3D can take twice as long as to render [37], however much work has been done to speed the up the process. Sorbier et al. describes a method to accelerate stereoscopic rendering by only rendering the scene once.

As described above, the difference between stereoscopic images pairs is their viewpoint. The purposed method in the paper, makes use of geometry shaders to clone input primitives. The algorithm first computes the left and right modelview and projection matrices, then renders the scene from the left viewpoint. In the geometry shader, a new programmable shader in the graphics pipeline where new geometry can be created, the geometry of the scene is copied creating two identical sets of the scene. The modelview and projection transformations for the left and right viewpoints are applied to the original and new copy of the geometry respectively, before emitting the new primitives to the fragment shader. The fragment shader should render the results into two separate buffers [37]. Although, this technique wasn't possible on Sony's PlayStation 3 or Microsoft's Xbox 360, which don't have programmable geometry shaders. Another technique described by Kalaiah et al. [74] purposes multi-viewport rendering as a generalization, allowing multiple viewports to be rendered in a single pass. They emulated it on current GPU, but if in the future GPUs supported multiple viewport rendering, both the left and right images could be rendered in a single pass.

There has also been extensive work in image-based approaches where one view is constructed from the other view. In Fu et al. [52] they make use of coherence between the stereoscopic pair and transform pixels in the left view to the right view by storing the depth values and offsetting the pixels in the x direction of the right view. While the majority of polygons are visible to both eyes, occasionally a hole develops in the right view that must be filled(see Figure 2.11). These holes occur, by either local image expansion or visibility change of a few objects [52]. These holes are common across all image-based approaches, but different solutions exist to fill them. In Fu et al. they fill the holes by linear interpolating between the intensives of the neighboring pixels [52]. In Wan et al., they fill the holes using volumetric ray casting [140]. Other techniques to fill the holes include blurring the depth buffer by a Gaussian filter [46], and averaging the textures from neighboring pixels [147]. Sony's reprojection technique is similar, except they suggest that rendering a central eye and creating both the left and right images from the depth buffer reduces artifacts in both eyes [19]. Creating a second image from the first tends to be faster, but also produces less accurate imagery. The benefit to this approach is its not dependent on scene complexity but rather image resolution, which can reduce time to compute one of the views. There has also been extensive work in ray tracing and volume rendering,such as Adelson and Hodges [11] and He and Kaufman [59], but these techniques are not applicable to real-time rendering.

Figure 2.11: Image depicting the creation of a hole when creating the image of the second eye from the depth buffer, using the reprojection technique [19]. Copyright Sony 2013.

2.2.2 Creating a Comfortable Stereoscopic 3D Games

When developing stereoscopic 3D content, creators must develop comfortable user experiences. It is very easy to make a user feel uncomfortable and sick with stereoscopic 3D. The issues with S3D content in films are the same as ones in video games. Developers need to be aware of vergence-accommodation, crosstalk, conflicting depth cues and window violations as well picking comfortable negative and positive parallax budgets. However, developers of video games aren't in total control of the final picture presented to a user. A developer can't determine where the user will walk or look, because the player is often in control of these variables. Therefore developers must develop systems to make sure their games always presents comfortable S3D images.

As mentioned above, the vergence-accommodation conflict causes visual discomfort. The larger the distance between the two cues, the faster the user experiences discomfort. This suggests users can comfortably view small variations between these two cues for sustained amounts of time, but large amounts of variation should only occur for brief amounts of time. The area where users feel comfortable for sustained amounts of time is sometimes referred to as comfortable viewing range. This area is only a few centimeters behind and in front of the screen and is determined by the size of the screen and distance of viewer. This comfortable viewing range typically meaning the scene's depth requires scaling to fit. In film, this is the directors job, to make sure each shot conforms to this area. In games the designer is in control of the scene at all times, requiring algorithms to automate this process. Jones et. al provides an algorithm to map the virtual depth range into the comfortable viewing area [73]. Another technique presented by Holliman created nonlinear mapping by splitting the scene into three separate regions using a multi pass rendering algorithm [65]. A similar technique was used in Killzone 3, for rendering the foreground(player's HUD), middle ground or area of action, and the background or sky-box [19]. Another method presented in Sun and Holliman, is dynamic depth mapping which fits depth into a comfortable range dynamically [122]. The comfortable viewing area can be expanded for objects where the viewers attention is not focused, as visual discomfort deceases with objects that aren't looked at often [77]. In film directors make use of cinematic storytelling to lead a viewers eyes around, giving them some control over where the viewer is looking [122]. This allows film makers to push the comfortable viewing area, even using diverging parallaxes in background, if the viewer's attention is at a comfortable depth [88]. However, it is difficult for developers to control where the users attention is during a game.

Stereoscopic acuity or a person's ability to see stereoscopic 3D varies widely in the population. Many factors such as interocular distance, accommodation ability, maximum pupil size all affect stereoscopic acuity [113]. Other external factors such as distance to target, spatial frequency and luminance of target, distance from fixation, observation time also affect a person stereoscopic acuity and viewing comfort [113]. Because there are so many different variables that can affect the viewing comfort, a common solution is to reduce parallax settings to a comfortable viewing range by decreasing the interaxial distance. However since stereoscopic 3D images are produced in real-time, we can modify parallax settings on an individual bases. In games a common method is a to include a slider in the game or driver to modify the interaxial between the two cameras, allowing the user to determine comfortable settings. The average user however may not understand what the comfortable settings are for themselves. Tawadrous et al. [130] presented another solution allowing them to pick their settings by choosing between two different settings. In there setup they had the user select the more comfortable setting between two screens displaying different stereoscopic settings. They kept the player's choice and replaced the other with new settings, and repeated this till the user ended up with comfortable results. Their study showed no significant difference between the two methods. Currently there is no way to absolutely ensure a comfortable experience in games [113].

Another area or issue where games have trouble borrowing solutions from film is window violations. Unlike film, developers don't have the opportunity to frame their shots and correct any problems after production. Sony's approach to overcoming this problem is the dynamically adjusted stereoscopic camera [19]. This approach is similar to the method presented in Sun and Holliman [122] mentioned above, which dynamically adjusts the stereoscopic settings based of the depth range to maintain a predefined parallax range. This process can eliminate window violations by re-calculating if an edge violation occurs, which can be detected by storing the depth of the closest object hitting the screen [19]. Another technique based off the idea of the "floating window" attempted to enhance the negative parallax space and reduce window violations by creating a virtual window at the zero parallax. They found they could manipulate the user into perceiving objects at distances further or closer than they actually were placed [121].

Designing Stereoscopic 3D Games

Stereopsis is an important part of our visual system, allowing humans to better perceive depth in the world around them. Fielder and Moseley [49] showed that being stereo acute at certain tasks is beneficial, especially with comprehension of complex visual presentations and those requiring good hand—eye coordination. Games consist of complex visual presentations and typically require good hand—eye coordination due to the real-time nature of the task, suggesting stereoscopic 3D should be beneficial to users of S3D Games. Litwiller and LaViola Jr. performed a study [81] to measure and compare player performance and learning, under 2D and S3D conditions. Participants were required to play five different games, including a racing, first and third person shooter, and sports game. They reported that S3D did not provide a significant advantage over 2D; learning rates were similar between the two modes. Their study used existing games designed for 2D displays. The tasks presented to the user in those games may not have benefited from S3D viewing. Tory et al. presented a study comparing 2D(orthographic), 3D (non-stereoscopic), and combined 2D/3D displays for relative position, estimation, orientation, and volume of interest tasks [133]. Their results indicated that 3D or perspective viewing was effective at approximation and relative positions when appropriate cues(such as shadows) are present, but were not effective for precise navigation and positioning except for specific circumstances, such as good viewing angles. They also found combined displays had as good or better performance, inspired higher confidence, and allowed natural, integrated navigation. Developers purposefully build games around good viewing angles, include additional cues like shadows, or a combination of 3D/2D display by including a HUD. Shirah and Brandt performed a similar study [69] with the inclusion of S3D, comparing it to a traditional 3D perspective with and without shadows for positioning and resizing tasks. It found while shadows increase accuracy compared to a traditional 3D perspective viewing, they had no effect on the speed of object positioning or on object resizing. It was also not as effective as stereoscopic 3D with positioning and resizing tasks. It also found that task performances of shadows worsened with stair-step scene backgrounds and when the number of light sources increased from one to two. While most games today likely conform their tasks to an appropriate or good viewing-angle for the task assigned to the player, studies like Shirah and Brandt's study suggest that different task which might be difficult under traditional 3D perspective viewing, may become easier with stereoscopic 3D cues.

Very little work has been done on designing mechanics specifically for stereoscopic 3D. Zachara and Zagal review the failure of Nintendo's Virtual Boy [146], with one of the reasons being a lack of focused design and a need for S3D game mechanics. Many supporters of S3D feel that a game which is only playable with S3D is needed. Schild and Masuch explore opportunities, and propose a list of possible future innovations in S3D game design [113]. They developed their list by reviewing psycho-psychological and technological literature on 3D movie making. They break the challenges of designing an S3D game into four categories: interactive S3D camera effects, stereoscopic game challenges and design ideas, S3D game GUI and information visualization and extreme S3D: double vision and abusive effects. They present several game design concepts within the stereoscopic game challenges and design idea category including depth-estimation tasks, balancing towards easy tasks, balancing towards difficult tasks, memory tasks(no impact expected), S3D game scenarios and depth-based level design. For depth-estimation tasks they suggest possibly creating unique challenges by deliberately creating cognitive conflicts of depth cues. This among other suggestions, have yet to be tested or developed, but many good ideas are presented in their paper that still need to be explored.

2.2.3 Impact of S3D on User Experience in Games

Developers and researchers are beginning to understand how to technically produce quality stereoscopic 3D visuals in games, and they are making progress on designing for stereoscopic 3D. It is expected S3D will have an impact on user experience, and hypothesized that S3D will create more engaging content. Evaluating user experience is a major area of games research, with aspects borrowed from both HCI and psychology [18]. Understanding user experience is critical for game developers seeking to maximize their profits, as players choose games that provide the best experience. User experience evaluation in games refers to the investigation of a person's feelings about using a game. Often times researchers are attempting to measure player's level of enjoyment, immersion, engagement and fun. User experience still doesn't have a clear definition, but the International Organization for Standardization(ISO) describes it as a person's perception and the responses resulting from the use or anticipated use of a product, system, or service [17]. Nacke et al. argue that user experience in games should be divided into two areas, playability and player experience [93]. Playability is focused on evaluating the game to improve it's design, while player experience investigates the player to improve gaming. They also mention that good playability is a prerequisite for evaluating game experience. Our primary concern is to determine the benefits of stereoscopic 3D on gaming, but first an understanding of the affect stereoscopic 3D has on a game's design is needed. Above details were provided some of the existing fundamentals of stereoscopic 3D design, but first we need a method to test and validate these suggestions before studying the effects on player experience. There are many useful and valid heuristics to assess playability and player experience, but currently there is no integrated model and often heuristics are isolated, repetitive, and contradictory [125]. A multi-measure approach is a common belief within the field, by providing a better understanding of the game experience [93].

Evaluating User Experience in Games

One method for assessing the playability of a game is the expert review or heuristics, which is a method used throughout the development process [93]. Heuristic sets have been developed to help experts evaluate gameplay (the problems and challenges of a game), game story, game mechanics (the structure of interactions within the environment), and game usability (interface of the game) [39]. Methods are usually broken into qualitative measures including think-aloud protocols, interviews, surveys or a combination of them [76] and quantitative methods such as gameplay [136] metrics and biometrics [91]. Gameplay metrics are numerical data of the players interactions within a game or piece of software. The methodologies were adopted from human-computer interaction (HCI) and are very useful in determining what a player did in the game. Drachen and Canossa demonstrated gameplay metrics to be useful in providing quantitative and detailed data on player behaviour, especially in finding patterns within large datasets of user behaviour [41]. They found it complements existing methods. While it is very useful at explaining what behaviours emerge, it doesn't explain why certain behaviours emerge [93], as it is often combined with other user experience methods such as surveys and usability methods. This helps directly link game experience with game design elements. As discussed in Nacke et al. [91] game metrics can also be used with biometrics to evaluate player experience and playability. Biometrics are psychophysiological measurements taken from players while playing a game. Various evaluation techniques including electromyography (EMG), electroencephalography (EEG), and eye tracking exists. Electromyography is a measure of muscle activity, which has been shown to correlate with negatively valenced emotions such as frustration, fear and sadness [94]. Another similar physiological measure is Galvanic skin response (GSR) which is an indicator of skin conductance and can be an indication of arousal. Electroencephalography (EEG) measures electrical brain activity, through an noninvasive process of placing electrodes on a user's scalp. EEGs can be used to record arousal levels in users by examining asymmetric frontal alpha activity [30]. Eye tracking allows researchers to study visual and display-based information processing, helping them to understand the usability of a system [105]. A major benefit to biometrics compared to surveys and interviews, is they allow noninvasive measurements while the player is absorbed in the game.

Aside from quantitative methods, there has also been development with qualitative methods, particularly with developing and assessing basic psychometric properties [93]. IJsselsteijn at al. describe two potential candidates in evaluating gameplay as flow and immersion [70]. Flow (described by Csikszentmihalyi [33]) is a psychological state that describes when a person is completely absorbed in an activity. At the center of flow is the balance between the challenges posed by the activity and the skill level of the player. Sweetser and Wyeth present GameFlow, a model to evaluate user experience which is structured around flow [125]. Their model measures eight elements: concentration, challenge, skills, control, clear goals, feedback, immersion, and social interaction. They found their model to be useful in reviewing games, with potential to develop tools to designing and evaluating enjoyment in games. Immersion is used to refer to the amount of involvement or engagement a user experiences with a game. In Sweetser and Wyeth's gameflow model it's describe as "deep but effortless involvement, reduced concern for self, and sense of time", which IJsselsteijn at al. state isn't clear or distinct from flow [70]. Ermi and Mäyrä suggest there are three forms: Sensory immersion, challenge-based immersion, and imaginative immersion [44]. Due to the absences of a standard definition of immersion, Brown and Cairns performed a series of interviews with games to determine what they felt immersion meant [26]. The interviews lead them to a describe immersion as the degree of involvement within a game, and purpose three levels: Engagement, engrossment, and total immersion. Many of the terms engagement, immersion, involvement, etc. tend to be interchanged as there is no accepted or agreed upon framework for describing user experiences.

Several models have been developed to clarify and understand user experience. One such example is The Game Engagement Questionnaire(GEQ) which was developed by Brockmyer et al. [25] The GEQ is a scientifically validated self assessment tool for determining players engagement in video games. In their paper they describe engagement as a term used for involvement, which is a combination of immersion, presence, flow, psychological absorption and dissociation. It was developed using classical and Rasch analyses. Their results indicated that the GEQ provides a psychometrically strong measure of levels of engagement. Another questionnaire called the Game Experience Questionnaire(GEQ2) was report in IJsselsteijn at al. as a metric for determining player engagement [70]. It was used in Nacke [92] and validated statistically [35] [36] [102]. Unfortunately this questionnaire is not publicly available.

User experience of S3D Games

Recently, research in S3D games has been focused on determining the impact and benefits S3D has on the user experience of games. As reported above, Litwiller and LaViola Jr. demonstrated that stereoscopic 3D did not provide any significant performance advantage over players on monoscopic displays within existing genres [81]. They did however report players preferred the S3D version of the game. Performance is a form of gameplay metric, and is typically an indication of playability rather then a metric used to explain player experience. In Litwiller and LaViola Jr. playability isn't being affected by S3D, but player experience is being affected as indicated by players preference. This indicates the visual aspect of S3D may affect player experience. Rajae-Joordens also reported similar results [107]. A few studies have focused on developing or using existing games with some interaction along the depth axis like Kulshreshth et al., who evaluated S3D in motion enabled video games [78]. They reported a positive effect of S3D on gaming performance, depending on user expertise and if it was an isolated tasks. Schild et al. also evaluated existing games, demonstrating that S3D in games increased immersion, spatial presence, and simulator sickness [112]. Using self-reporting questionnaires and one psychophysiological instrument(NeuroSky), they studied 60 participants who each played one of three games. Their study indicated a more natural experience with stereopsis. They also reported the effects differed across the three games and for both genders, with males and games involving depth animations being more affected. Takatalo et al. reported a higher presence in stereoscopic 3D then monoscopic displays, but found no effect in emotional factors like fun or enjoyment [126].

The prior literature discussed above, indicates stereoscopic 3D may positively effect user experience under certain conditions. The purpose of this thesis and the studies presented below, is to investigate the conditions needed in a game for stereoscopic 3D to improve the user experience. Past research has been limited to only studying the effects stereoscopic 3D has on an existing game developed for a two dimensional display. Little has been done to explore the effect stereoscopic 3D can have on the design of a game. This thesis explores whether it is possible to develop a game specifically for stereoscopic 3D, and if the inclusion of stereoscopic 3D improves its user experience.

Chapter 3

Engagement in Stereoscopic 3D Games

It is important that developers are aware of the impact stereoscopic 3D has on player experience, so they can make specific design choices around S3D. It is a popular belief that consumer engagement increases sales, as seen in loyalty programs, achievement systems, advertisements, and others. It is beneficial for developers to understand stereoscopic 3D (S3D) can provide a simple solution to increase engagement without the need of much work from them. In this chapter we explore the effects of S3D on player engagement. A study was conducted to investigate the effect stereoscopic 3D has on player experience within an existing game [64]. The purpose of the study was to determine if a game engaged a user more in stereoscopic 3D compared to a traditional monoscopic display. It focused on an existing game developed for a monoscopic display, with no changes other then the addition of stereo rendering. This setup was chosen to develop an understanding of how the visual difference impacted engagement within a game. Participants played under both conditions(monoscopic and stereoscopic views) where their engagement was recorded with a previous validated self-reporting measure. The results from this study will provide an indication of the effects stereoscopic 3D has on player experience within an existing game and genre.

3.1 Game Engagement Questionnaire

To measure engagement we use the previously validated Game Engagement Questionnaire(GEQ), a self-reporting measure described above in section 2.2.3. It was

	Questions	Engagement Measure
1	I lose track of time	Presence
2	Things seem to happen automatically	Presence
3	I feel different	Absorption
4	I feel scared	Absorption
5	The game feels real	Flow
6	If someone talks to me, I don't hear them	Flow
7	I get wound up	Flow
8	Time seems to kind of stand still or stop	Absorption
9	I feel spaced out	Absorption
10	I don't answer when someone talks to me	Flow
11	I can't tell that I'm getting tired	Flow
12	Playing seems automatic	Flow
13	My thoughts go fast	Presence
14	I lose track of where I am	Absorption
15	I play without thinking about how to play	Flow
16	Playing makes me feel calm	Flow
17	I play longer than I meant to	Presence
18	I really get into the game	Immersion
19	I feel like I just can't stop playing	Flow

Table 3.1: Game Engagement Questionnaire. Responses are No=1, Maybe=2, Yes=3

developed by Brockmyer et al. [25], and defines engagement as a combination of immersion, presence, flow and psychological absorption. The GEQ was analyzed and verified with the Rasch rating scale model, in additional to Classical Test Theory. The GEQ consist of 19 questions each pertaining to a measure of immersion, flow, presence or absorption as listed below in table 3.1. Participants respond to each question with a No, Maybe, or Yes which correspond to 1, 2, and 3 respectively. The total sum is referred to as the GEQ score and is proportional to player engagement, with higher scores indicating higher engagement.

3.2 Method

The study required every participant to play the game under two conditions, (i) non-stereoscopic 2D and (ii) stereoscopic 3D. Participants were required to wear stereoscopic 3D polarized glasses under both conditions. The experiment was counter-balanced, with participants chosen randomly as being part of either group A or group B. Group A played the S3D condition first, followed by the non-S3D condition. Group B performed the condition in the opposite order. To ensure the game ran with similar performance under both conditions, the non-S3D condition was rendered with the stereoscopic 3D drivers, but with zero depth. Rendering stereoscopic 3D images can be performance intensive, and we wanted both conditions to be kept as consistent as possible, with any loss of frame-rate present it both conditions. Any drop in frame-rate could impact the visual experience as well as the responsiveness of the controls; these differences could impact the experience.

Participants were first asked to complete a general demographic questionnaire (see Appendix A) to gather some general information about them and their experience with S3D and games. After completing the demographic questionnaire, they played the game for 35 minutes with or without S3D depending on their group. Upon completion of the 35 minutes, participants were instructed to fill out the Game Engagement Questionnaire and given a five minute break before continuing. They then repeated the process under the other condition, starting the game from the beginning again. They did not fill out the demographics questionnaire again. After the completion of both conditions and Game Engagement Questionnaires, participants were asked for their general free-form comments.

3.2.1 Participants

A total of 21 participants, with one female were selected from the Game Development and Entrepreneurship program at the University of Ontario Institute of Technology (UOIT). Due to an unbalanced gender pool, the female participant's data was not used leaving 20 male participants. Volunteers were between the age of 18 and 26, with the majority (50%) between 18-20. Nine of the participants had never played a stereoscopic 3D game, with one of them never having seen a stereoscopic 3D movie. Participants were very experienced at playing video games with the majority playing over 10 hours a week. All participants started playing games before the age of 13.

3.2.2 Setup

The experiment was conducted within the University of Ontario Institute of Technology's undergraduate game development laboratory. The laboratory is approximately $40ft \times 20ft \times 9.5ft$, with equipment such as workstations, tables, chairs, etc inside. The room was kept as quiet as possible with extra equipment turned off

Figure 3.1: Screenshot of Trine. Copyright Frozenbyte studios.

and non-essential individuals removed from the room. Lights remained off while participants played the game. Each participant was seated in front of a passively polarized stereoscopic 24" Zalman Trimon(ZMM240W) monitor, and instructed to rise or lower their seat and/or tilt their monitor to find the stereoscopic sweet spot. The Zalman Trimon monitors can produce a double image if the user isn't seated in the right spot, especially if they are seating too high or too low. Theses monitors were chosen because they worked well with a number of drivers like DDD's TriDef and Nvidia's 3D vision. We ended up using the TriDef driver, due to its ability to control the depth, and percentage out of screen, unlike Nvidia's solution which only provides a single slider.

The game Trine by Frozenbyte Studios was selected for its superb quality of the stereoscopic experience using the TriDef driver. It was recommended by the community at MTBS3D [115](Meant to be Seen), a website and advocacy group for stereoscopic 3D Certification. Trine is a classic side-scrolling platform similar to the original Mario games, where players must navigate from the left to the right of the screen avoid enemies, jumping over obstacles and solving a variety of puzzles to reach the end of a level. The player is given three characters they can switch between each with different abilities such as a sword and shield, grappling hooks, or magic. An example of a puzzle is moving a block with magic onto a switch to open a locked door. It's a simple game for any player to easily become familiar with, making it a great choice for participants of all skill level. A tutorial is provided to help players unfamiliar with the game. Trine was developed for a monoscopic display, and all interaction lies along the xy plane of the screen. It may seem like an odd choice compared to a first person shooter, to measure immersion and engagement, but this genre allows us to better isolate the effect S3D has on engagement. It allows us to investigate the use of stereoscopic 3D to enhance the user experience, rather then make it integral to the experience.

3.2.3 S3D Driver Settings

The settings for the stereoscopic driver were kept fixed across all participants, with a scene depth at 44, 48% in front of the screen, a near plane at 97 and far plane at 100. In the TriDef driver, scene depth controls the interaxial while the percentage in front of the screen modifies the convergence plane. These settings were chosen qualitatively by the experimenters, because they provided a good amount of depth into and out of the screen in all the levels the participants would be playing.

3.2.4 Hypothesis

It was predicted that participants would report a higher GEQ score for stereoscopic 3D than in the 2D viewing condition, indicating a higher level of engagement for the S3D condition.

3.3 Results

3.3.1 Participants Expectations of Stereoscopic 3D

Within the demographics questionnaire, participants were asked a series of questions about their expectations about the importance of different aspects regarding video games and stereoscopic 3D. These questions were asked before participants played the game under either condition to investigate their prior experiences and expectations towards stereoscopic 3D. Participants were asked to rate their stereoscopic experiences with respect to traditional 2D or monocular experiences on a seven point scale, with 1 being 2D is more enjoyable and 7 being stereoscopic 3D is more enjoyable. Participants indicated they didn't have a strong opinion between stereoscopic 3D and traditional displays for either films or games; with a mean rating of 4.38 for games and 4.57 for movies. Participants were also asked about the importance of different qualities in video games using a five point Likert scale, with 1 being not important to 5 being the most important. The average ratings were: multi-player gameplay=3.7, single-player gameplay=4.45, realistic graphics=3.45, audio quality=4, surround sound audio=3.3, story=4.1, quality of interaction=4.25. They were also asked about the importance of different aspects of stereoscopic 3D using the five point scale. They reported the following average ratings: seeing deeply into the screen=3.75, out of screen effects=3.8, not wearing glasses during gameplay=3.45, playing for more than 1 hour=3.85. The results to these and additional questions are available in Appendix A.

3.3.2 Game Engagement Scores

A paired-samples t-test was conducted to compare the Game Engagement Questionnaire scores when playing with stereoscopic 3D and playing without stereoscopic 3D. There was no significant difference in the Game Engagement Questionnaire scores for stereoscopic 3D (M=35.15, SD=8.25) and without stereosopic 3D (M=32.85, SD=7.15); $t(19) = 1.78$, $p = 0.091$. These results suggests that stereosopic 3D does not affect player's engagement for the game Trine. See Appendix A.0.2 for participants responses.

3.3.3 Free-form comments

The final part of the experiment asked participants to provide free-form comments about their experience under the two conditions. Sixteen of the twenty participants described the S3D experience to be compelling, fun, engaging and interesting. Eight of the participants also reported that the stereoscopic 3D condition was uncomfortable due to difficulty fusing the two images, especially with out of screen effects. This could possibly be due to participants moving out of the sweet spot. It could also be attributed to improper, fixed stereoscopic 3D settings. Some example responses include:

> "I thought the 3D was more fun but I was so immersed I missed some important pop ups such as when the characters leveled up" (Participant 20, November 2011).

> "3D was definitely better. The feel of depth made a huge difference. If I had a 3D TV I would invest in 3D games" (Participant 18, November 2011).

> "Both sessions were fun, however it was much harder for me to play the 3D one of the two because my eyes were not able to focus clearly.

As a result many of the things that were supposed to be appearing to pop out of the screen ended up appearing as two images. This also caused me to get a headache. While playing the 2D version, I felt more immersed into the experience but that may be simply because I wasn't so focused on trying to see the game properly". (Participant 1, November 2011).

3.4 Discussion

The results from this study indicate that players do not feel an increased sense of engagement in stereoscopic 3D compared to a traditional monoscopic viewing. These results are contradictory to previous work. Rajae-Joordens [107] and Schild et al. [112] found stereoscopic 3D to increase the level of engagement within a video game. Rajae-Joordens asked participants to play Quake III Arena a First-Person Shooter under the same two conditions as this study, and found stereoscopic 3D to increase positive emotions and create a stronger feeling of presence. Schild et al. [112] selected three different games for participants to play including James Cameron's Avatar: The Game, Blur, and Trine. Both James Cameron's Avatar: The Game(adventure game) and Blur(racing game) offer a lot of depth animation, participants reported a higher impact on immersion than games with little to no depth animation like Trine. This is consistent with our results. A first person shooter is a drastically different genre than Trine which was initially chosen since interactions along the xy plane were limited, along with animations going in and out of the screen. This was chosen to isolate the S3D effect, and investigate the affects on a simple 3D scene. It appears that genre, amount of depth animation, and interaction into and out of the screen could all have a significant impact on the effect S3D has on player engagement; further investigation is needed. It was our hypothesis going forward, that a game with animations along the depth axis and interactions along the depth axis will result in a higher level of engagement when playing in stereoscopic 3D, then when not playing in stereoscopic 3D.

We found the Game Engagement Questionnaire to be a useful measure of engagement in video games (consistent results with the results of Schild et al. [112]) and one that is easily administered. It was also used in the Schild et al. [112] study, where it was used to show a significant difference in player engagement within the male population for both James Cameron's Avatar: The Game and Blur. Interestingly they reported no effect on female's GEQ scores between the two conditions. Further investigation into why this occurred is needed, as it is not clear whether stereoscopic 3D effects the female experience differently or whether the GEQ is not a suitable questionnaire for that demographic. Although differences in the female demographic were found in other metrics within the Schild et al study, like the MEC Spatial Presence Questionnaire [139], which found a higher level of presence in females while playing Trine in S3D.

3.4.1 Free-Form Comments

The free form comments indicate a preference for stereoscopic 3D with the majority of participants finding it better. Many (16 out of 20) found it to be compelling, fun, engaging and more interesting. While our GEQ scores do not indicate this, a preference for stereoscopic 3D has been report in other studies such as Litwiller and LaViola Jr. [81]. One explanation could be the novelty factor, with seven of the participants having never experienced a stereoscopic 3D game and with no participants owning a 3D capable display. Although no literature exists to support this hypothesis.

Almost half of the participants(8 out of 20), commented on the stereoscopic 3D settings being uncomfortable. This study fixed the stereoscopic 3D settings for each user to maintain consistency throughout the study. An uncomfortable experience could definitely contribute to lower engagement scores, as developing a playable and comfortable experience is a prerequisite to measuring engagement [93]. There is plenty of literature including the work of Schild et al. [113], on the varying perceptions of stereoscopic 3D and the need for individual stereoscopic 3D settings. It was also hypothesized that the menu provide by Tridef drivers would be too complicated for beginner, and novice users of stereoscopic 3D. Further investigation is needed to find a suitable solution to this problem. Going forward with future studies attention must be payed to choose suitable settings for all users, even if it means decreasing the amount of depth within a scene.

3.5 Summary for Developers

Developers should be aware that simply adding stereoscopic 3D support to their game, may not improve player experience. Prior literature does indicate that stereoscopic 3D can increase engagement in certain games that may possess certain qualities. Players did indicate a preference for stereoscopic 3D. Developers must assess whether the player experience of their game would benefit from the inclusion of stereoscopic 3D. Further research is needed to help developers determine when stereoscopic 3D should be included in their game.

Chapter 4

S3D Depth-Axis Interaction for Video Games: Performance and Engagement

In chapter 3, we investigated a game with minimal motion and zero interaction along the depth axis to better isolate the affect stereoscopic 3D has on engagement. While this study did not show significant differences between the effect of S3D and non-S3D on engagement, Schild et al. [112] did provide evidence that stereoscopic 3D does increase levels of engagement within certain genres. Their study hypothesized this may be caused by more animation along the depth axis, which was found to be common across the genres where they found S3D increased engagement. Further investigation is needed regarding whether the S3D effect on engagement increases or deceases when motion or animation into depth increases. This information is important to determine when a game experience may benefit from stereoscopic 3D. While these experiments specifically looked at how stereoscopic 3D could benefit existing games, more research is needed to investigate how stereoscopic 3D can affect the design of the game. Traditionally, developers have viewed S3D as a mode that can be disabled throughout the design process and rarely developed designs with mechanics that take advantage of the stereoscopic 3D medium. Video games, unlike films, are interactive in nature and understanding how the interactivity affects the player experience is an important piece of information that designers need to know when developing a stereoscopic 3D game. Many ideas about developing a game specifically for stereoscopic 3D viewing are presented in Schild and Masuch [113], but very little work to justify or explore these concepts has been done. One such proposed method was the inclusion of a depth ordinated task as a mechanic of a stereoscopic 3D game. Schild et al. [112] suggest that increasing the amount of animation along the depth axis may increase engagement, but their results may also suggest that engagement may increase when interactions make use of the depth axis.

It is important to explore the ideas presented in Schild and Masuch [113], to investigate the affordances offered when viewing a game in stereoscopic 3D. Studying existing games with stereoscopic 3D drivers only allows us to investigate the effect S3D has on the visual component of a game. Video games require interactivity. Only studying existing games with stereoscopic 3D drivers prevents us from studying the effect S3D has on interactivity. An understanding of the effect S3D has on both the visual and interactive component of a game is needed before the effect stereoscopic 3D has on player experience is determined. Exploring the design of stereoscopic 3D games will help control the conditions being studied, to help determine conditions where stereoscopic 3D increases engagement in a game.

The preliminary study presented in this chapter describes Z-Fighter, a game specifically designed for stereoscopic 3D viewing with its core game mechanics (interaction mechanisms) customized around the nature of the display. Video games are an interactive medium and it is therefore possible that not only the visual component but the interactions with the content effect the engagement of the user. This chapter explores how the nature of stereoscopic displays and the affordances presented by it may present new user experiences. It outlines an experiment conducted to investigate the performance, perception, and enjoyment of Z-Fighter in stereoscopic 3D vs. traditional 2D viewing.

4.0.1 Game Mechanics for S3D

A game mechanic is an "action invoked by an agent to interact with the game world" [119]. In essence, a game mechanic is an action that the player can choose to take that interacts with the game system, which in turn interacts with other game systems. Game mechanics allow the player to access the game system [71]. The repeated actions of both the player and the system causes gameplay to emerge. Common examples of game mechanics include running, jumping, flying, shooting, climbing, and placing tiles (see Figure 4.1 for example) . The mechanics can be defined as either a binary state (which can be mapped to a joystick button) or an analog axis (which can be mapped to the variable position of the analog joystick normalized to be within the range [-1,1]). Joysticks usually consist of two axes: an x and y-axis. Most video games contain a movement mechanic that allows the player

Figure 4.1: Screenshot of Super Mario Bros., depicting a run (x-axis) and jump mechanic(y-axis). Copyright Nintendo. [90]

to control a character or object movement within the game world. Early games were usually two-dimensional (2D) sprite-based games that limited movement to the x-y screen plane or axis. An example of this is the classic Super Mario Bros, the mechanics allow the player to control Mario's left-right movement (x-axis) and a jumping mechanic allows the player to control the up-down movement(x-axis) by jumping and falling. Another extremely common genre with simple mechanics along the x-y axis are top-down shooters such as Xevious or 1942. Mechanics allow the player to move the ship forward-backward along the y-axis and side-to-side along the x-axis to avoid and dodge enemies. Older 2D games used to simulate depth through the use of parallax with multi-layered sprite backgrounds. Creating multiple layers (all moving at different rates) enabled designers to simulate different depths with objects appearing further away moving slower then objects appearing closer to the foreground. Players were rarely able to move and interact with the other layers, often being locked to a single depth.

Most games are designed specifically for 2D displays, with interactions primarily along the x-y axis. Due to the display drivers that automate the stereoscopic 3D rendering, games like Trine and Limbo can be displayed in stereoscopic 3D,

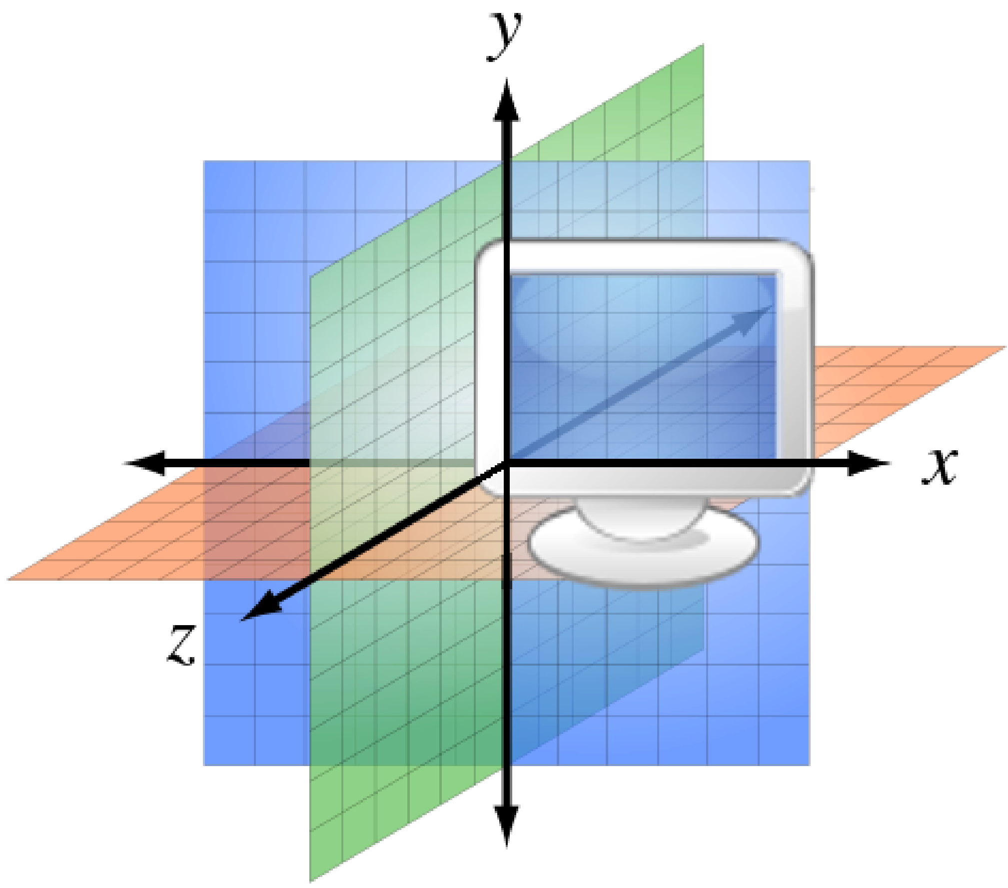

Figure 4.2: Diagram of the xy screen plane, with the depth axis (z-axis) extruding out of the screen. [5]

but the interactions remain unchanged. They are still a 2D platformer where the player controls the character's movement along the x-axis (left-right movement) and its jumping/falling along the y-axis. Stereoscopic displays provide additional depth cues to a viewer helping them perceive object locations in depth. In this chapter we explore those affordances, by adhering to stereoscopic 3D game design guidelines in Schild et al. [113] to create a game(Z-Fighter) with mechanics similar to YouDash3D's described in Schild et al. [114], which are specifically designed around interacting with the depth axis (see Figure 4.2).

4.1 Z-Fighter: The S3D Game

To effectively study depth axis interaction in S3D, a game called Z-Fighter was developed specifically for this study. It is a simple top-down space shooter game

Figure 4.3: Screenshots (from left to right) of Xevious, 1943, and Z-fighter.

(see Figure 4.4), similar to classic arcade games such as Xevious or 1943 (see Figure 4.3). Players are responsible for flying a ship along the x-y screen plane, avoiding and attacking enemies as they advance throughout the level. This genre was adopted to investigate designing a game specifically for S3D displays, because interactions are clearly defined along the x-y axis, with no interaction along the depth axis. Since no interactions were present along the depth axis, additional mechanics along the depth axis was easy to implement. Therefore Z-fighter was developed to not only allow players to move forward-back, and side-to-side but to also fly at different elevations above a blocky terrain. This additional movement in the depth axis, allows for novel gameplay and problem solving. For example, players can now dodge enemies by moving in and out of the screen plane. They also have the ability to move above and below obstacles which might be in their way. The objective of Z-fighter is to navigate a spacecraft that is constantly moving forward to the end of a level by avoiding blocks and enemies. Rather than designing a 2D game and then enabling S3D viewing as an after thought, we took the opposite approach to design and designed this game specifically for S3D viewing and then enabled 2D viewing.

4.1.1 Gameplay and Controls

Z-fighter uses an Xbox 360 controller for the player to interface with the game. The analog sticks are used to control the x-y axis, while the shoulder buttons and analog triggers are used to control the elevation (depth axis) of both the the ship and targeting system (see Figure 4.5). As the ship moves up along the y-axis, the world scrolls faster. The world is made up of a series of colored blocks positioned at different depths(five layers), and are arranged in a visual style similar to Tetris. If the ship collides with a block it causes the ship to be destroyed. The player must avoid the blocks and successfully navigate to the end of the level. The challenge is created by enabling the user to move between different elevations, moving along

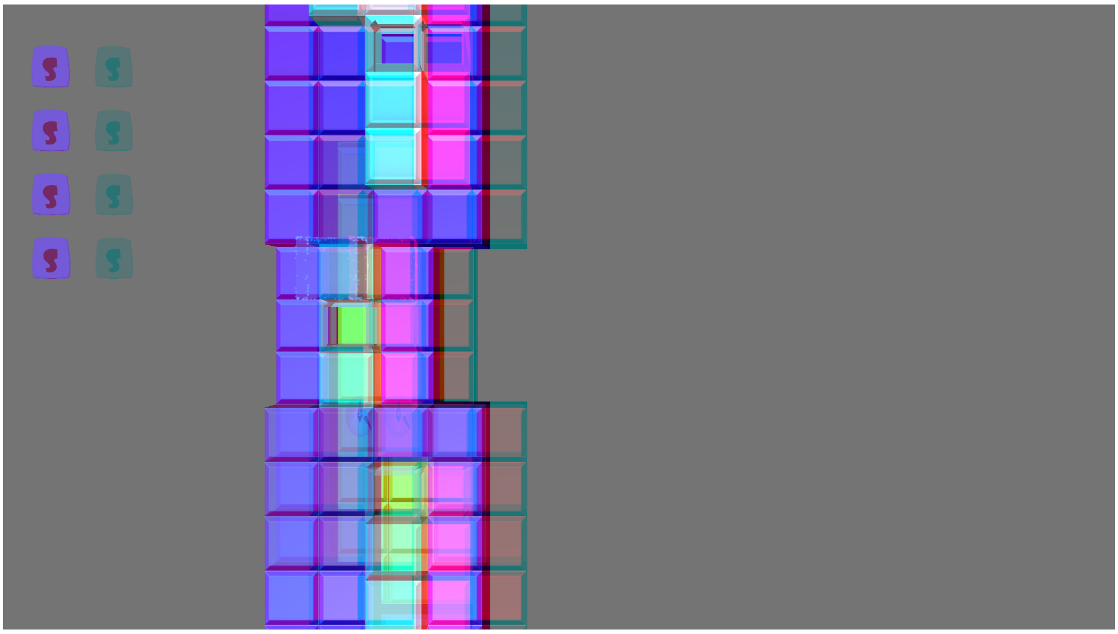

Figure 4.4: An anaglyph screenshot of Z-fighter. Screen shot from the second level where vertical navigation is introduced.

Figure 4.5: Diagram of the control mappings used for Z-fighter.

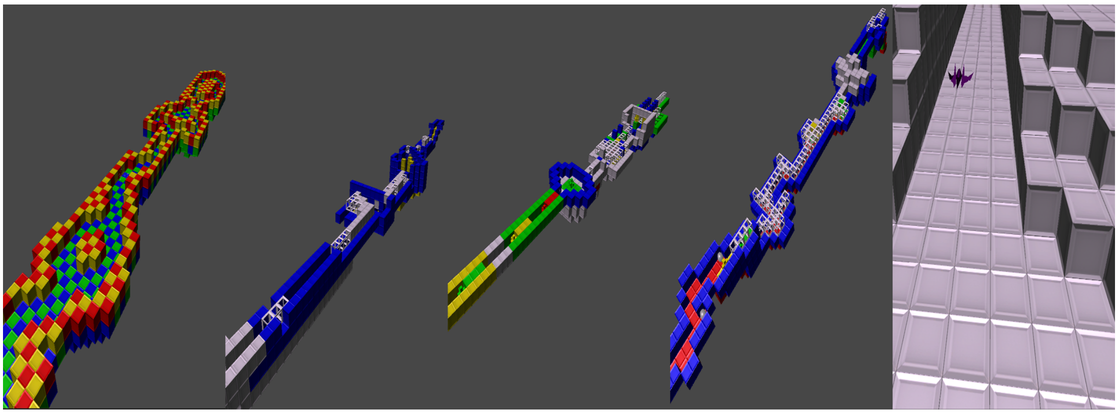

Figure 4.6: Images of the five levels in Z-fighter. From left to right, basic navigation, vertical navigation, basic targeting, combination (navigation + targeting), and the Boss level.

the depth axis using the shoulder buttons and analog triggers on the controller. This allows the player to fly higher (out of the screen) or lower (into the screen) to avoid blocks. A second mechanic allows the players to target blocks with a homing missile, which will go to the target position. The target is also able to move along the x-y and depth axes, and can be positioned by the player at different positions in front of the ship.

To teach the game slowly to players, a specific progression of levels was developed that would help them adjust to the new mechanics.

- **Level 1:** Basic Navigation. Players must navigate through the level and reach the end using only the x-y axis to navigate their craft. This allows players to learn the basic flying controls.
- **Level 2:** Vertical Navigation. Players must navigate through the level successfully using movement along both the x-y and depth axis. This introduces the players to the depth axis, allowing them to change elevations.
- **Level 3:** Basic Targeting. Players must shoot specially marked blocks(called detonators) to advance through the level. These blocks must be targeted at different depths and increase in difficulty. There is minimal movement along the x-y-depth axes, and any movement that is required is simpler than obstacles seen in previous levels. Targeting is the main interaction mechanism in this level.
- **Level 4:** Combination (Navigation + Targeting). Players must navigate along the x-y-depth axes and target in the x-y-depth axes to complete the level successfully.

- **Level 5:** Boss Combat. Players must defeat a "boss" who is also moving along x-y-depth axes. To defeat the boss, players must avoid the boss' missiles (movement) and target the boss at the appropriate location.

4.2 Study Design

To understand the effectiveness of this game mechanic, a user study was designed to investigate whether S3D viewing out-performs traditional 2D viewing, when the primary interaction is along the depth axis. The study evaluated quantitative performance characteristics and qualitative measures to determine comfort, enjoyment, and engagement. Participants were required to play under two conditions, with and without stereoscopic 3D. The conditions were counterbalanced with two groups, each starting under different conditions. The game recorded participant performance by logging i) the time taken to complete the game, ii) number of deaths, and iii)targeting accuracy. A comparison of S3D and non-S3D conditions using these statistics provides an indication of participants performance under the two conditions. Although, the game was designed specifically for S3D, it is playable under both conditions. Participants were also required to complete the Game Engagement Questionnaire (GEQ) after each play session to gauge engagement.

Participants were first given a Stereo Randot Test [1] to determine their ability to see stereoscopic 3D. If participants passed, they were seated in the Games and User Research Lab at the University of Ontario Institute of Technology(UOIT), a dedicated space to study user experience in games. Both noise and light were kept to a minimum and the same for all participants. Participants were randomly assigned to one of two groups, A or B, to determine which starting condition(with or without S3D). Participants wore polarized stereoscopic 3D glasses under both conditions, but were informed they could remove them while not playing. Next, participants were instructed to fill out a demographics questionnaire that asked questions related to general information, experience playing video games, and experience with stereoscopic 3D (see Appendix B). They were then instructed on how to play the game, and told to play for 30 minutes or until they gave up or finished. After they finished playing, participants were asked to complete the GEQ survey, before playing the game under the other condition. After completing the second condition, participants filled out the GEQ again and were encouraged to fill out freeform comments to describe their preferences.

4.2.1 Participants

A total of 15 male participants were selected from the University of Ontario Institute of Technology's (UOIT) Game Development and Entrepreneurship undergraduate program (10 participants) and the Masters of Computer Science program (5 participants). The majority (66.7%) were between the ages of 18–23, with four between the ages of 24-26, and one over the age of 35. The participants were well practiced with video games (73.3% played more than 5 hours a week). All participants had been to a stereoscopic 3D movie, with 60.0% having previously played a game in stereoscopic 3D. Prescription eye glasses were worn by three of the 15 participants at the time of the study. The demographics questionnaire also asked a series of questions to understand participants' general feelings toward S3D prior to the beginning of the experiment. Only 20.0% found stereoscopic 3D less enjoyable compared to 53.3% who found it more enjoyable than without. Similarly, 40.9% of the participants found S3D movies to be more enjoyable, while 20.0% found movies less enjoyable in S3D. Participants were also asked about which component of traditional 2D games are most important to them, with the majority selecting interactivity. This was followed by single-player gameplay, quality of audio, story, realistic graphics, multi-player and then Surround sound which was rated the least important component of participants gaming experience. Similarly when participants were asked which components of stereoscopic 3D games are most important, they rated seeing deeply into the screen and having objects come out-of-the-screen as most important.

4.2.2 Setup

A polarized 1080p Zalman ZM-M240 24" stereoscopic 3D monitor with 5 ms response time was used to display the game; participants were seated 30-60 cm in front of the monitor. The Zalman monitors have a sweet spot located 90 degrees on the horizontal and 12 degrees on the vertical. Participants were instructed to sit directly in front of there monitor and told to adjust their seat or tilt the monitor until they were able to fuse the image properly (no longer see two images). Passive polarized glasses were given at the start of the experiment; participants were instructed to wear the glasses during the game at all times (both conditions). They were allowed to remove the glasses when filling out questionnaires. The lights in the room were turned off to reduce glare on the monitors. An Xbox 360 controller was used to interact with the game (the control mappings can be found in Figure 4.5). A standard Dell XPS 720 computer with ATI Radeon 6870 video card was used to run the game. The game was developed in Unity 3D Pro v3.0 and used the Stereoskopix 3D plugin (now called FOV2GO) to render the game in stereoscopic 3D. The game used fixed stereoscopic settings across participants to keep consistency: The field of view was set at 24 degrees, with an interaxial distance of 100 units, and a zero parallax plane a 1275 units away, with our furthest object being 1500 units away from the virtual camera.

4.2.3 Hypothesis

It was predicted that when presented with a game where the mechanics have been designed specifically for interacting with the depth axis, participants will perform better and be more engaged when playing with S3D then without it. More specifically participants will complete the game using stereoscopic 3D faster, with fewer deaths, and higher targeting accuracy then when playing without. This is in contrast to the results of LaViola et al [81], who found no significant performance benefits in commercial video games when viewing with S3D. Similarly we expect higher GEQ scores playing in stereoscopic 3D then without, indicating a higher level of engagement with the S3D version. It is expected that free-form comments will also indicate a higher level of enjoyment.

4.3 Results

As previously mentioned, the game measured the performance of the participant as they played by recording attributes such as time of completion, number of deaths, and accuracy. Prior to running the study, it was our belief that these metrics would provide a good indication of player performance. However due to the difficulty of the game, many participants were unable to complete the game within the allotted time(35 minutes). This affected the results of both accuracy and completion time. A few participants were unable to advance far enough on their first play through to make it to the Basic Targeting Level, where shooting is introduced.

A paired-samples t-test [48] was conducted to compare the average completion times when playing with stereoscopic 3D than playing without stereoscopic 3D. There was no significant difference in the average completion times for stereoscopic 3D and without stereoscopic 3D; $t(15) = 1.473$, $p = 0.163$ (See Figure 4.7). The t-value is the size of the difference between the means of two sample (S3D and non-S3D). The p-value is the probability of getting that t-value if the null hypothesis (no difference between S3D and non-S3D) is true. In this case, the null hypothesis

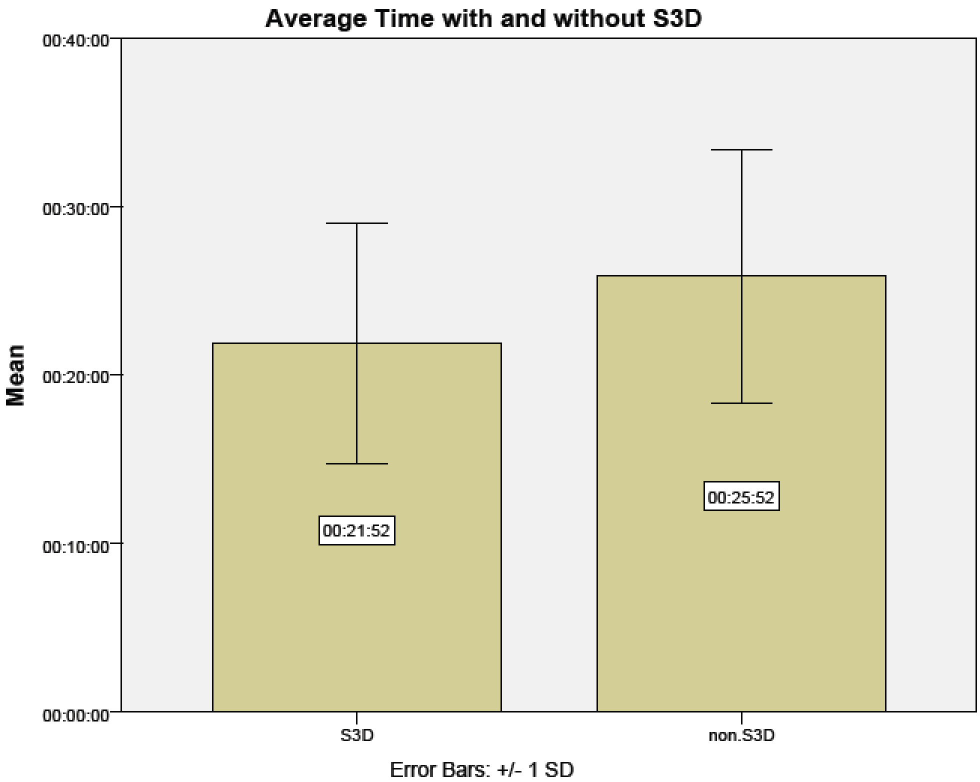

Figure 4.7: The average play time, along with standard deviation bars, when playing with S3D and without S3D.

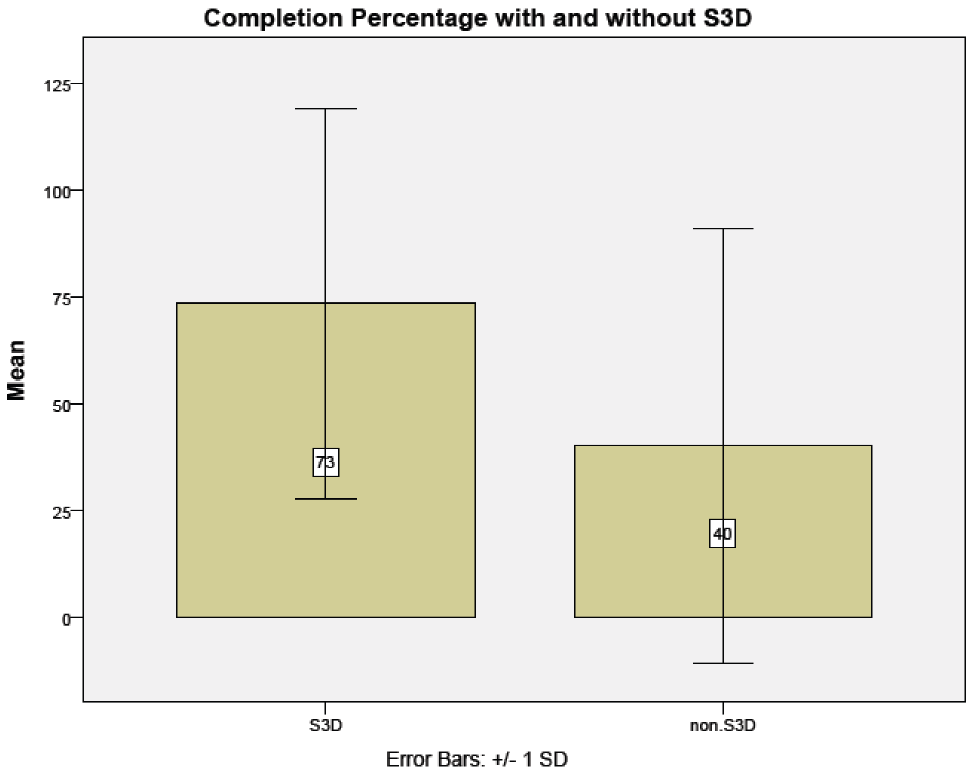

Figure 4.8: Completion percentage, along with standard deviation bars, for participants playing with S3D and without S3D.

is not rejected because of p-value is greater than 0.05. These results suggests that stereoscopic 3D does not affect player's average completion times for Z-fighter. This could be attributed to the artificial restriction placed on time. For instance, it was possible for a player to fail on their first attempt and then complete the game on their second attempt, just before the 35 minute mark and have relatively the same competition time.

Instead we chose a simple comparison of completion percentages between S3D and non-S3D. This was primarily chosen due to the large number of participants that were unable to finish the game. Participants playing under the S3D condition had a higher completion percentage (M=0.733, SD= 0.458) compared to without (M=0.333, SD= 0.507), t(15) = 3.06, p = 0.009 (See Figure 4.8). These results suggest participants were more likely to complete the game and therefore must have performed better with S3D than without.

It was hypothesized that participants would have fewer deaths when playing under the S3D condition. A paired samples t-test indicated a significant difference between the number of deaths with and without S3D, with S3D having an average of 59.4 deaths per session, while non-S3D had 94.5 deaths per session (t(15) =

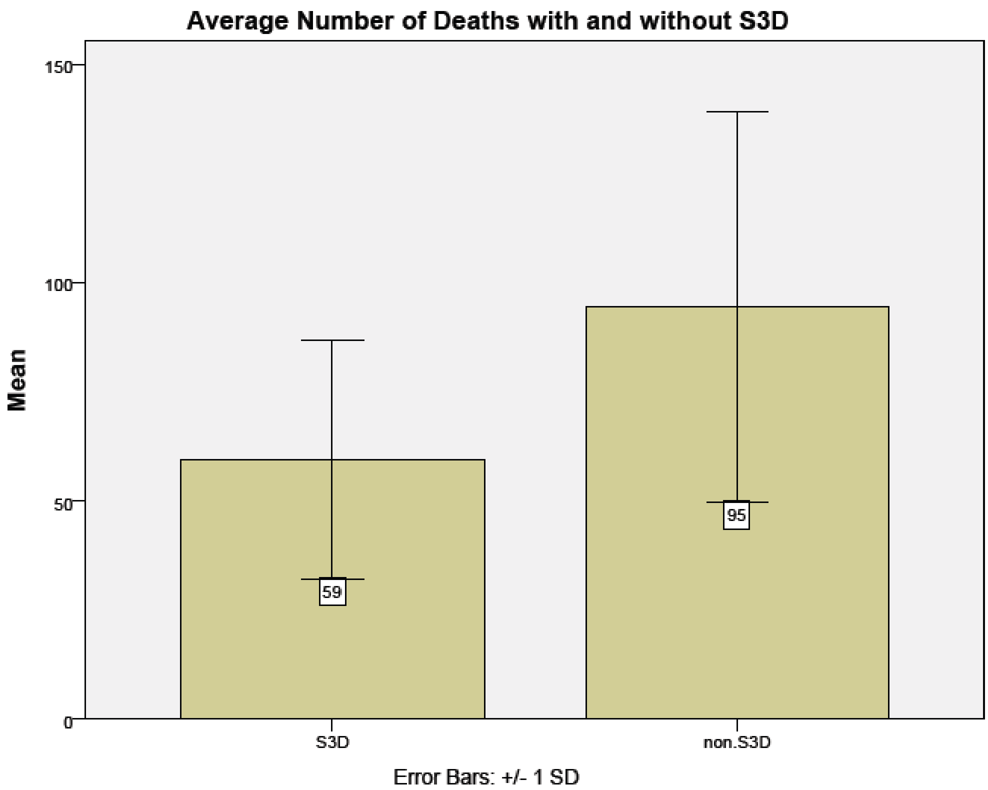

Figure 4.9: Average number of deaths, along with standard deviation bars, for participants playing with S3D and without S3D.

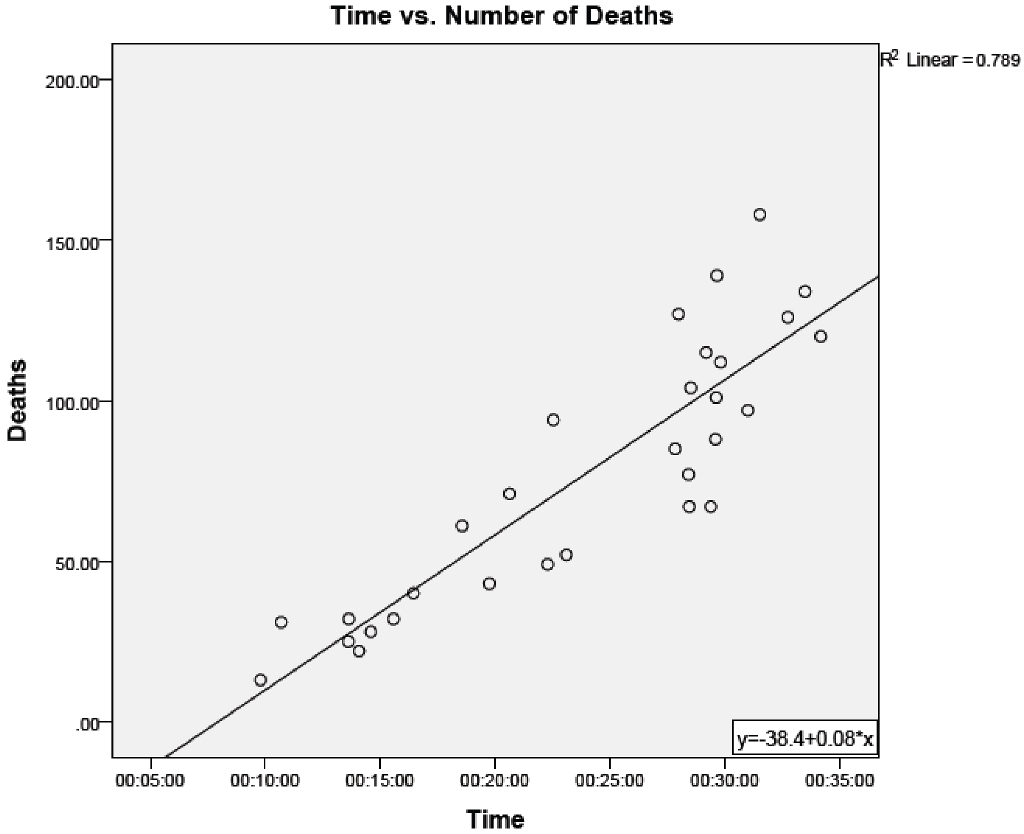

Figure 4.10: Average number of deaths per time spent playing.

2.569, p = 0.022). This demonstrates players died less with S3D than without, indicating a performance increase when S3D viewing is enabled.

Our initial assumption implied that completion time would be dependent on the number of deaths. We performed a regression (see Figure 4.10) between completion time and the number of deaths, and found an adjusted R^2 value of 0.7813, indicating correlation between the two variables. A correlation coefficient between average completion time and number of deaths was calculated to be 0.89. This suggests that completion time is partially determined by the number of deaths a participant undergoes. Completion time could also be affected by accuracy and location of the death. The location of the death might affect completion time, because a death far away from a checkpoint requires more time for the player to comeback to, than if the death occurred close to the checkpoint. Unfortunately, no data about the death location was recorded.

A quick examination of the completion percentages between S3D and non-S3D throughout the different levels as shown in Figure 4.11, suggest participants began

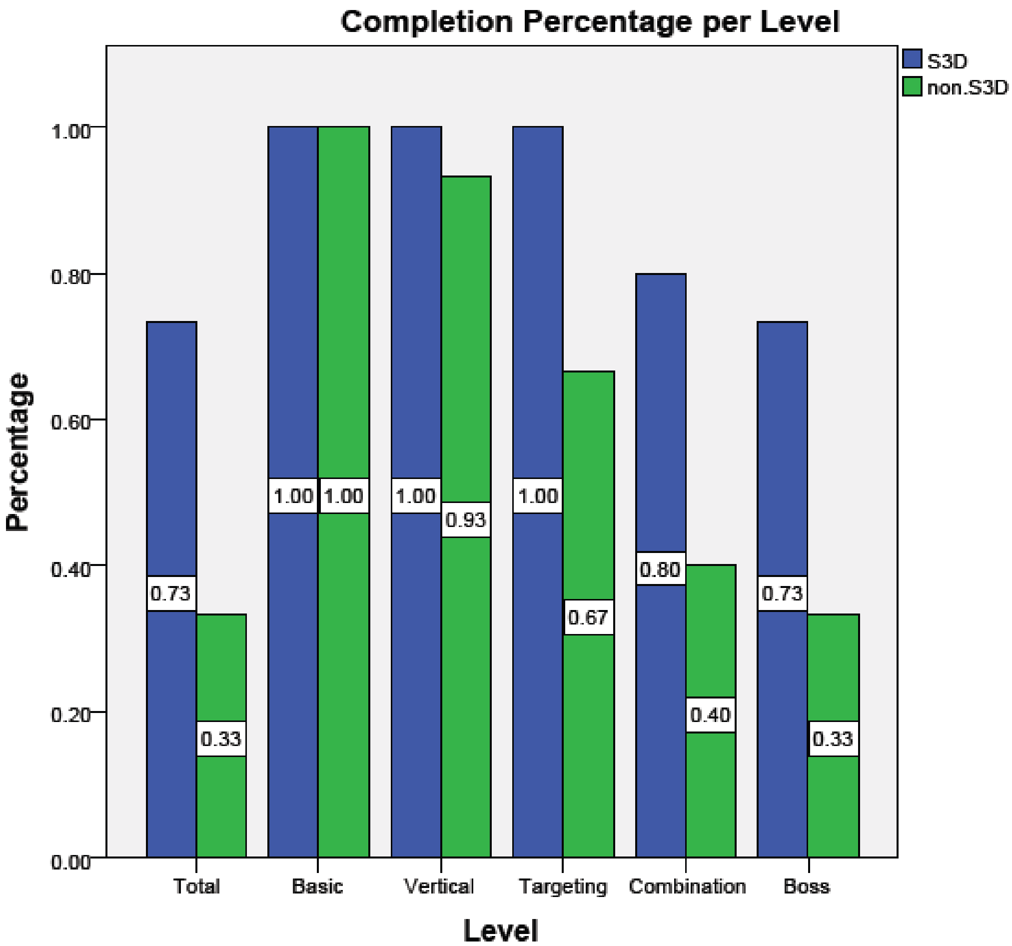

Figure 4.11: Completion percentage per level. 1.00 percentage is 100%.

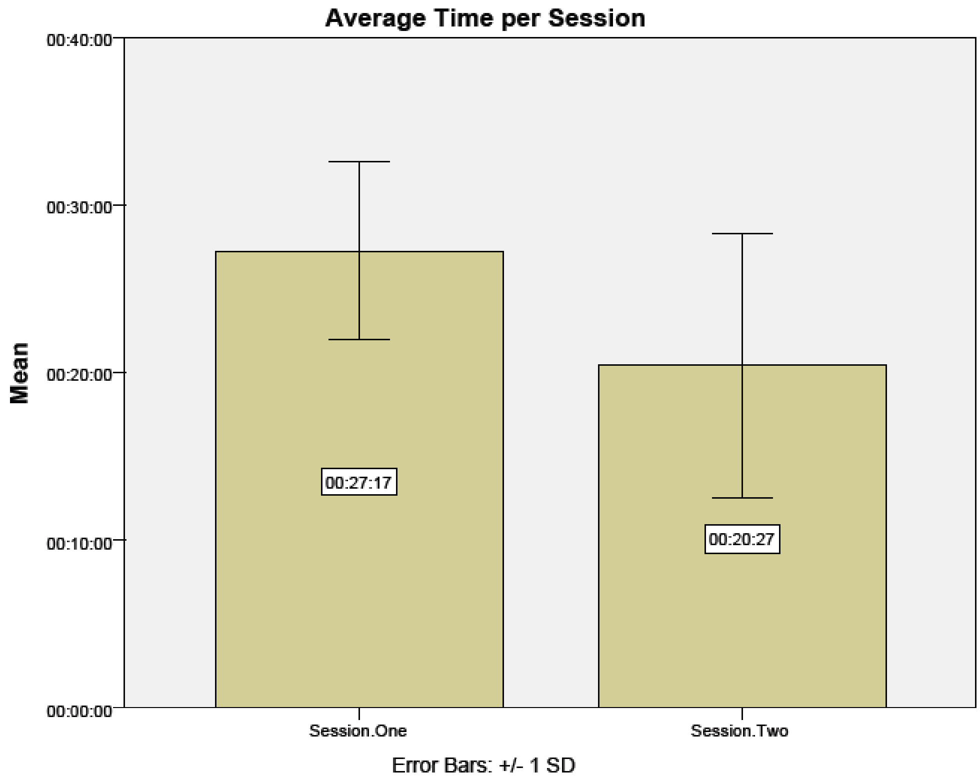

Figure 4.12: Average time for each session, along with standard deviation bars.

having trouble without S3D as soon as the depth mechanic was introduced. All of the participants were able to complete the basic navigation level, while almost all also completed the vertical navigation level, with the except of one participant. A paired samples t-test of completion times for the basic navigation level revealed no significant difference between participants playing in S3D and without S3D; t(15)=1.06, p=0.153. However participants playing the vertical navigation level in S3D had an average time of 4 minutes and 41 seconds, while those playing without S3D had an average time of 10 minutes. A paired samples t-test of completion times for vertical navigation level suggests a significant difference between S3D and non-S3D; t(15)=2.455, p=0.028. This suggest S3D does have an advantage when a mechanic along the depth axis is introduced.

A paired-samples t-test indicated a significant difference between average completion times of participants' first (M=27:18, SD=5:20) and second (M=20:27, SD=7:54) session; t(15)=3.006, p=0.009 (see Figure 4.12). This suggest a significant learning effect was present, players time improved on their second play through. This may be attributed to the nature of the gameplay, and more specifically, there are several navigational and targeting puzzles throughout the levels which may become easier if solved previously. Additionally a paired-samples t-test indicated a significant difference between the average number of deaths of participants' first (M=96.13, SD=37.63) and second (M=57.86, SD=35.11) session; t(15)=2.94, p=0.011. This supports the suggestion that learning took place between the first and second session. However, no significant difference between completion percentages of participants' first and second sessions was found.

4.3.1 GEQ and Free-Form Comments

Participants were required to complete the Game Engagement Questionnaire after each session to measure their engagement. They were also encouraged to provide free-form comments at the end of the survey about their general preferences. 11 out of the 15 participants reported in their comments that S3D was more fun and enjoyable then when playing without it.

> "The 2nd time [S3D] was more fun"(Participant 1, September 2012).

One remained neutral and indicated the S3D setting may have been a bit too strong for him saying:

> "Both equally fun. 3D is a bit harder to concentrate on. It seems that only if you really focus on the screen that it is 3D. Vertical height is quite tricky to determine."(Participant 9, September 2012)

One other player also indicated problems with the S3D settings:

> "The 3D was easier to get through but kind of strained my eyes a little."(Participant 2, September 2012)

Only three participants indicated they preferred playing without S3D. All three preferred non-S3D during their second session, after already playing in S3D. One even indicated that S3D helped them in their second session:

> "The second session was more fun [non-S3D], since I had picked up the nuances of the game in the first session [S3D]. During the first session

> I had to become familiar with the up-and-down movement of the ship, and how the environment changes to match my elevation (i.e. blocks becoming transparent if I am under them)."(Participant 3, September 2012)

Several participants found the game to be difficult in general.

> "3D was much more fun. Needs to be easier to tell when level of elevation you are at."(Participant 3, September 2012)

> "2D mode was evil, yet I had a pressure to keep playing because I was hoping that I could nab the title of "made furthest progression of all testers". I almost completed it, but was so close to facing the boss. Either way, evil evil evil. 3D Mode was more fair, however one frustrating thing that still didn't change from the 2D version, was the altitude that the ship was at. The 3D mode gave me a better visual for which altitude I was at, but not entirely accurately. This is why I still slammed into floors and ceilings whenever I had to adjust my altitude. Besides that, I enjoyed the game's challenge, and I conquered the 3D version. Because of that, I feel accomplished and proud of myself, and now I should probably get on my homework... :/"(Participant 10, September 2012)

While a few participants had issues with controls.

> "3D was over 9000 times better than 2D. One part I would always respawn right beside a wall and would have to quickly move away. I immediately forgot that pushing R3 is bombs, I was stuck trying to use a button."(Participant 8, September 2012)

A paired samples t-test indicated that there were no significant differences between the GEQ scores of S3D and non-S3D; $t\ (15) = 0.238317292$, $p = 0.815$. This suggest players' engagement was not affected by which condition they played. Figure 4.13 shows the difference between GEQ Scores.

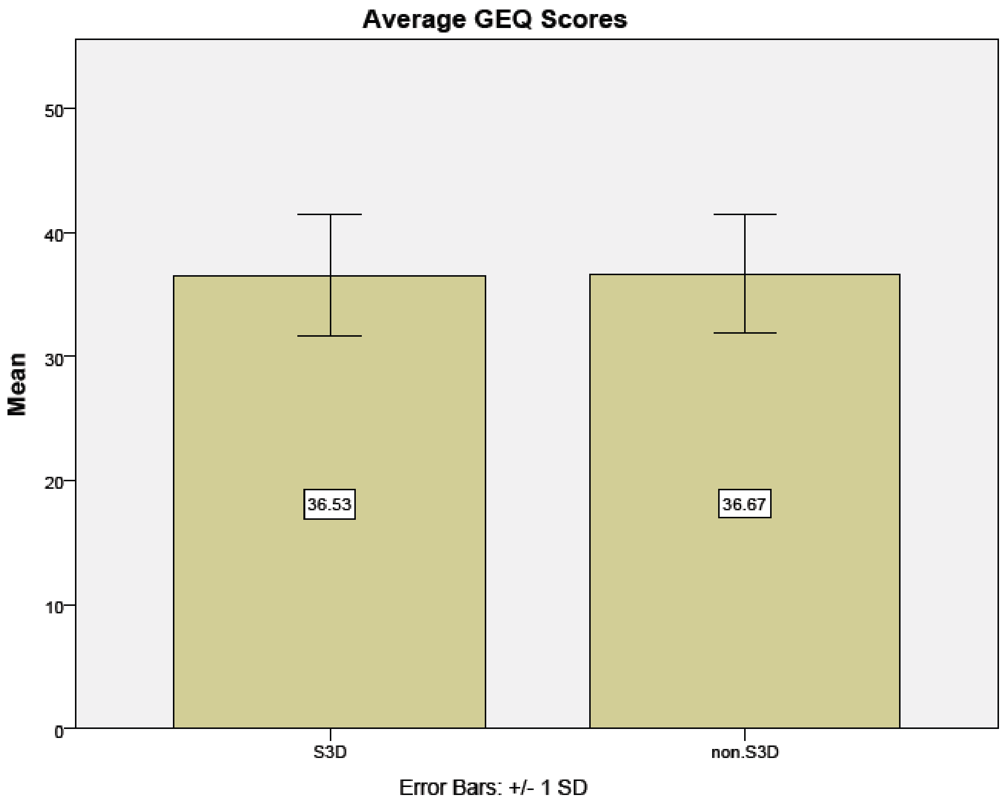

Figure 4.13: Game Engagement Scores, along with standard deviation bars, with and without S3D.

4.4 Discussion

This chapter presented Z-fighter, a game developed and designed to ensure users interacted with the depth axis. The game was designed for stereoscopic 3D viewing, but it does support a non-S3D viewing mode. A preliminary study was also presented, where participants played under both viewing conditions, to investigate performance, perception, and enjoyment with and without S3D. As expected, the results indicated participants have a significant advantage with S3D for this game, when interacting along the depth axis. These results were expected, as the game was developed primary for S3D viewing, creating conditions optimal for S3D experience. In contrast to LaViola et al [81], who found no significant performance benefits in commercial S3D games, this study found clear benefits when tasks were performed along the depth axis, demonstrating that increases in performance between S3D and non-S3D is task dependent. Developers should consider the task required when developing a game and whether the inclusion of stereoscopic 3D would help the player.

The results demonstrate that game designers can create enjoyable experiences specifically tailored to stereoscopic viewing, that will not be easily playable on non-S3D screens. It indicates that designers should be able to create experiences that are not possible without S3D. The results of this study indicate a designer can not simply design for S3D first and include a 2D "mode", as presented here. The difficulty of levels need to be revised for a non-S3D version, and the depth mechanic may need to be removed. This is easily seen when vertical navigation is introduced, as players immediately begin to have difficulty without S3D. This study indicates that the content needs to be specifically designed for S3D, and developers will have difficulty porting it to non-S3D displays. The results suggest that depth-axis mechanics are very difficult to adapt to non-S3D displays. Investigation into depth cues other than S3D which can similarly provide additional information about depth is needed. For now, designers must view an S3D game or mechanic as something separate. The performance increase for interactions along the depth axes, as observed in this study, should be something designers can take advantage of to create unique experiences. They must also be aware that these unique S3D experiences will be much more difficult than the intended design when viewed without S3D.

4.4.1 GEQ and Free-form comments

The results of the GEQ showed no significant difference between S3D and non-S3D. This goes against our initial hypothesis, where it was predicted GEQ scores would be higher under the S3D condition, suggesting participants would be more engaged with S3D then without. This hypothesis was based off the conclusions presented in Schild et al [112], who provided evidence that stereoscopic 3D does increase levels of engagement within certain genres. They hypothesized the results differed by genre due to different amounts of movement along the depth axis within different genres. Two variables that might explain the difference between our results and theirs are the limited amount of motion, and the inclusion of interaction. In Z-fighter, the motion along the depth axis was limited to the object the participant controlled (the spacecraft), while the games used in their study had many parts of the screen moving along the depth axis. A future study could be run to test this hypothesis by inverting the motion of spacecraft and blocks: locking the spacecraft to the zero parallax, while moving the blocks along the depth axis.

The lack of significance in the GEQ scores may be due to general difficulties with the game. The free-form comments indicated that the game may be too difficult in either configuration, which would make it difficult for players to become immersed and reach a state of flow in the game. As mentioned in Section 2.2.3, good playability is a prerequisite for evaluating game experience and there appears to still be flaws within the games design. Although several free-form comments do indicate players prefer stereoscopic 3D mode, they also indicated problems with both the game and settings.

While this study does show significant promise in creating new interactions and mechanics in stereoscopic 3D; it provides no indication of whether these new mechanics outweigh the negative aspects of stereoscopic 3D, such as player discomfort and increased development time. Other future work includes examining other depth cues (such as shadows and HUD) and player performance when dealing with interactions along the depth axis compared to S3D. Chapter 5 of this thesis explores and investigates this question in a follow up study.

Chapter 5

Depth Representation and Player Performance with Depth-Axis Interactivity

Chapter 4 presented a stereoscopic 3D game, that explored the affordances provided by S3D and utilized those affordances to develop mechanics. It was hypothesized with an additional depth cue present, player's would find it easier to estimate their depth within a scene. The results of the study indicate that S3D does provide a significant benefit to players when estimating their location in depth, and this benefit can be used to develop mechanics specifically designed around S3D. The game presented in Chapter 4 was specifically designed for S3D, and then played on a traditional monoscopic viewing with no additional changes made. However there are additional ways to represent depth within a monoscopic display that may help the viewer to better estimate their depth. The original version of Z-fighter presented in Chapter 4 had a limited amount of depth cues, such as perspective, and minor occlusions. There are other depth cues such as shadows, which can be included to help with depth estimation [86]. Additionally other techniques, such as multiple view points, that don't occur naturally in the human perception system can be used.

The chapter presents a follow-up study to investigate performance and engagement of a game requiring interactions along the depth axis when different types of depth cues are present. This study compares the use of different depth cues including stereoscopic 3D, shadows and heads up display(HUD) to traditional monoscopic viewing with no additional depth cues present. This chapter describes an updated version of Z-Fighter, which was modified based on feedback and lessons learned from the prior study. It includes four separate viewing modes; stereoscopic 3D, shadow, heads up display(HUD) and a monoscopic mode with no additional changes (referred to as none).

5.0.2 Other representations of Depth

As mentioned in Section 2.1, there are many different cues the human visual system can use to interpret depth. Beside stereopsis [138], a binocular cue and the one primary used in stereoscopic 3D, many monocular cues exists. Some are even common in games which are played on traditional 2D displays, like perspective, image size, interposition (occlusion), lighting and shading, and texture. In our previous study a few of these were present including perspective, image size, interposition (occlusion), and texture. The non-S3D condition did provide limited depth perception to the player due to these cues, but it wasn't accurate enough for interacting along the depth axis. Many developers implement shadows in their games, including most modern franchises, for either artistic purposes or to help the player determine the location of objects. Shadows were omitted from the original version as stereoscopic 3D was the only additional cue. Shadows have been shown to provide depth information, and they are especially useful for determining the relative distance between the object casting the shadow and the surface the shadow falls on [86]. A study by Tory et al. [133] investigated the effect of different display configurations on participant performance in position estimation, orientation, and volume of interest tasks. Several different display configurations were compared, including a 2D display (a thin slice of the world from a front-back, right-left, or top-bottom orthographic projection), a 3D display (orthographic or perspective projection that shows spatial structure), and combination of both a 2D/3D display. Their results indicated players using a 3D display with shadows enabled was significantly faster then other configurations, but had a large amount of errors. However the errors were relatively small, and indicated participants understood the position but misjudged the height. This configuration was added as a condition to Z-fighter, because it was hypothesized the game would require a fast understanding of the ships position, and didn't require complete accuracy.

Another configuration from the Tory et al study, is their 2D/3D combination display. In their study they presented two different 2D/ 3D displays, the results showed very few errors for either configuration. However in both configurations players were not very fast, and when errors did occur, the size of the errors were quite large. It was predicted these configurations would be beneficial at certain spots within the game, but not useful in others. Information in games is commonly displayed on a heads up display (HUD), which are usually transparent two dimensional images layered on top of the scene. The 2D/3D combination display can easily be applied to the game by rendering the scene normally (3D display), and then render an additional orthographic side view, which will be displayed on the HUD. HUDs have been shown to be distracting, as players are required to divide their attention between two sources of information [57]. For this reason and the results shown in Tory et al study, it is hypothesized participants will find the condition with HUD less engaging then other conditions, while participants will perform worst than both shadows or stereoscopic 3D.

5.1 Z-Fighter 2.0

A decision was made to modify the game to correct issues that participants indicated in the free-form section of the original study. Participants in the prior study indicated problems with controls, stereoscopic 3D settings, and a general difficulty in determining their location in depth. Experimenters also observed a learning effect, which may be attributed to the many targeting and navigation puzzles. Players spent time learning where to go during their first session, something experimenters would like to reduce. A design decision was made to reduce visual complexity of the scene; in the originally version players were asked to fly underneath blocks almost constantly, making it difficult for players to determine their ships location. The reason for these blocks, was to contain the ship inside a maze instead of allowing the ship to simply fly above all the obstacles. However, the blocks above the ship obscured the players view of the ship and other parts of the level. To reduce these obstructions, a system to modify the block transparency based on the elevation of the ship was developed. However players were still peering through a semi-transparent block. It was hypothesized that this, along with improper stereoscopic 3D settings, contributed to player's confusion when determining their depth. The original stereoscopic 3D settings, had the majority of the objects appearing in front of the z-parallax, meaning they were protruding out of the screen. This was easily fixed, by changing the settings to allow objects behind and in front of the screen plane. By allowing objects in front and behind the screen plane, the scene's depth budget increased providing an opportunity to reduce the interocular distance, while still gaining additional depth. Reducing the interocular distance created a more comfortable viewing condition, so players weren't as distracted by eye fatigue, seen in the original study. The controls and removal of transparent blocks were more difficult problems to fix, and required a modified design of the game.

5.1.1 New Gameplay, New Controls

An updated version of the game Z-Fighter, refereed to as Z-Fighter 2.0 was used for this study. It remained a simple top-down space shooter game, where the player is responsible for successfully navigating a ship to the end of a level by avoiding obstacles. The player still controls the ship along the x-y and depth axis, allowing them to fly at different elevations above blocky terrain. The ship is still constantly moving forward, and players can speed up or slow down movement by moving forward or background along the y axis. The homing missile and target blocks were also kept from the original game. Players can target specially marked blocks, and destroy them using a homing missile. When these blocks are destroyed they also destroy adjacent blocks of the same color. The target can still be moved along the x-y and depth axes. However the target no longer relative to the ship's movement; meaning it doesn't move forward as the ship moves forward. Instead the target stays at its position in world space, unless the target falls behind the ship. In that case the target is kept just in front of the ship, it should never be behind the ship. This change was made during the preliminary study and QA sessions, where participants found it odd or confusing compared to other games they play. Control mappings have also been slightly modified, see Figure 5.1 for an updated version. Players now fire a homing missile by pressing the A Button, where as before it was controlled by clicking in on the right analog stick.

Figure 5.1: Modified control scheme for Z-Fighter 2.0.

Additional tweaks were made to the behaviour of the ship's movement with both the forward-back, and side-to-side movement of the ship made faster. In the original version of the game, the location of the ship in depth slowly snapped to different elevation layers. The intention was to make motion along the depth axis easier, by allowing users to only focus on which layer they needed the ship to be on. Some participants, especially when starting in non-S3D, had difficulty determining whether the ship had changed levels; they also weren't sure if the button needed to be clicked or held. Therefore we removed the snapping system, and used a completely continuous, analog, player controlled motion for movement along the depth axis; similar to the motion along the x-y screen plane. Additional help navigating along the depth axis would be provided by new mechanics created to replace the transparent blocks.

A New Mechanic: A Simple Path, Not A Maze

Since the decision was made to no longer include blocks above the ship, at least for sustained periods of time, a new mechanic needed to be introduced to contain the ship within the maze. The problem with a maze is the requirement for players to solve or learn the proper route through a maze; they become easier the second time unless the maze is reconfigured. It was hypothesized that this problem directly related to the learning curve and general difficultly reported in the feedback of the first experiment. While a 3D maze successfully created the type of forward-back, up-down, side-top-side motion we wanted in our game, it also created other unwanted difficulties. Therefore a new design paradigm was developed that focused more on having players follow a path, rather then wander a maze. This chapter investigates the players ability to judge the depth of objects and move along the depth axis. Encouraging a player to follow a path instead of solving a maze should provide more relevant data, by focusing on the challenge of the game. It was hypothesized that this design decision would not only reduce visual complexity, but also reduce the learning curve by eliminating navigational and targeting puzzles. To implement this new challenge, a new mechanic was developed that required the ship to have energy to keep flying. The only way to get energy was to fly close to blocks of certain colors. If players deviated from the path for too long, the ship would lose energy and be destroyed, forcing them to restart the level. The default block color was grey, meaning players were required to follow the grey blocks. However later the ship was able to pick up power ups to change the color of path, allowing it to follow blocks of other colors. This is primarily used to vary the aesthetics, but it was later discovered that picking up floating power ups was a useful task to measure.

To reduce the difficulty in controlling the ship along the depth axis, and prevent problems of crashing into the floor and sides of blocks, blocks with the same color as the current path prevent collisions with the ship. The ship can not collide with the top or sides of blocks with the same color as the current path. The ship can still collide into the front of any block. Furthermore, the ship can still collide with the top, front and sides of blocks that are not the same color as the current path. A decision was made to reduce the number of these crashes, but still leave room within the level design where skilled descents are still required. The idea was to reduce frustration, but still be able to test participants performance at certain locations with a level. The level progression is designed as follows:

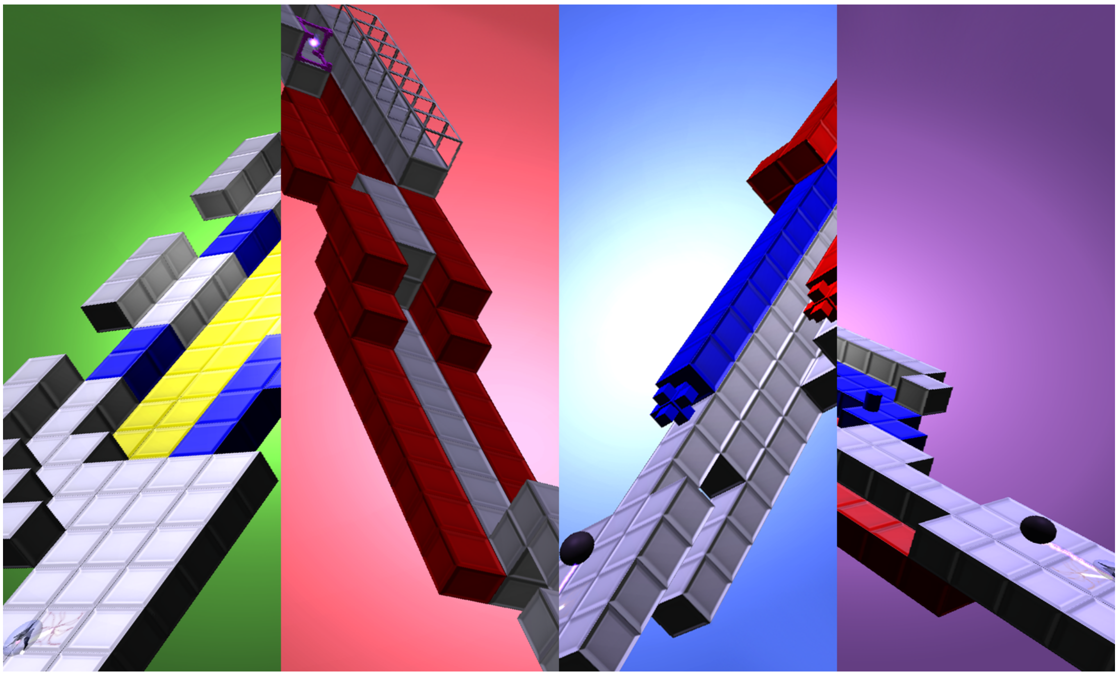

Figure 5.2: Image of the four basic training levels. From left to right: Basic Navigation, Vertical Navigation, Basic Targeting, and An Introduction to Path Following

- **Level 1:** Basic Navigation. Players must navigate through the level and reach the end using only the x-y axis to navigate their craft. It also introduces them to their ships energy system, demonstrating the need to stay close to grey blocks.
- **Level 2:** Vertical Navigation. Introduces players to navigation along the depth axis.
- **Level 3:** Basic Targeting. Players are introduced to specially marked blocks(called detonators). These blocks can be targeted at different depths. The player must quickly destroy two detonators to complete this level. There is minimal movement along the x-y-depth axes.
- **Level 4:** Introduction to Path Following. Players have already been introduce to the core concept of following a path in Basic Navigation. This level teaches players to change path colors by picking up certain power ups.

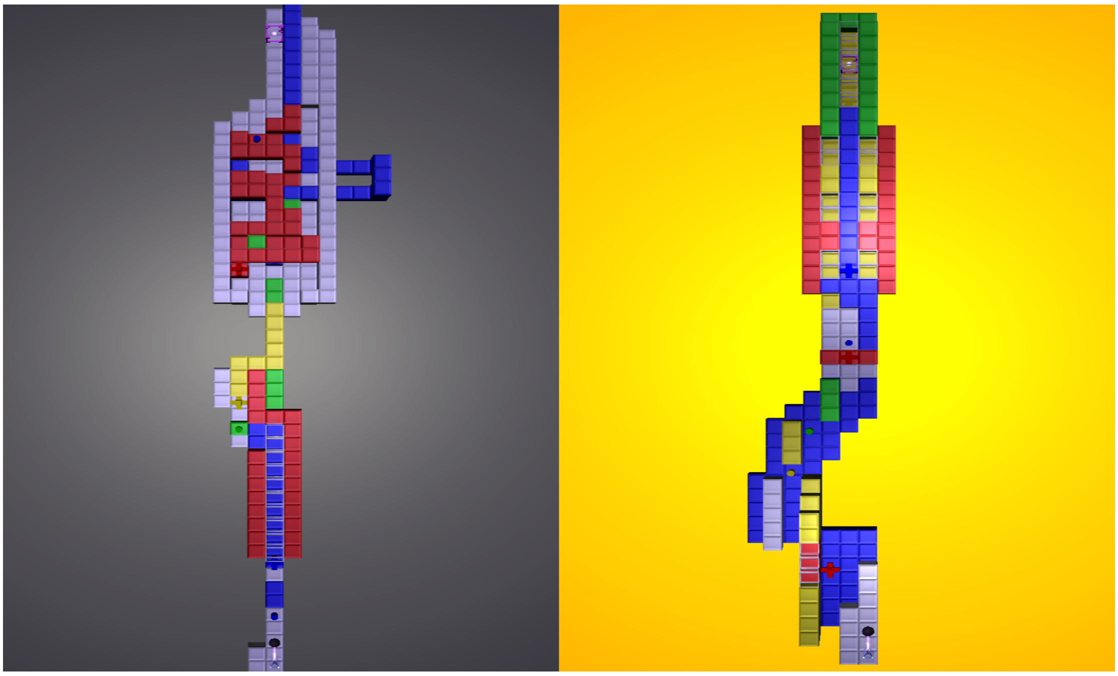

Figure 5.3: Image of the two additional levels created for Z-fighter 2.0

Two additional levels were developed to specifically test participants abilities to navigate along the x-y and depth axes. The two levels combined the lessons taught in the training phase, to create much more challenging levels. Along with the inclusion of an S3D and non-S3D viewing mode (now referred to as none), two additional viewing modes were developed. A non-S3D viewing mode with shadows turned on was created; it required a specific lighting set up to ensure objects only casts one shadow into the scene. The lighting system was used in all other viewing modes, but shadows were not enabled. The final viewing mode included a HUD, which displayed a side view of the blocks and objects directly in front of the ship. See Figure 5.4 for an example of the four viewing modes available in Z-fighter 2.0.

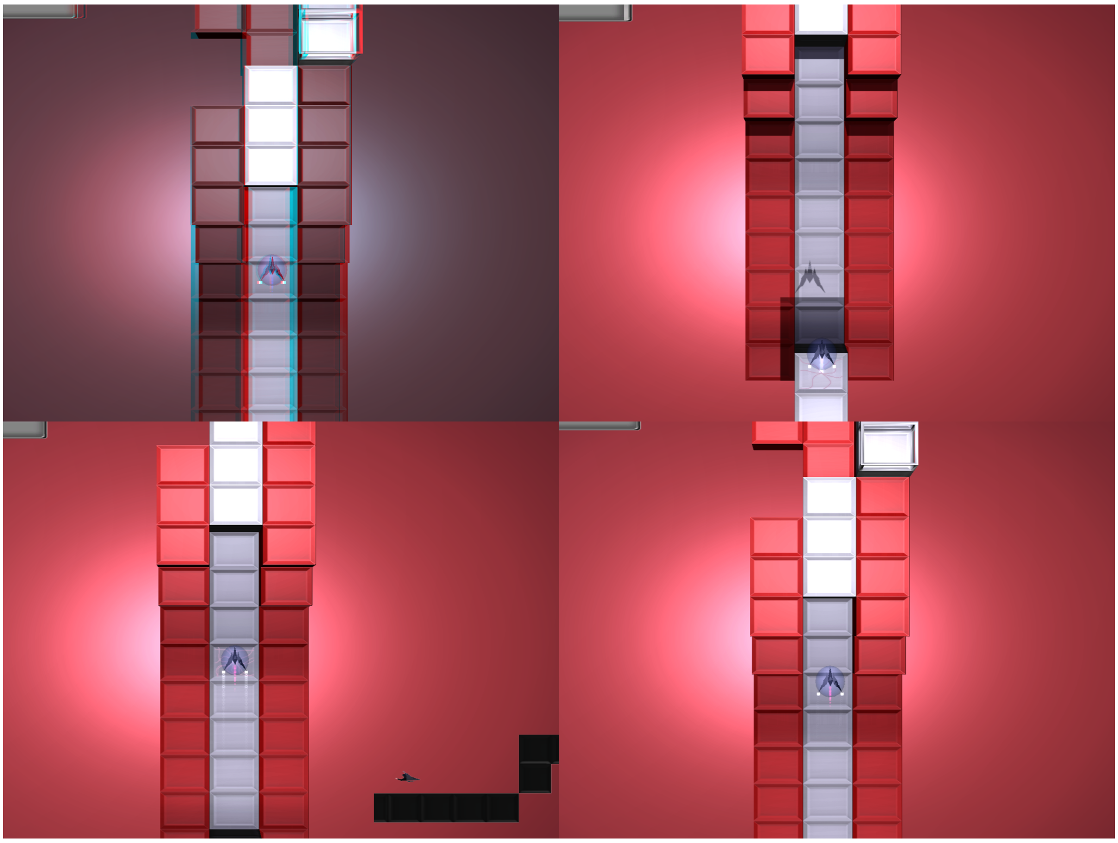

Figure 5.4: Image of the four viewing modes, including the two additional viewing modes: Stereoscopic 3D (top-left in anaglyph), Shadow(top-right), HUD(bottom-left), and None(bottom-right).

5.2 Study Design

A user study was developed to investigate the effect depth cues have on the performance and engagement of players when interacting along the depth axis. The study used quantitative measurements of player actions within the game to measure performance, and qualitative measures to assess participants enjoyment, and engagement. The within-group study consisted of four different conditions or depth cues: stereoscopic 3D, shadows, HUD, and none. Every participant was required to play under all conditions. The conditions were counterbalanced, with 24 different configurations as listed in Table 5.1. The game logged participants' performance by recording i) the time taken to complete the game, ii) number of deaths, and their iii) targeting accuracy. The game also recorded whether each level was complete, but the study design required players to complete all levels under all conditions. Participants were also required to complete the Game Engagement Questionnaire (GEQ) after each condition to gauge their engagement.

	Order of Conditions			
ID	C1	C2	C3	C4
A	Shadow	HUD	3D	None
B	3D	HUD	None	Shadow
C	3D	None	Shadow	HUD
D	Shadow	None	HUD	3D
E	3D	Shadow	HUD	None
F	None	HUD	3D	Shadow
G	HUD	3D	None	Shadow
H	None	Shadow	3D	HUD
I	Shadow	3D	HUD	None
J	HUD	Shadow	3D	None
K	None	HUD	Shadow	3D
L	HUD	3D	Shadow	None
M	HUD	None	Shadow	3D
N	Shadow	None	3D	HUD
O	HUD	Shadow	None	3D
P	Shadow	HUD	None	3D
Q	3D	None	HUD	Shadow
R	None	3D	Shadow	HUD
S	None	3D	HUD	Shadow
T	HUD	None	3D	Shadow
U	Shadow	3D	None	HUD
V	None	Shadow	HUD	3D
W	3D	Shadow	None	HUD
X	3D	HUD	Shadow	None

Table 5.1: Condition Configurations

The study began with a Stereo Randot Test [1], to make sure all participants had stereo-vision. Participants who failed the Randot Test were instructed their results would not be used, but were allowed to proceed with the study if they wished. Otherwise participants were seated in Undergraduate Game Development Lab at the University of Ontario Institute of Technology(UOIT) and asked to fill out a demographics questionnaire. The demographics questionnaire was used to provide general information about each participant, and used to get indication of their video game playing habits, and experience levels with stereoscopic 3D. The lights were turned off in the lab for all participants, and noise was limited to minimum levels to reduce distractions. Participants were informed they were required to wear polarized stereoscopic 3D glasses under all conditions, but could remove them when filling out the GEQ.

Participants began the experiment by playing through a set of four training levels referred to in section 5.1.1. Training levels were included to reduce the learning curve, and allow players to learn the mechanics of the game before actually playing. In the training levels players were given all three of the depth cues: Shadows, HUD, and stereoscopic 3D. They were informed of this. The game did record their performance data during the training levels, but it wasn't used in the analysis. After completing the training phase of the experiment, participants were instructed to continue playing under the first of four conditions. Their first condition was dependent on the first initial of their participant identifier, which they were assigned by the experimenter at the begin of the study (See table 5.1). Each condition required the participant to complete two levels, by successfully navigating to the end. Participants were not given a time limit, and were instructed they must complete each level during all conditions. They were also informed they could leave the study for any reason, including if they were too frustrated, or it was taking too long. After successfully completing each condition, participants were required to fill out the Game Engagement Questionnaire. They were also asked to select which condition they felt they had just experienced. Upon successfully completing all conditions and the final Game Engagement Questionnaire participants were asked the following interview questions:

- **Question 1:** Which session did you enjoy more? Have more fun with? And Why?
- **Question 2:** Which session do you feel you preformed best in? And Why?

- **Question 3:** Any other remarks about the differences between each session?
- **Question 4:** Any general comments about the game?

5.2.1 Participants

Forty-eight (48) male volunteers participated in the study, with thirty (30) selected from the University of Ontario Institute of Technology's (UOIT) Game Development and Entrepreneurship undergraduate program. The general information provided by the demographic questionnaire, indicated the majority (56.25%) of participants were between the age of 21 and 23. All participants began playing games before the age of 13, with the majority beginning between ages 6 and 9. The approximate number of hours participants spent playing video games in a week varied from less then 5 to about 20 hours, with a few (6 participants) indicating they played more then 20 hours. 40 out of 48 participants had played a stereoscopic 3D game before the experiment. Participants were asked to rate the experience of an S3D game to a non-S3D game using a seven point scale, with one indicating 2D is much more enjoyable and seven indicating stereoscopic 3D is much more enjoyable. They remained neutral with an average of 3.85, indicating no preference. Only one participant hadn't seen a stereoscopic 3D film. Using the same seven point scale to compare an S3D movie theater experiences to a non-S3D experiences, participants indicated they had no preference between the two with an average of 3.70. Half of the participants wore prescription eye glasses during the study.

5.2.2 Setup

The same 1080p Zalman ZM-M240 24" polarized stereoscopic 3D monitors used in Chapter 4 were used to display the game. Participants were once again seated and instructed to adjust the monitor and their seat so that they were in the sweet spot. They were also instructed to wear passive polarized glasses (to permit stereoscopic 3D) at all times during the game, but allowed to remove them while filling out questionnaires. The lights were turned off to reduce glare, the lab was kept as quiet as possible. A custom alienware computer with an Nvidia GTX690 graphics card was used to run the game. An Xbox 360 controller was used to play the game. The game was developed in Unity 3D Pro v3.0 and also used the Stereoskopix 3D plugin (now called FOV2GO) to render in stereoscopic 3D. The game used fixed stereoscopic settings to ensure consistency across participants:

The interaxial distance was set at of 45 units, and the zero parallax plane was set to 285 units away, with the furthest object being 2100 units away. These settings where a bit more conservative then the last study, with the majority of objects pushed back into the screen instead of out. These changes where made based on feedback from users. Pushing the objects into the screen provided a much bigger depth budget, allowing us to pick more conservative settings.

5.2.3 Hypothesis

Based on prior studies, it was predicted stereoscopic 3D will outperform the other conditions, while shadow will outperform HUD which will in turn outperform the base condition. In terms of performance we predict the following relationship.

$$S3D > Shadow > HUD > None$$

Due to an improved difficulty it is expected stereoscopic 3D and shadows will see higher GEQ score, suggesting higher engagement, while HUD will decrease immersion and GEQ scores. It is expected free-form comments and interview questions will indicate similar results.

5.3 Results

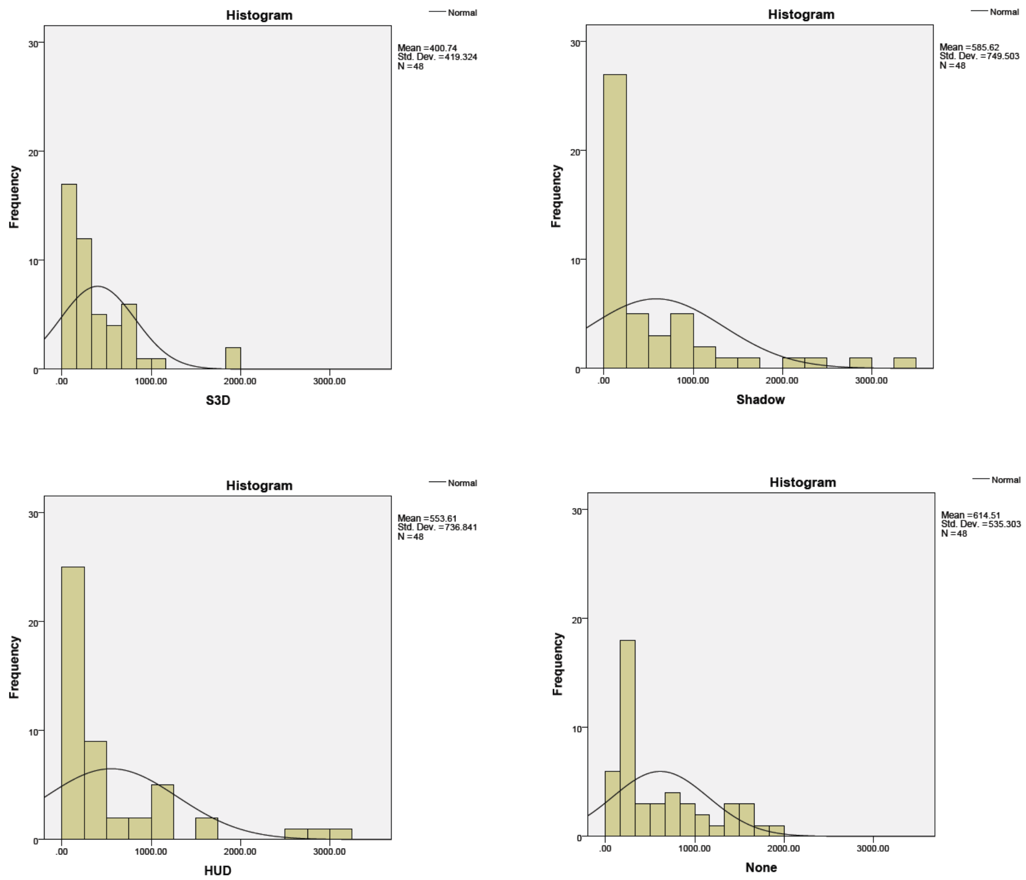

Figure 5.5: Histograms for the completion times of the four conditions, showing non-normal distributed data for each.

Several performance characteristics were measured by the game, including completion time, number of deaths and accuracy. Four different conditions were tested, each presenting an additional depth cue: i) HUD, ii) stereoscopic 3D, iii) shadows, and iv) a base condition with no additional depth cues (None). Analysis of completion time was conducted using a Friedman Test, because the data was not normally distributed (see Figure 5.5). A Shapiro-Wilk Test was performed to test normality. All four conditions had a significant value less then .001, indicating the data isn't normally distributed. The Friedman Test showed no significant difference between the four conditions, $X^2(2) = 6.525, p = 0.089$. X^2 is the chi-squared value, and is used to test the distribution of a sum of the squares, which is useful in testing the null hypothesis. Since our p value is greater then 0.05 we can't reject the null hypothesis, indicating none of these conditions had any benefit over the other. Both number of deaths and accuracy had similar distributions, and neither showed significant differences between the four conditions. Contradictory to the prior study presented in Chapter 4, this data suggests there is no significant differences between the conditions, indicating that stereoscopic 3D does not provide any benefit for performance along the depth axis. There are many different factors this could be attributed to, as changes were made to both the game and study design. Modifications to the game and study design include adding a training mode, new mechanics, the removal of the imposed time limit and the addition of two additional viewing modes. Many of these changes were implemented in an attempt to reduce the learning or practice effect observed in the prior study.

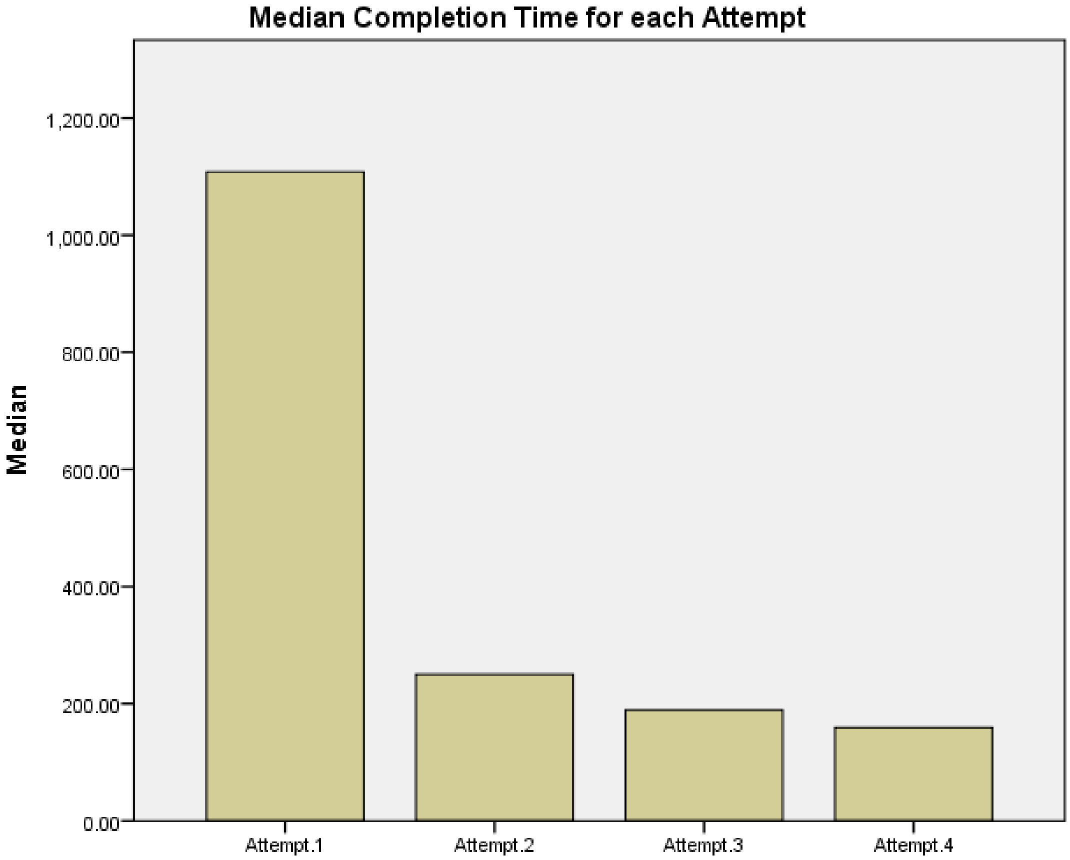

Figure 5.6: The median for each attempt's completion time

To investigate whether the learning effect was reduced, an analysis of completion times between participants' first, second, third and fourth attempts was performed using a Friedman Test. It revealed there was a significant difference between completion times for each attempt, $X^2(2) = 82.050, p < 0.001$. A post-hoc analysis was performed using a Wilcoxon signed-rank tests, the significance level was adjusted to $p < 0.0125$, using a Bonferroni correction. Median(inter quartile range) completion times for the first, second, third and fourth attempts were 1107.68(824.37 to 1697.76), 249.55 (165.87 to 520.33), 189.19(113.48 to 284.55), 159.33(119.31 to 234.49). There was no significant difference between attempts three and four (Z=-0.503, p=0.615), although every other combination was significantly differ-

Test Statistics[a]

	Attempt.2 - Attempt.1	Attempt.3 - Attempt.1	Attempt.4 - Attempt.1	Attempt.3 - Attempt.2	Attempt.4 - Attempt.2	Attempt.4 - Attempt.3
Z	-5.877[b]	-6.031[b]	-5.969[b]	-2.697[b]	-2.944[b]	-.503[b]
Asymp. Sig. (2-tailed)	.000	.000	.000	.007	.003	.615

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

Figure 5.7: Results of the Wilcoxon Signed-Rank tests between each attempt.

ent(see Figure 5.7). Attempt one required significantly more time to complete than attempts two(Z=-5.877, p<0.001), three(Z=-6.031, p<0.001), and four(Z=-5.969, p<0.001). Attempt two required significantly more time to complete than attempts three(Z=-2.697, p=0.007), and four(Z=-2.944, p=0.003). This suggests participants' performance improved after every attempt, until the fourth attempt which had similar times to attempt three. It demonstrates a significant learning or practice effect exists, and the changes made to the study design and game were unable to reduce or remove it.

While the conditions were counter-balanced, the significant learning or practice effect in this study may be causing the results between conditions to be insignificant. It might be important to consider whether the viewing condition had an effect during the initial or early attempts, before the participants learned the game. To examine this closer, an analysis of variance (ANOVA) was performed between the four conditions (HUD, S3D, Shadows and None) for participants' completion times during each attempt. Each condition had 12 participants during each attempt, for a total of 48 participants. A square-root transformation was first applied to each set of data, to conform them to a normal distribution.

For participants' first attempt, the assumption of homogeneity of variance was violated, therefore the Welch F-ratio is reported for the ANOVA analysis, while Games-Howell post hoc test was used if significances was found. A significant difference between completion times for the four viewing conditions was found, F(3,44)=4.322, p=0.015. The Games-Howell post hoc test (see Figure 5.8) found significant different between S3D and the base condition, p=0.012, d=0.888, as well as between S3D and HUD, p=0.034, d=1.349. No significant difference was found between any other conditions during the participants' first attempt.

During the participants' second attempt, the assumption of homogeneity of variance was valid, however no significant difference was found between the four conditions, p=0.086. Similar results were found for attempts three (p=0.050) and four(0.460).

Multiple Comparisons

Dependent Variable: Time.invSqrt

Games-Howell

(I) DisplayType	(J) DisplayType	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
S3D	Shadow	.00751	.00352	.174	-.0023	.0173
	HUD	.00897*	.00301	.034	.0006	.0174
	None	.00945*	.00257	.012	.0020	.0169
Shadow	S3D	-.00751	.00352	.174	-.0173	.0023
	HUD	.00146	.00314	.966	-.0073	.0102
	None	.00194	.00272	.890	-.0060	.0099
HUD	S3D	-.00897*	.00301	.034	-.0174	-.0006
	Shadow	-.00146	.00314	.966	-.0102	.0073
	None	.00048	.00201	.995	-.0053	.0062
None	S3D	-.00945*	.00257	.012	-.0169	-.0020
	Shadow	-.00194	.00272	.890	-.0099	.0060
	HUD	-.00048	.00201	.995	-.0062	.0053

*. The mean difference is significant at the 0.05 level.

Figure 5.8: Results of the Games-Howell post hoc tests.

5.3.1 Heat Maps: Taking a Closer Look at the Data

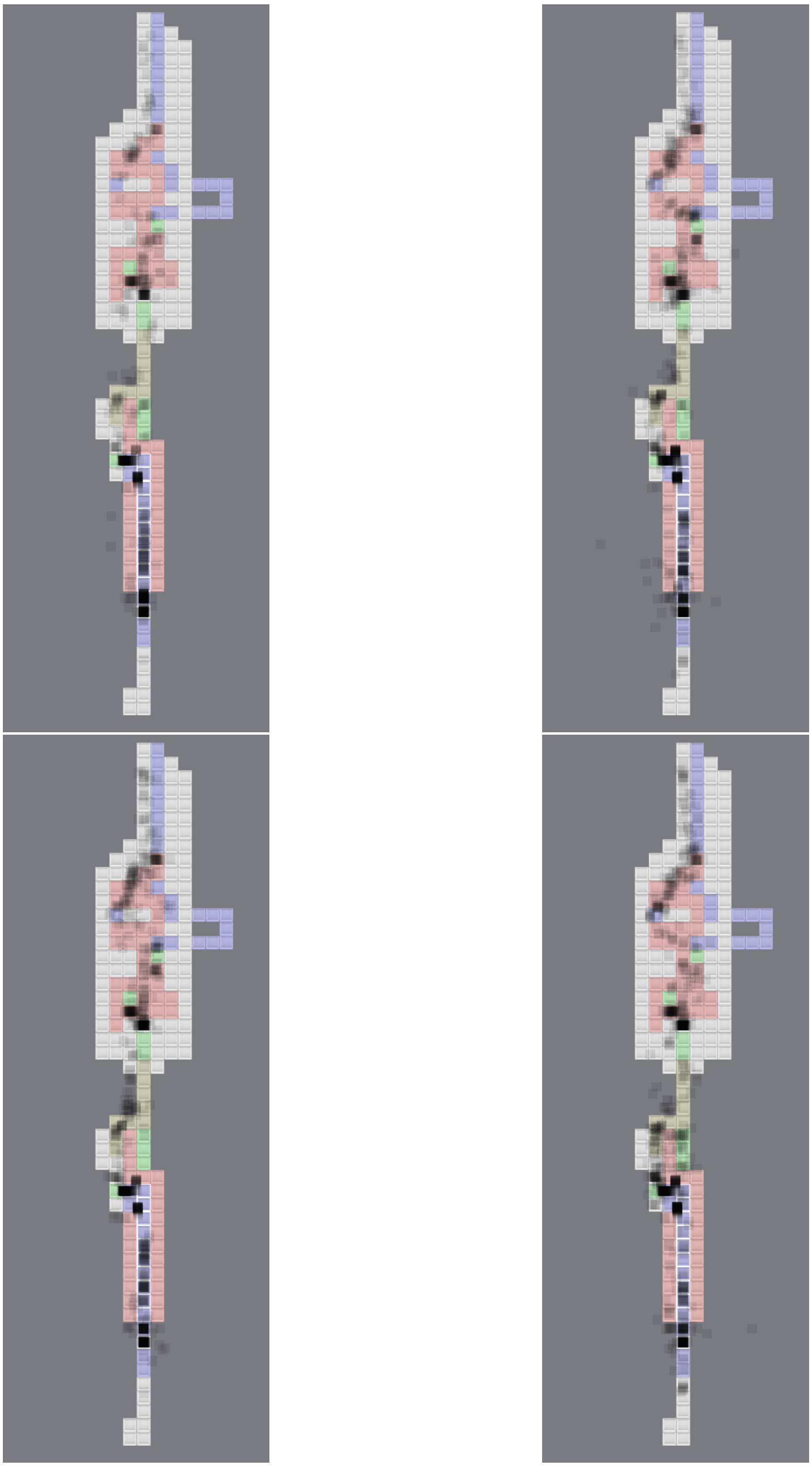

Figure 5.9: Heat Maps of players deaths for level one: Top-left is S3D, top-right is Shadow, bottom-left is None, and bottom-right is HUD

In additional to recoding completion times, number of deaths, and accuracy, the game also recorded the location of participants' deaths. From this data, heat maps

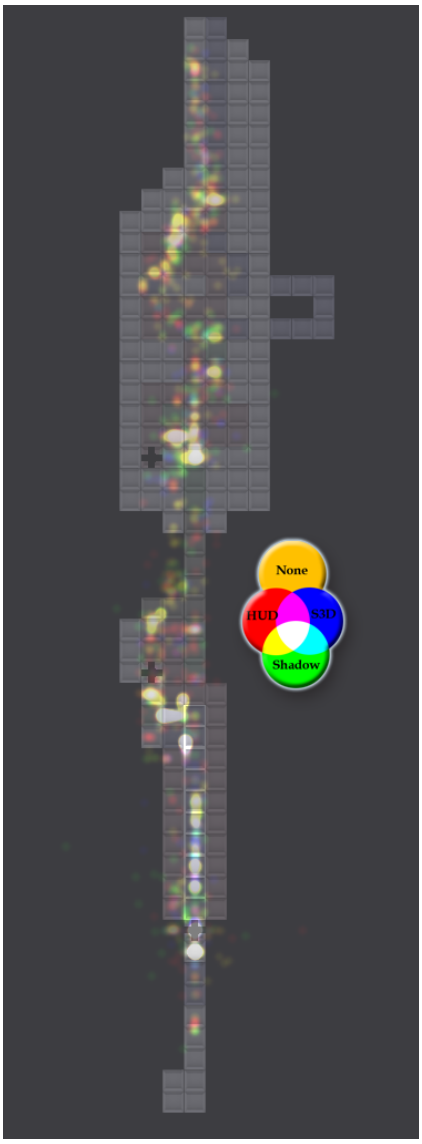

Figure 5.10: All Deaths during level one on one map, condition can be determined by color: HUD (Red), S3D (Blue), Shadow (Green), and None (Orange)

for each level were generated to observe where participants had the majority of the trouble.

For level one, participants under any condition struggled with the initial part of the level. However in the middle and later sections of the level, it appears S3D has fewer deaths then the other three conditions. The beginning section was broken into three separate steps, requiring the player to focus on moving forward-and-back, side-to-side, and then up-and-down separately. The middle and end section however required the participant to navigate both side-to-side, up-and-down, and forward-and-back simultaneously. There were also a couple of targets that had to be destroyed.

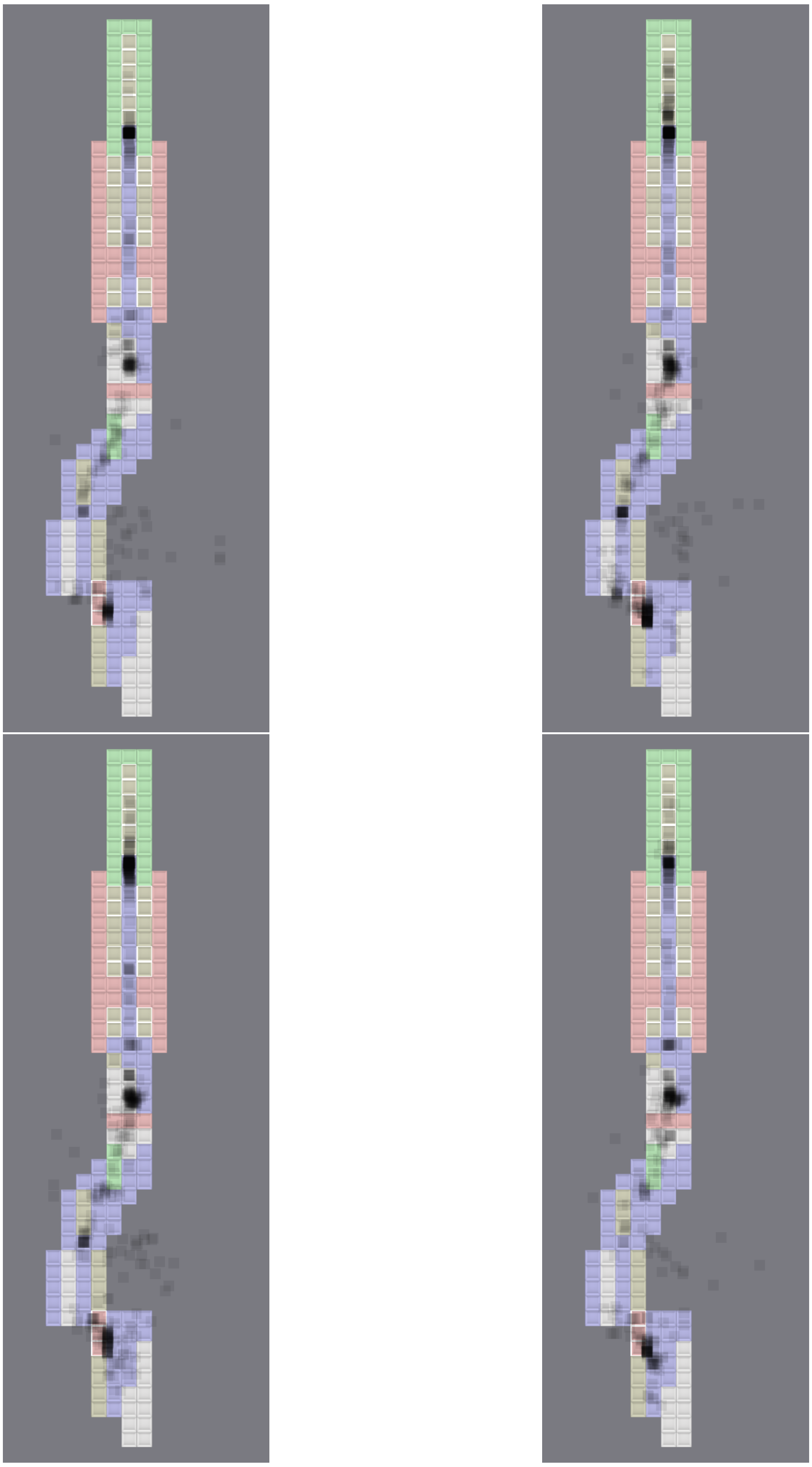

Figure 5.11: Heat Maps of players deaths for level two: Top-left is S3D, top-right is Shadow, bottom-left is None, and bottom-right is HUD

The second level, had three difficult points as seen in Figure 5.11. The beginning point required the players to blow up a target, move down under a block. It appears that participants playing with Shadows, and under the None condition had more trouble at this point. Between the beginning and middle, participants were required to collect path changing power ups, which were floating at different levels above the path. Again it appears that Shadow and None had the most trouble in this section. The middle point seemed fairly consistent at across the board. There wasn't much challenge between the middle and end point, participants were only required to move forward and then back. The end point was one of the more difficult points. Participants were required to wait for a block to disappear, before having to drop below another block. It did not require any side-to-side motion, but did require timing. Once again it appeared Shadow, and None had the most trouble, while HUD outperformed S3D in this particular section.

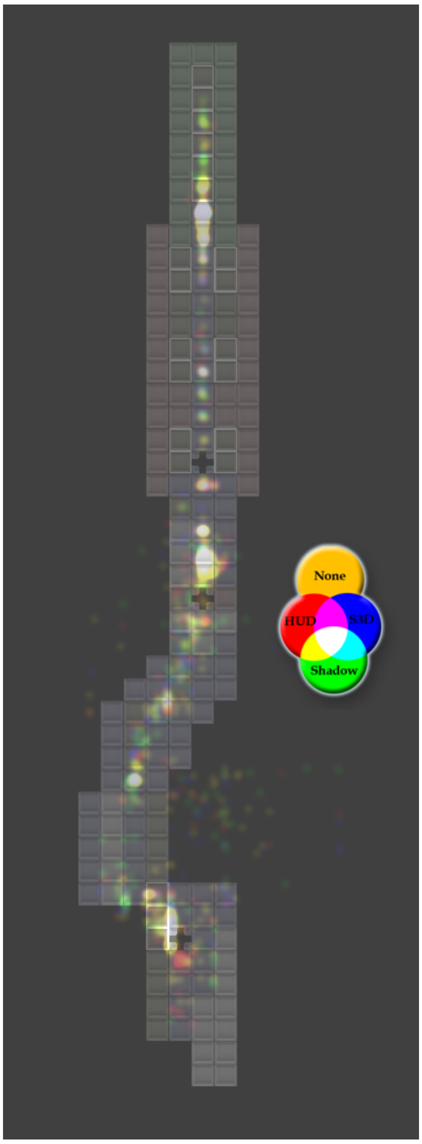

Figure 5.12: All Deaths during level one on one map, condition can be determined by color: HUD (Red), S3D (Blue), Shadow (Green), and None (Orange)

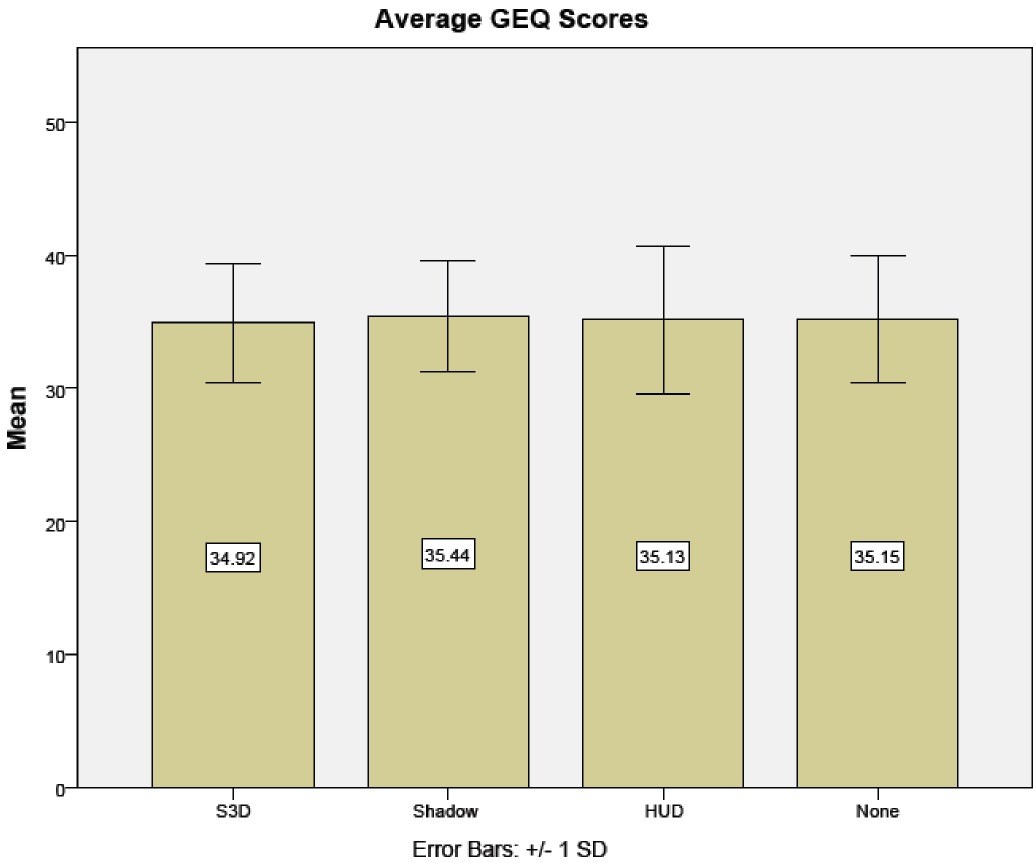

Figure 5.13: Average GEQ Scores of each condition with standard deviation bars.

5.3.2 GEQ and Free-Form Comments

A one-way within subjects (or repeated measures) ANOVA was conducted to compare the effect different depth representations had on Game Engagement Questionnaire scores in S3D (M=34.87, SD=4.48), HUD (M=35.08, SD=5.54), Shadows (M=35.44, SD=4.19), and None (M=35.10, SD=4.80) conditions (see Figure 5.13). No significant difference between the four conditions was found. These results suggest the viewing condition has no effect on player's engagement in this particular game.

The free form section consists of several questions to determine the condition participants found the most enjoyable, and easiest, as well as a few questions related to the game in general. When asked, 50% of participants found S3D to be the most enjoyable, compared to 35% who found Shadow to be the most enjoyable. A total of six participants(12.5%) found HUD to be the most enjoyable, while only one participant(2.1%) found none to be most enjoyable. Some of the reasons participants gave for finding stereoscopic 3D the most enjoyable include (see Appendix C for additional responses):

> "The game felt very real, and judging depth felt natural and was easy." (Participant 44, June 2013)

> "The particle effects, cubes and ship felt more 'real', and seemed to be 'inside' of the screen. This helped me navigate the depth mazes and was more entertaining to experience. The laser particle effects were also much more noticeable with 3D, which helped me orient myself in relation to other cubes." (Participant 36, July 2013)

Most Participants indicated it was because it felt easiest:

> "It was easiest" (Participant 4, August 2013)

> "I could easily tell the depth of all the objects." (Participant 45, June 2013)

> "It was much easier to determine where the ship was positioned" (Participant 8, August 2013)

Comments for Shadows included:

> "It looked the best." (Participant 30, July 2013)

> "Looks awesome!" (Participant 29, July 2013)

> "The shadows provided a frame of reference to how high or low each object was, and that information was available for all rows at a glance rather than having to look at the HUD or make guesses based on 3D without shadows." (Participant 39, July 2013)

Comments for HUD focused mainly on how it helped them:

> “Easy to tell height difference” (Participant 3, August 2013)

> “Of all the methods, it gives you the best perception of where you are vertically, while not as intuitive, the second level has a really tight fit at the end, and the HUD was the one that made it the easiest, though i got hang of the timing near the end.” (Participant 16, August 2013)

> “I was most successful with this one. It made it really easy to finish the last drop on the second level. This was a real difficulty with the other sessions.” (Participant 33, July 2013)

The participant who enjoyed none, indicated it was because “Practice made it easiest”. Participant 28, July 2013)

Participants were also asked under which condition they performed best. Out of 47 participants who responded, 19 or 40.4% selected HUD as the easiest condition to play under. This was closely followed by S3D, with 17 or 36.2% selecting it as the easiest condition. Shadow was select by 9 participants(19.1%), while only 2 selected none as the easiest condition. Comments as to why HUD felt the easiest include:

> “easy to judge depth” (Participant 43, June 2013)

> “Of all the methods, it gives you the best perception of where you are vertically, while not as intuitive, the second level has a really tight fit at the end, and the HUD was the one that made it the easiest, though i got hang of the timing near the end.” (Participant 16, August 2013)

> “I preformed best with the HUD when it came to seeing if I was going to crash into the floor. Shadows did help in this case, but it helped much more to see the actual depth through the HUD. Though when it came down to finding things above the ship, the HUD was not needed.” (Participant 32, July 2013)

Comments for Stereoscopic 3D included:

> "It was much easier to see/feel where my ship was in relation to the rest of the level, so it was easier to navigate levels" (Participant 41, July 2013)

> "I didn't have to put any effort into determining the depth of game objects, so I was able to focus more on the other tasks at hand." (Participant 44, June 2013)

Comments for Shadow:

> "It gave an easy way to tell distance from the ground" (Participant 10, August 2013)

> "BECAUSE I COULD SEE THE HEIGHT OF MY SHIP" (Participant 27, July 2013)

Both comments about None, indicated it was because it was their last condition.

> "I was horrible at the game at first. I had trouble figuring out what to do. I eventually got the hang of it but I was still terrible at the game!" (Participant 17, July 2013)

> "I knew the levels and was able to clearly see" (Participant 25, July 2013)

The free-form comment section also included a section for participants to describe their observations about the differences between the four conditions. Participants indicated in this section, that the game became easier to complete after each successful attempt, largely due to an increase in skill level with the controls.

> "easier to play in later playthroughs when use to mechanics/controls" (Participant 2, August 2013)

> "The levels got easier each play through, the first time through was really hard, the second wasnt bad, but the 3rd and 4th time I was breezing through them." (Participant 18, July 2013)

> "It became a lot easier once I knew the layout of each level, and understood the controls more. It was really fun once stereoscopic 3d was introduced." (Participant 25, July 2013)

> "My skill level at the controls grew really fast, so the earlier tests are biased towards being harder, at the end I beat it in no time at all because not only was I better at the game, I played those levels already, so even without the indicators such as shadows and 3d I could easily get through as I already knew everything about the level. If I had to play the tests in random order or different levels each time I think it would have been better." (Participant 12, August 2013)

The final section provide an opportunity for participants to fill out general comments about the game. Participants' comments primary focused on the perceived difficultly on their initial attempts, some minor issues with the control schemes, and whether they enjoyed playing.

> "It seemed very challenging at first, maybe not enough reinforcement of the rules, as the first trial I had to learn by trial and error, even though I had read the rules, I didn't yet really get how they worked." (Participant 8, August 2013)

> "The game itself was hard, but I do like hard games.However, once in a while I felt I was struggling with the controls. The visuals and the 3D we good anyway." (Participant 9, August 2013)

> "Challenging, addictive, loved it - I would actually buy a full-version of this, in stereoscopic 3D" (Participant 36, July 2013)

5.4 Discussion

This chapter investigated the effect that the addition of different depth cues can have on performance and engagement of a participant, when tasked with interacting along the depth axis. It presented a modified version of the game Z-fighter, now referred to as Z-fighter 2.0. The game included four different display configurations to test the four additional depth cues: stereoscopic 3D, Shadow, HUD and none. The results of the study indicated there was no significant difference between the four conditions, indicating no significant performance advantage for any of them. This directly contradicted the results of the prior study, presented in Chapter 4, that demonstrated a performance advantage for stereoscopic 3D compared to none. One possible cause of this contradiction was an observed learning effect. To further investigate the learning effect, analysis of the four conditions' performance during each attempt was performed. The results indicated there was a significant difference between the conditions during participants first attempt. However after playing once, any difference between the conditions disappeared. Therefore as participants developed their skill and became better at the game, the condition they play under becomes less important. Further analysis between the conditions for the first attempt, indicated stereoscopic 3D outperformed both HUD and None. There was no significant difference between Shadow and any of the other conditions. Interestingly, participants indicated in the free form section that stereoscopic 3D and HUD were the most useful and easiest to play. The difference between the comments and results, could be attributed to HUD requiring another thing to learn on the participants initial attempt.

The heat maps suggest that specific sections and actions are easier under different conditions. For instance, the final drop on the second level was much easier under the HUD condition. This is further supported by participants free-form comments. A possible explanation is that the section didn't require the participant to split their focus between the HUD and the scene. The section didn't require side-to-side motion, enabling the participant to only focus on moving the ship along the depth axis. However at the end of the first level, HUD performed poorly as this section require both side-to-side and up-and-down motion. This indicates designers and developers must consider the actions of their games, before choosing which additional depth cues to present to the player.

The perceived positives and negative of each depth cue (requires further investigation):

- **Shadows:** useful when the task requires the player to judge the relative depth of objects
- **Heads-up Display (HUD):** extremely useful when accuracy is needed, the task isn't time sensitive, and attention is not required in multiple places

- **Stereoscopic 3D:** provides the most natural depth cue, maybe sustainable to over and under estimation of position in depth. Requires individual settings.

5.4.1 Study Design

A repeated measures design was chosen due to the difficulty in finding participants during the summer months (study was run in July) and time constraints. A between-group design would have enabled us to remove the learning effect observed in this experiment. It also would have required a larger participant pool. The addition of a rest or break between conditions would also have helped reduce the learning effect; each condition could have be run on separate day, allowing time for participants to forget the levels and controls. This study design was outside the scope of this experiment, again due to limited number of participants and time. The final suggestion to improve the study's design, would be to include a control group (having participants play the same version four times) to observe the learning effect independent from the affect of the conditions.

5.4.2 Free-Form Comments

While the GEQ didn't reveal any significant difference between the four conditions, the free-form comments did indicate a preference for Stereoscopic 3D and Shadows. Participants choosing stereoscopic 3D indicated it was because they felt more immersed in the world, or because the felt it was easier. Both of these types of responses indicate there should be some differences between GEQ score; one is directly referring to immersion, while the other indicates S3D has better flow. The majority of participants who choose the shadow condition, indicated it was because it looked the best. Although when asked in the general demographics section, to rate the importance of different aspects of a game, it (graphics) was rated as one of the least important aspects. Developers should be aware that certain graphical elements are extremely important to player.

A lot of the free form comments confirmed the learning curve, stating the game became easier the longer they played. Initially the learning curve was thought to be caused by the maze of the prior study, however comments indicate that participants may simply be memorizing the movements required to complete the level. A lot of comments focused on the difficulty of the game. The data and observed learning effect support these observations. One reason participants provided was difficulty with controls. The controls for this game are extremely complex. This is largely due to the complex nature of the game, which allows the player to move along three axes for both the ship and target. Future studies need to address both the controls and difficulty, as the learning curve is too steep. This will prove to be quite challenging as the participant pool is usually not experienced with moving objects in depth.

Issues with the game

To reduce the learning curve future design attempts should concentrate on reducing the control complexity. The game should be easier for participants to pick up and play. The current control interfaces has one analog stick, and two additional buttons just for movement of the ships. A simpler solution is to add a single jump or hover button instead of both and up and down button. Additionally the path system was supposed to reduce difficulty, however it created another system the player had to learn on their first attempt. Although a training mode to teach this concept was included, many participants didn't fully understand the idea until part way into the first level. This suggests a longer training mode is needed. It also points out a difficulty spike. The levels used in training were much easier then the ones used in the study. Future level designs should be refined to remove these difficulty spikes, and design tasks to investigate certain questions; under what level condition does one viewing condition out perform the other viewing conditions. One last mistake in the game design, was the removal of checkpoints. Checkpoints helped by reducing the number of repetitions participants needed for each section of a level. In the prior study they made the game easier and less frustrating for the player. In this study, it is hypothesized they may have limited the player's memorizing the level.

Chapter 6

Conclusion

Every form of entertainment seeks to immerse its audience within its content. There are many ways to improve immersion and engagement with the audience. One area artists often use to improve their medium is the adoption of new technologies. A recent example of this can be seen in films with the inclusion of stereoscopic 3D. And while not necessarily a new technology, it has recently become much more reliable, affordable, and widely available. This is largely due to decades of research into understanding and reducing the limitations of the technology. The film industry has finally adopted the technology, with many filmmakers beginning to explore the artistic benefits of the new medium. The successful stereoscopic 3D filmmakers recognize that stereoscopic 3D is another tool to engage the audience with, and are aware of both the limitations and affordences.

Another medium many thought would benefit from improved stereoscopic 3D technologies, was the games industry. This belief was largely due to the perception that producing interactive stereoscopic 3D content was easy, and required limited work by the developer. While this was true, producing good stereoscopic quality images proved to be more difficult. Much of the work by developers has revolved around creating more comfortable viewing conditions and optimizing rendering technologies to support S3D within their current games. Game developers have done very little to explore the affordances of the medium and often view S3D as an additional viewing mode. There is also still a need to study the effects S3D has on the user experience of a game. This thesis presented three studies which explored the affordances of S3D in interactive applications, by investigating the design of an S3D game and its effect on the user experience.

The initial study presented in Chapter 3, investigated the effect stereoscopic 3D had on engagement compared to a traditional 2D display when playing the same game. It required participants to play Frozenbytes' Trine, a side-scrolling action game with three dimensional graphics, under both conditions. The study found no significant difference between stereoscopic 3D and traditional 2D displays for engagement using participants score from the Game Engagement Questionnaire. These results were consistent with prior work by Schild et al. [112]. They found stereoscopic 3D increased engagement within certain genres of games but not in others, including side-scrolling action games. They hypothesized this difference in genre was due to the amount of motion or animation into and out of the screen(depth axis).

A second study was developed and run to further investigate whether stereoscopic 3D increased engagement compared to traditional 2D displays when motion along the depth axis was present. The study explored the concept of a stereoscopic 3D game, by designing and developing a game specially for stereoscopic 3D. It was hypothesized that stereoscopic 3D provided an additional depth cue, that could utilized to build a mechanic where interaction along the depth axis was necessary. A game that required the player to navigate a ship along both the x-y plane and depth axis was developed based off the ideas presented in Schild et al. [113]. A study of this game was conducted to compare both the performance and engagement of stereoscopic 3D viewing verses traditional 2D displays. Stereoscopic 3D out-performed traditional 2D displays indicating that designers and developers can create experiences specifically tailored to stereoscopic 3D viewing. It demonstrates that depth-axis related mechanics can be incorporated into stereoscopic 3D games, but these depth-axis mechanics are very difficult to adapt to non-S3D displays. Developing a game specifically for stereoscopic 3D, won't be playable on traditional 2D displays without revision. Additional investigation into other depth cues, which can provide similar information about depth is needed. The results of the GEQ showed no significant difference between S3D and non-S3D. This was attributed to general difficulties with the game. Good playability is a prerequisite for evaluating user experience; the design of the game still needs to be adjusted as many free-form comments indicated problems with both the game and stereoscopic 3D settings. Free-form comments also indicated a preference for stereoscopic 3D when playing.

The final study presented in this paper was a follow up to the second experiment. It investigated whether other depth cues could provide sufficient information to get similar performance to stereoscopic 3D, when interacting along the depth axis. The study included four different conditions each using a different depth cue including stereoscopic 3D, shadow, HUD and none. It also examined the affect each depth cue had on user experience. The game Z-fighter was modified in an attempt to reduce difficulty. The study design was also modified, in an attempt to reduce the learning curve. The results of the study, indicated no significance between the different conditions. Although this was a direct contradiction to the prior study, further investigation showed significant results on participants first attempt. Participants playing in stereoscopic 3D performed better than those playing with HUD or none, until the participant completed the game once. After learning the game, the condition the participant played under didn't matter. Additionally, heat maps indicated participants might perform better with certain depth cues in certain areas. The Game Engagement Questionnaire didn't provide any significant results. Free-form comments did indicate a preference for shadow and stereoscopic 3D.

It my opinion that further investigation of both the design practices of stereoscopic 3D games and its effect on user engagement is needed. This thesis demonstrates that the affordances offered by stereoscopic 3D can be utilized to create unique experiences, although there may be additional depth cues available to offer similar experiences. Until a stereoscopic 3D game with good playability is developed, measuring user experience will remain inconclusive. Although prior literature does support that under certain conditions stereoscopic 3D can improve engagement, but these conditions are not yet known.

6.1 Contributions

This thesis investigates the benefits and affordances of stereoscopic 3D in games, by exploring the effect it has on design and user experience of a game. An initial study, determined stereoscopic 3D did not provide any significant benefit, compared to traditional 2D display, for user engagement or immersion. A second study, found stereoscopic 3D out performed traditional 2D displays when the task was along the depth axis. Finally a third study, determined there maybe additional ways to represent depth to help performance along the depth axis, including shadows. It also indicated, repeated training an individual on a task, outweighs any benefit a viewing condition might give a person. The results of these studies are important to developers and designers when determining whether to include stereoscopic 3D in their games. It suggests that developers might be able to create unique experiences using stereoscopic 3D, or other depth cues to create interactions along the depth axis. The results also suggest when developing content for stereoscopic 3D and traditional 2D displays, depending on the interactions available in the game, the difficulty will need to be adjusted for both viewing modes. And finally, developers need to be aware that S3D can provide a benefit, but it is completely dependent on the game. And just like filmmakers, developers, along with researchers need to identify where and when stereoscopic 3D can provide this benefit.

6.2 Limitations and Future Work

Further research is needed for both the design of stereoscopic 3D games and the effect stereoscopic 3D has on user engagement. A stereoscopic 3D game with good playability, and relativity few issues needs to be developed. This was an issue identified in both studies presented in Chapters 4 & 5. While the concept of interactions along the depth axis is solid in its foundation and remains very promising, further refinement of the idea is required before investigating the effect S3D has on user experience.

A few issues need to be address with the game, such as issues with controls, and difficulty spikes. The other major issue studying user experience and performance of S3D games, is the need for individualized stereoscopic 3D settings. Currently there was no way to determine the quality of stereoscopic 3D being presented to the participant, due to individualized nature of it. Additional investigation is needed into either a standardized method of determining participants stereoscopic 3D settings, or a method for testing the quality of the stereoscopic 3D seen in experiment.

The third study, present the idea that other depth cues such as shadows could provide similar performance when interactions were along the depth axis. Further investigation into the benefits and limitations of each depth cues is needed. Prior literature such as Tory et al. [133] provides an indication of the limitations of both shadows and heads-up displays (HUD), but the impact these limitations have on games still needs to be explored. Interactions along the depth axis was not the only design idea presented in Schild et al. [113], and the other ideas presented are worth exploring. This is one area of stereoscopic 3D research that might spark interest with developers.

6.2.1 User Experience

Schild et al. [112] presented a study where stereoscopic 3D did increase engagement within certain games, but not in others. The study also provided a hypothesis as to why this occurred, based of the differences between the games, stating it was due to the increased amount of motion along the depth axis. Further investigation is required to determine under what conditions stereoscopic 3D can increase engagement. Chapter 4 & 5 of this thesis presented the hypothesis that stereoscopic 3D increased engagement when interaction along the depth axis was present in the mechanics of the game. The results of these studies, found no significant difference in engagement scores, indicating that engagement did not increase when interacting along the depth axis. There are several other hypothesis including the one presented in Schild et al. [112], that stereoscopic 3D increases engagement when motion along the depth axis is present. If this is the case, then the amount and frequency of motion, as well as whether the motion is system or user controlled needs to be investigated. Determining the conditions under which stereoscopic 3D increases engagement, is extremely important to developers, because it will help them to determine when stereoscopic 3D should be included within their game.

The Game Engagement Questionnaire(GEQ) was the only measurement used to assess user engagement in all three studies presented in this thesis. This was largely due to it being the only verified method, and the constraints of this thesis and author. In every study presented within this thesis, participants comments always indicated a preference for stereoscopic 3D, however GEQ scores were always insignificant. Future studies should include additional measures of user experience, such as biometrics, to verify the results of the GEQ.

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Appendices

Appendix A

Demographics and Game Engagement Questionnaire Results for Experiment One

iGO3D Engagement Questionnaire

1. Interviewee ID (Ask the interviewing supervisor to fill this out)

	Response Count
	20
answered question	20
skipped question	0

2. Are you a Game Development & Entrepreneurship student at UOIT

	Response Percent	Response Count
Yes	**90.0%**	**18**
No	10.0%	2
answered question		20
skipped question		0

3. Please indicate your gender:

	Response Percent	Response Count
Male	**100.0%**	**20**
Female	0.0%	0
answered question		20
skipped question		0

4. Please indicate your age range:

	Response Percent	Response Count
18-20	**50.0%**	**10**
21-23	45.0%	9
24-26	5.0%	1
27-29	0.0%	0
30-32	0.0%	0
33-35	0.0%	0
35+	0.0%	0
	answered question	**20**
	skipped question	**0**

5. At what age did you start playing video games?

	Response Percent	Response Count
2-5	35.0%	7
6-9	**55.0%**	**11**
10-13	10.0%	2
14-17	0.0%	0
18-21	0.0%	0
22-25	0.0%	0
26+	0.0%	0
	answered question	**20**
	skipped question	**0**

6. Approximately how many hours per week do you play video games?

	Response Percent	Response Count
Less than 5	**25.0%**	**5**
5-10	20.0%	4
11-15	15.0%	3
16-20	10.0%	2
21-25	20.0%	4
26-30	0.0%	0
More than 30	10.0%	2
	answered question	**20**
	skipped question	**0**

7. Have you ever played a game in stereoscopic 3D before?

	Response Percent	Response Count
Yes	**55.0%**	**11**
No	45.0%	9
	answered question	**20**
	skipped question	**0**

8. For video games, how would you rate the stereoscopic 3D experience (vs traditional 2D games) (1 = 2D is much more enjoyable, 4 = equally enjoyable, 7 = stereoscopic 3D is much more enjoyable)

	Response Percent	Response Count
1	0.0%	0
2	5.6%	1
3	5.6%	1
4	**50.0%**	**9**
5	33.3%	6
6	5.6%	1
7	0.0%	0
	answered question	**18**
	skipped question	**2**

9. Have you ever seen a movie in stereoscopic 3D before?

	Response Percent	Response Count
Yes	**95.0%**	**19**
No	5.0%	1
	answered question	**20**
	skipped question	**0**

10. In the movie theatre, how would you rate the stereoscopic 3D experience (vs traditional 2D movies) (1 = 2D is much more enjoyable, 4 = equally enjoyable, 7 = stereoscopic 3D is much more enjoyable)

	Response Percent	Response Count
1	0.0%	0
2	5.0%	1
3	15.0%	3
4	**25.0%**	**5**
5	20.0%	4
6	**25.0%**	**5**
7	10.0%	2
	answered question	**20**
	skipped question	**0**

11. Do you currently own a HDTV

	Response Percent	Response Count
Yes	**77.8%**	**14**
No	16.7%	3
I don't know	5.6%	1
	answered question	**18**
	skipped question	**2**

12. Do you currently own a 3D capable HDTV

	Response Percent	Response Count
Yes	0.0%	0
No	**94.4%**	**17**
I don't know	5.6%	1
	answered question	**18**
	skipped question	**2**

13. Do you currently own a 3D capable PC Monitor

	Response Percent	Response Count
Yes	5.0%	1
No	**90.0%**	**18**
I don't know	5.0%	1
	answered question	**20**
	skipped question	**0**

14. Do you currently own a gaming console

	Response Percent	Response Count
Yes	**85.0%**	**17**
No	15.0%	3
	answered question	**20**
	skipped question	**0**

15. If you answered “Yes”, which console(s) do you currently own (specify all)

	Response Percent	Response Count
Playstation 3	**70.6%**	**12**
Xbox 360	64.7%	11
Nintendo Wii	41.2%	7
Nintendo 3DS	11.8%	2
Other	52.9%	9
	Other (please specify)	9
	answered question	**17**
	skipped question	**3**

16. Approximately how much money have you spent in the last year on console games?

	Response Percent	Response Count
None	23.5%	4
$10-$49	0.0%	0
$50-$99	23.5%	4
$100-$199	11.8%	2
$200-$299	**29.4%**	**5**
$300-$399	0.0%	0
$400-$499	11.8%	2
$500 or more	0.0%	0
	answered question	**17**
	skipped question	**3**

17. Do you currently play games on your PC?

	Response Percent	Response Count
Yes	**95.0%**	**19**
No	5.0%	1
	answered question	**20**
	skipped question	**0**

18. Do you currently wear prescription eye glasses?

	Response Percent	Response Count
Yes	40.0%	8
No	**60.0%**	**12**
	answered question	**20**
	skipped question	**0**

19. In your traditional 2D gaming experience please indicate the importance of the following, 1=not-important, 5 being most important:

	1	2	3	4	5	Rating Average	Rating Count
Multi-Player Mode	10.0% (2)	10.0% (2)	15.0% (3)	**45.0% (9)**	20.0% (4)	3.55	20
Single Player Mode	0.0% (0)	5.0% (1)	10.0% (2)	20.0% (4)	**65.0% (13)**	4.45	20
Realistic Graphics (visuals)	5.0% (1)	10.0% (2)	**45.0% (9)**	35.0% (7)	5.0% (1)	3.25	20
Quality of Audio	0.0% (0)	0.0% (0)	30.0% (6)	30.0% (6)	**40.0% (8)**	4.10	20
Surround Sound Audio	0.0% (0)	5.0% (1)	**65.0% (13)**	20.0% (4)	10.0% (2)	3.35	20
Story	0.0% (0)	0.0% (0)	15.0% (3)	**60.0% (12)**	25.0% (5)	4.10	20
Interactivity	0.0% (0)	0.0% (0)	15.0% (3)	40.0% (8)	**45.0% (9)**	4.30	20
						answered question	**20**
						skipped question	**0**

20. For games in stereoscopic 3D, please indicate the importance of the following:

	1	2	3	4	5	Rating Average	Rating Count
Seeing deeply INTO the screen	0.0% (0)	0.0% (0)	25.0% (5)	**45.0% (9)**	30.0% (6)	4.05	20
Having objects come OUT of the screen	0.0% (0)	0.0% (0)	**35.0% (7)**	**35.0% (7)**	30.0% (6)	3.95	20
Not wearing glasses while playing	0.0% (0)	15.0% (3)	**45.0% (9)**	15.0% (3)	25.0% (5)	3.50	20
Playing for more than 1 hour	0.0% (0)	0.0% (0)	30.0% (6)	**45.0% (9)**	25.0% (5)	3.95	20
Realistic Graphics (visuals)	0.0% (0)	15.0% (3)	**30.0% (6)**	**30.0% (6)**	25.0% (5)	3.65	20
Multiplayer Mode	10.0% (2)	5.0% (1)	**55.0% (11)**	25.0% (5)	5.0% (1)	3.10	20
						answered question	**20**
						skipped question	**0**

21. Was the game in 3D or 2D?

	Response Percent	Response Count
3D	**65.0%**	**13**
2D	35.0%	7
	answered question	**20**
	skipped question	**0**

22. Have you played this game before?

	Response Percent	Response Count
Yes	30.0%	6
No	**70.0%**	**14**
answered question		**20**
skipped question		**0**

23. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of time	**65.0% (13)**	20.0% (4)	15.0% (3)	1.50	20
				answered question	**20**
				skipped question	**0**

24. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Things seem to happen automatically	20.0% (4)	**45.0% (9)**	35.0% (7)	2.15	20
				answered question	**20**
				skipped question	**0**

25. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel different	35.0% (7)	**50.0% (10)**	15.0% (3)	1.80	20
				answered question	**20**
				skipped question	**0**

26. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel scared	5.0% (1)	**95.0% (19)**	0.0% (0)	1.95	20
				answered question	**20**
				skipped question	**0**

27. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
The game feels real	10.0% (2)	**55.0% (11)**	35.0% (7)	2.25	20
				answered question	**20**
				skipped question	**0**

28. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
If someone talks to me, I don't hear them	5.0% (1)	**75.0% (15)**	20.0% (4)	2.15	20
				answered question	**20**
				skipped question	**0**

29. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I get wound up	10.0% (2)	**80.0% (16)**	10.0% (2)	2.00	20
				answered question	**20**
				skipped question	**0**

30. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Time seems to kind of standstill or stop	20.0% (4)	**45.0% (9)**	35.0% (7)	2.15	20
				answered question	**20**
				skipped question	**0**

31. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel spaced out	30.0% (6)	**50.0% (10)**	20.0% (4)	1.90	20
				answered question	**20**
				skipped question	**0**

32. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I don’t answer when someone talks to me	0.0% (0)	**85.0% (17)**	15.0% (3)	2.15	20
				answered question	**20**
				skipped question	**0**

33. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I can’t tell that I’m getting tired	30.0% (6)	**45.0% (9)**	25.0% (5)	1.95	20
				answered question	**20**
				skipped question	**0**

34. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing seems automatic	**40.0% (8)**	**40.0% (8)**	20.0% (4)	1.80	20
				answered question	**20**
				skipped question	**0**

35. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
My thoughts go fast	30.0% (6)	**45.0% (9)**	25.0% (5)	1.95	20
				answered question	**20**
				skipped question	**0**

36. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of where I am	15.0% (3)	**80.0% (16)**	5.0% (1)	1.90	20
				answered question	**20**
				skipped question	**0**

37. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play without thinking about how to play	**50.0% (10)**	30.0% (6)	20.0% (4)	1.70	20
				answered question	**20**
				skipped question	**0**

38. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing makes me feel calm	**60.0% (12)**	15.0% (3)	25.0% (5)	1.65	20
				answered question	**20**
				skipped question	**0**

39. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play longer than I meant to	40.0% (8)	**45.0% (9)**	15.0% (3)	1.75	20
				answered question	**20**
				skipped question	**0**

40. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I really get into the game	**75.0% (15)**	10.0% (2)	15.0% (3)	1.40	20
				answered question	**20**
				skipped question	**0**

41. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel like I just can’t stop playing	30.0% (6)	**40.0% (8)**	30.0% (6)	2.00	20
				answered question	**20**
				skipped question	**0**

42. Was the game in 3D or 2D?

	Response Percent	Response Count
3D	45.0%	9
2D	**55.0%**	**11**
answered question		**20**
skipped question		**0**

43. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of time	**55.0% (11)**	40.0% (8)	5.0% (1)	1.50	20
				answered question	**20**
				skipped question	**0**

44. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Things seem to happen automatically	30.0% (6)	**65.0% (13)**	5.0% (1)	1.75	20
				answered question	**20**
				skipped question	**0**

45. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel different	30.0% (6)	**65.0% (13)**	5.0% (1)	1.75	20
				answered question	**20**
				skipped question	**0**

46. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel scared	0.0% (0)	**100.0% (20)**	0.0% (0)	2.00	20
				answered question	**20**
				skipped question	**0**

47. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
The game feels real	25.0% (5)	**55.0% (11)**	20.0% (4)	1.95	20
				answered question	**20**
				skipped question	**0**

48. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
If someone talks to me, I don't hear them	5.0% (1)	**75.0% (15)**	20.0% (4)	2.15	20
				answered question	**20**
				skipped question	**0**

49. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I get wound up	5.0% (1)	**80.0% (16)**	15.0% (3)	2.10	20
				answered question	**20**
				skipped question	**0**

50. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Time seems to kind of standstill or stop	40.0% (8)	**50.0% (10)**	10.0% (2)	1.70	20
				answered question	**20**
				skipped question	**0**

51. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel spaced out	25.0% (5)	**70.0% (14)**	5.0% (1)	1.80	20
				answered question	**20**
				skipped question	**0**

52. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I don't answer when someone talks to me	5.0% (1)	**75.0% (15)**	20.0% (4)	2.15	20
				answered question	**20**
				skipped question	**0**

53. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I can't tell that I'm getting tired	25.0% (5)	**60.0% (12)**	15.0% (3)	1.90	20
				answered question	**20**
				skipped question	**0**

54. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing seems automatic	**40.0% (8)**	**40.0% (8)**	20.0% (4)	1.80	20
				answered question	**20**
				skipped question	**0**

55. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
My thoughts go fast	**55.0% (11)**	35.0% (7)	10.0% (2)	1.55	20
				answered question	**20**
				skipped question	**0**

56. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of where I am	10.0% (2)	**85.0% (17)**	5.0% (1)	1.95	20
				answered question	**20**
				skipped question	**0**

57. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play without thinking about how to play	**60.0% (12)**	30.0% (6)	10.0% (2)	1.50	20
				answered question	**20**
				skipped question	**0**

58. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing makes me feel calm	**55.0% (11)**	15.0% (3)	30.0% (6)	1.75	20
				answered question	**20**
				skipped question	**0**

59. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play longer than I meant to	45.0% (9)	**50.0% (10)**	5.0% (1)	1.60	20
				answered question	**20**
				skipped question	**0**

60. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I really get into the game	**75.0% (15)**	10.0% (2)	15.0% (3)	1.40	20
				answered question	**20**
				skipped question	**0**

61. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel like I just can't stop playing	**40.0% (8)**	**40.0% (8)**	20.0% (4)	1.80	20
				answered question	**20**
				skipped question	**0**

62. Please comment or compare your two sessions? (Which one was more fun, any other remarks)

	Response Count
	20
answered question	**20**
skipped question	**0**

Page 1, Q1. Interviewee ID (Ask the interviewing supervisor to fill this out)		
1	A 012	Nov 25, 2011 2:22 PM
2	B 011	Nov 25, 2011 2:21 PM
3	A 011	Nov 24, 2011 2:44 PM
4	B 010	Nov 24, 2011 2:44 PM
5	A 010	Nov 24, 2011 2:44 PM
6	B 009	Nov 24, 2011 2:43 PM
7	A 009	Nov 24, 2011 2:43 PM
8	B 008	Nov 24, 2011 2:43 PM
9	A 008	Nov 18, 2011 2:13 PM
10	B 007	Nov 17, 2011 2:19 PM
11	A 007	Nov 17, 2011 2:15 PM
12	B 006	Nov 15, 2011 3:09 PM
13	B 005	Nov 15, 2011 2:28 PM
14	A 002	Nov 14, 2011 3:26 PM
15	A 004	Nov 14, 2011 2:48 PM
16	B 003	Nov 14, 2011 2:46 PM
17	A 005	Nov 14, 2011 2:44 PM
18	B 004	Nov 14, 2011 2:43 PM
19	B 002	Nov 14, 2011 2:39 PM
20	A 003	Nov 14, 2011 2:39 PM

Page 2, Q15. If you answered “Yes”, which console(s) do you currently own (specify all)		
1	NES, SNES, N64, Gamecube, Game Boy, Gam Boy Color, Game Boy Advance, Nintendo DS, PSP	Nov 25, 2011 2:24 PM
2	Nintendo DS	Nov 25, 2011 2:21 PM
3	NES, SNES, Sega Genesis, PS, N64, PS2	Nov 24, 2011 2:44 PM
4	SNES	Nov 24, 2011 2:43 PM
5	Nintendo DS, PSP	Nov 17, 2011 2:20 PM
6	PS2, Gamecube	Nov 15, 2011 3:12 PM
7	PC	Nov 15, 2011 2:29 PM
8	N64, Super Nintendo System	Nov 14, 2011 2:45 PM
9	Playstation 2	Nov 14, 2011 2:40 PM

Page 47, Q62. Please comment or compare your two sessions? (Which one was more fun, any other remarks)		
1	Both sessions were fun, however it was much harder for me to play the 3D one of the two because my eyes were not able to focus clearly. As a result many of the things that were supposed to be appearing to "pop out of the screen" ended up appearing as two images. This also caused me to get a headache. While playing the 2D version I felt more immersed into the experience but that may be simply because I wasn't so focused on trying to see the game properly.	Nov 25, 2011 3:44 PM
2	Both looked amazing, and I enjoyed the 3D	Nov 25, 2011 3:42 PM
3	The 3D session was horrible. My eyes/head hurt most of the time when the camera was not zoomed out too much. When the camera was zoomed out (example, in the first area where all 3 characters meet) the 3D works nicely and looks great, it feels real. Overall, the 3D was not a good experience although I can imagine it being better if I didn't see two of everything. In 3D when it 'did' work right, I could not tell sometime where to jump (the foreground hid the background in such a way that I could not tell which platform to jump to and would get hurt).	Nov 24, 2011 4:07 PM
4	my eyes need to refocus. An option that allows the user to scroll how far apart the 2 layers are in order to adjust for a specific user's eyes would be a big help.	Nov 24, 2011 4:07 PM
5	The 3d version was really jarring on the 3rd level. I also didnt like that I had to sit so far away from my comfort zone in order for the 3d layers to converge. Fun game over all :D. I'd definately play more 3d games if i had a 3d monitor. I liked how some parts of the level had really extreme 3d objects. I also liked the subtle 3d objects. I think a balance between both adds to the experience. Something needs to be done to make it easier to focus though,	Nov 24, 2011 4:07 PM
6	Although a lot of the scene looked great in the 3D, the entire foreground was ruined. The game not only lost it's apeal it became much harder to play.	Nov 24, 2011 4:06 PM
7	3D takes a little getting used to, but once you get used to it it is pretty cool. I wouldn't say either was more fun than the other, it's just a different way to experience the game.	Nov 24, 2011 4:06 PM
8	3d was more fun, both were playing a bad game. Initial batch of questions need to be re-orderd/ worded	Nov 24, 2011 4:05 PM
9	2D somehow felt faster, as in framerate. 3D felt kind of odd, there was doubling in some areas. I noticed immedeately the switch to 2D from 3D	Nov 18, 2011 3:33 PM
10	noticed the 3D almost right away with the foreground and background affects. A little blurry around some edges and a slight headache at times. Game still felt the same control wise, but the visual stood out.	Nov 17, 2011 3:40 PM
11	I felt the first session was more fun because the graphics felt more live and realatilc. Everything in the game seen to pop out at you and the background is amazning.	Nov 17, 2011 3:40 PM
12	3D hurt my eyes, both were fun. 3D was interesting but it was really hard to concentrate on the screen without my eyes hurting. I'm not sure if the monitor was too close or I was just at a bad angle to play the game in 3D. But sometimes I would get double vision and see the 3D as if I didnt have glasses. Thats what	Nov 15, 2011 3:56 PM

Page 47, Q62. Please comment or compare your two sessions? (Which one was more fun, any other remarks)		
	hurt my eyes when it didn't seem to focus properly.	
13	The 2nd time around was more fun for me. However I feel like the 3D didn't always register like I was sometimes seeing double images. Thanks	Nov 15, 2011 3:54 PM
14	The only main differwence between the 2 is that the 3d one at time was hard to see due to the fact that it wouldnt be in 3d but 2 different player images then it focuses into 3d and back out.... only noticed when the camera was zooming in or was zoomed in already. Enjoyed the working 3d graphics more then the 2d	Nov 14, 2011 4:17 PM
15	Session 2 started out painful on the eyes until I adjusted to the 3D, then it looked really cool	Nov 14, 2011 4:16 PM
16	The 3d was defenelty more fun. Got me into playing longer. the effects are much better on 3d	Nov 14, 2011 4:16 PM
17	3d was more engaging, though certain parts of the level (tree branches and stuff in the foreground) stuck out like a sore thumb and kind of distracted me from the rest of the game.	Nov 14, 2011 4:16 PM
18	3D was definitely better. The feel of depth made a huge difference. If I had a 3D tv I would invest in 3D games.	Nov 14, 2011 4:16 PM
19	3D was definetely more enjoyable and engaging, however the calibration for my eyes didn't seem quite right. So it enhanced the experience while making some parts of the experience less enjoyable since it would look too blurred.	Nov 14, 2011 4:16 PM
20	I thought the 3D was more fun but I was so immersed I missed some important pop ups such as when the characters leveled up.	Nov 14, 2011 4:15 PM

A.0.2 Results of Game Engagement Questionnaire per Condition

	Participate Response (S3D)			
GEQ Question	Maybe	No	Yes	Grand Total
Sum of I lose track of time	3	5	12	20
Sum of Things seem to happen automatically	6	11	3	20
Sum of I feel different	3	9	8	20
Sum of I feel scared	0	20	0	20
Sum of The game feels real	7	9	4	20
Sum of If someone talks to me, I don't hear them	5	14	1	20
Sum of I get wound up	2	16	2	20
Sum of Time seems to kind of standstill or stop	6	9	5	20
Sum of I feel spaced out	5	10	5	20
Sum of I don't answer when someone talks to me	5	15	0	20
Sum of I can't tell that I'm getting tired	3	12	5	20
Sum of Playing seems automatic	5	7	8	20
Sum of My thoughts go fast	3	8	9	20
Sum of I lose track of where I am	1	17	2	20
Sum of I play without thinking about how to play	3	6	11	20
Sum of Playing makes me feel calm	4	4	12	20
Sum of I play longer than I meant to	3	8	9	20
Sum of I really get into the game	2	2	16	20
Sum of I feel like I just can't stop playing	7	7	6	20

	Participate Response (non-S3D)			
Data	Maybe	No	Yes	Grand Total
Sum of I lose track of time	1	7	12	20
Sum of Things seem to happen automatically	2	11	7	20
Sum of I feel different	1	14	5	20
Sum of I feel scared	0	19	1	20
Sum of The game feels real	4	13	3	20
Sum of If someone talks to me, I don't hear them	3	16	1	20
Sum of I get wound up	3	16	1	20
Sum of Time seems to kind of standstill or stop	3	10	7	20
Sum of I feel spaced out	0	14	6	20
Sum of I don't answer when someone talks to me	2	17	1	20
Sum of I can't tell that I'm getting tired	5	9	6	20
Sum of Playing seems automatic	3	9	8	20
Sum of My thoughts go fast	4	8	8	20
Sum of I lose track of where I am	1	16	3	20
Sum of I play without thinking about how to play	3	6	11	20
Sum of Playing makes me feel calm	7	2	11	20
Sum of I play longer than I meant to	1	11	8	20
Sum of I really get into the game	4	2	14	20
Sum of I feel like I just can't stop playing	3	9	8	20

Appendix B

Demographics and Game Engagement Questionnaire Results for Experiment Two

EngagementQuestionnaire_InteractionDepthAxisExperiment

1. Interviewee ID (Ask the interviewing supervisor to fill this out)

	Response Count
	15
answered question	15
skipped question	0

2. Are you a Game Development & Entrepreneurship student at UOIT

	Response Percent	Response Count
Yes	**66.7%**	**10**
No	33.3%	5
answered question		15
skipped question		0

3. Please indicate your gender:

	Response Percent	Response Count
Male	**100.0%**	**15**
Female	0.0%	0
answered question		15
skipped question		0

4. Please indicate your age range:

	Response Percent	Response Count
18-20	**40.0%**	**6**
21-23	26.7%	4
24-26	26.7%	4
27-29	0.0%	0
30-32	0.0%	0
33-35	0.0%	0
35+	6.7%	1
	answered question	**15**
	skipped question	**0**

5. At what age did you start playing video games?

	Response Percent	Response Count
2-5	**46.7%**	**7**
6-9	26.7%	4
10-13	26.7%	4
14-17	0.0%	0
18-21	0.0%	0
22-25	0.0%	0
26+	0.0%	0
	answered question	**15**
	skipped question	**0**

6. Approximately how many hours per week do you play video games?

	Response Percent	Response Count
Less than 5	26.7%	4
5-10	**40.0%**	**6**
11-15	20.0%	3
16-20	13.3%	2
21-25	0.0%	0
26-30	0.0%	0
More than 30	0.0%	0
	answered question	**15**
	skipped question	**0**

7. Have you ever played a game in stereoscopic 3D before?

	Response Percent	Response Count
Yes	**60.0%**	**9**
No	40.0%	6
	answered question	**15**
	skipped question	**0**

8. For video games, how would you rate the stereoscopic 3D experience (vs traditional 2D games) (1 = 2D is much more enjoyable, 4 = equally enjoyable, 7 = stereoscopic 3D is much more enjoyable)

	Response Percent	Response Count
1	6.7%	1
2	0.0%	0
3	13.3%	2
4	26.7%	4
5	**33.3%**	**5**
6	20.0%	3
7	0.0%	0
	answered question	**15**
	skipped question	**0**

9. Have you ever seen a movie in stereoscopic 3D before?

	Response Percent	Response Count
Yes	**100.0%**	**15**
No	0.0%	0
	answered question	**15**
	skipped question	**0**

10. In the movie theatre, how would you rate the stereoscopic 3D experience (vs traditional 2D movies) (1 = 2D is much more enjoyable, 4 = equally enjoyable, 7 = stereoscopic 3D is much more enjoyable)

	Response Percent	Response Count
1	0.0%	0
2	6.7%	1
3	13.3%	2
4	26.7%	4
5	**33.3%**	**5**
6	20.0%	3
7	0.0%	0
	answered question	**15**
	skipped question	**0**

11. Do you currently own a HDTV

	Response Percent	Response Count
Yes	**73.3%**	**11**
No	26.7%	4
I don't know	0.0%	0
	answered question	**15**
	skipped question	**0**

12. Do you currently own a 3D capable HDTV

	Response Percent	Response Count
Yes	6.7%	1
No	**86.7%**	**13**
I don't know	6.7%	1
	answered question	**15**
	skipped question	**0**

13. Do you currently own a 3D capable PC Monitor

	Response Percent	Response Count
Yes	6.7%	1
No	**86.7%**	**13**
I don't know	6.7%	1
	answered question	**15**
	skipped question	**0**

14. Do you currently own a gaming console

	Response Percent	Response Count
Yes	**93.3%**	**14**
No	6.7%	1
	answered question	**15**
	skipped question	**0**

15. If you answered “Yes”, which console(s) do you currently own (specify all)

	Response Percent	Response Count
Playstation 3	**57.1%**	**8**
Xbox 360	50.0%	7
Nintendo Wii	42.9%	6
Nintendo 3DS	21.4%	3
Other	21.4%	3
	Other (please specify)	3
	answered question	**14**
	skipped question	**1**

16. Approximately how much money have you spent in the last year on console games?

	Response Percent	Response Count
None	21.4%	3
$10-$49	0.0%	0
$50-$99	21.4%	3
$100-$199	**28.6%**	**4**
$200-$299	7.1%	1
$300-$399	21.4%	3
$400-$499	0.0%	0
$500 or more	0.0%	0
	answered question	**14**
	skipped question	**1**

17. Do you currently play games on your PC?

	Response Percent	Response Count
Yes	**80.0%**	**12**
No	20.0%	3
	answered question	**15**
	skipped question	**0**

18. Do you currently wear prescription eye glasses?

	Response Percent	Response Count
Yes	20.0%	3
No	**80.0%**	**12**
	answered question	**15**
	skipped question	**0**

19. In your traditional 2D gaming experience please indicate the importance of the following, 1=not-important, 5 being most important:

	1	2	3	4	5	Rating Average	Rating Count
Multi-Player Mode	6.7% (1)	13.3% (2)	26.7% (4)	**33.3% (5)**	20.0% (3)	3.47	15
Single Player Mode	0.0% (0)	0.0% (0)	14.3% (2)	**50.0% (7)**	35.7% (5)	4.21	14
Realistic Graphics (visuals)	6.7% (1)	13.3% (2)	26.7% (4)	**33.3% (5)**	20.0% (3)	3.47	15
Quality of Audio	0.0% (0)	0.0% (0)	26.7% (4)	**53.3% (8)**	20.0% (3)	3.93	15
Surround Sound Audio	6.7% (1)	26.7% (4)	20.0% (3)	**33.3% (5)**	13.3% (2)	3.20	15
Story	6.7% (1)	0.0% (0)	**40.0% (6)**	26.7% (4)	26.7% (4)	3.67	15
Interactivity	0.0% (0)	0.0% (0)	14.3% (2)	14.3% (2)	**71.4% (10)**	4.57	14
						answered question	**15**
						skipped question	**0**

20. For games in stereoscopic 3D, please indicate the importance of the following:

	1	2	3	4	5	Rating Average	Rating Count
Seeing deeply INTO the screen	0.0% (0)	6.7% (1)	33.3% (5)	**40.0% (6)**	20.0% (3)	3.73	15
Having objects come OUT of the screen	0.0% (0)	6.7% (1)	**46.7% (7)**	26.7% (4)	20.0% (3)	3.60	15
Not wearing glasses while playing	13.3% (2)	20.0% (3)	**26.7% (4)**	13.3% (2)	**26.7% (4)**	3.20	15
Playing for more than 1 hour	6.7% (1)	13.3% (2)	**26.7% (4)**	**26.7% (4)**	**26.7% (4)**	3.53	15
Realistic Graphics (visuals)	6.7% (1)	6.7% (1)	26.7% (4)	**46.7% (7)**	13.3% (2)	3.53	15
Multiplayer Mode	13.3% (2)	**33.3% (5)**	**33.3% (5)**	13.3% (2)	6.7% (1)	2.67	15
						answered question	**15**
						skipped question	**0**

21. Was the game in 3D or 2D?

	Response Percent	Response Count
3D	**66.7%**	**10**
2D	33.3%	5
	answered question	**15**
	skipped question	**0**

22. Have you played this game before?

	Response Percent	Response Count
Yes	6.7%	1
No	**93.3%**	**14**
	answered question	**15**
	skipped question	**0**

23. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of time	**46.7% (7)**	20.0% (3)	33.3% (5)	1.87	15
				answered question	**15**
				skipped question	**0**

24. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Things seem to happen automatically	0.0% (0)	**86.7% (13)**	13.3% (2)	2.13	15
				answered question	**15**
				skipped question	**0**

25. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel different	33.3% (5)	**46.7% (7)**	20.0% (3)	1.87	15
				answered question	**15**
				skipped question	**0**

26. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel scared	0.0% (0)	**100.0% (15)**	0.0% (0)	2.00	15
				answered question	**15**
				skipped question	**0**

27. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
The game feels real	6.7% (1)	**80.0% (12)**	13.3% (2)	2.07	15
				answered question	**15**
				skipped question	**0**

28. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
If someone talks to me, I don't hear them	0.0% (0)	**86.7% (13)**	13.3% (2)	2.13	15
				answered question	**15**
				skipped question	**0**

29. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I get wound up	**53.3% (8)**	33.3% (5)	13.3% (2)	1.60	15
				answered question	**15**
				skipped question	**0**

30. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Time seems to kind of standstill or stop	6.7% (1)	**60.0% (9)**	33.3% (5)	2.27	15
				answered question	**15**
				skipped question	**0**

31. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel spaced out	13.3% (2)	**80.0% (12)**	6.7% (1)	1.93	15
				answered question	**15**
				skipped question	**0**

32. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I don’t answer when someone talks to me	0.0% (0)	**93.3% (14)**	6.7% (1)	2.07	15
				answered question	**15**
				skipped question	**0**

33. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I can't tell that I'm getting tired	13.3% (2)	**73.3% (11)**	13.3% (2)	2.00	15
				answered question	**15**
				skipped question	**0**

34. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing seems automatic	13.3% (2)	**80.0% (12)**	6.7% (1)	1.93	15
				answered question	**15**
				skipped question	**0**

35. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
My thoughts go fast	33.3% (5)	**53.3% (8)**	13.3% (2)	1.80	15
				answered question	**15**
				skipped question	**0**

36. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of where I am	26.7% (4)	**60.0% (9)**	13.3% (2)	1.87	15
				answered question	**15**
				skipped question	**0**

37. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play without thinking about how to play	26.7% (4)	**66.7% (10)**	6.7% (1)	1.80	15
				answered question	**15**
				skipped question	**0**

38. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing makes me feel calm	14.3% (2)	**50.0% (7)**	35.7% (5)	2.21	14
				answered question	**14**
				skipped question	**1**

39. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play longer than I meant to	33.3% (5)	**46.7% (7)**	20.0% (3)	1.87	15
				answered question	**15**
				skipped question	**0**

40. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I really get into the game	33.3% (5)	**46.7% (7)**	20.0% (3)	1.87	15
				answered question	**15**
				skipped question	**0**

41. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel like I just can't stop playing	20.0% (3)	**66.7% (10)**	13.3% (2)	1.93	15
				answered question	**15**
				skipped question	**0**

42. Was the game in 3D or 2D?

		Response Percent	Response Count
3D		**53.3%**	**8**
2D		46.7%	7
		answered question	**15**
		skipped question	**0**

43. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of time	**53.3% (8)**	26.7% (4)	20.0% (3)	1.67	15
				answered question	**15**
				skipped question	**0**

44. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Things seem to happen automatically	13.3% (2)	**66.7% (10)**	20.0% (3)	2.07	15
				answered question	**15**
				skipped question	**0**

45. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel different	20.0% (3)	**73.3% (11)**	6.7% (1)	1.87	15
				answered question	**15**
				skipped question	**0**

46. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel scared	0.0% (0)	**100.0% (15)**	0.0% (0)	2.00	15
				answered question	**15**
				skipped question	**0**

47. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
The game feels real	6.7% (1)	**86.7% (13)**	6.7% (1)	2.00	15
				answered question	**15**
				skipped question	**0**

48. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
If someone talks to me, I don't hear them	0.0% (0)	**86.7% (13)**	13.3% (2)	2.13	15
				answered question	**15**
				skipped question	**0**

49. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I get wound up	26.7% (4)	**53.3% (8)**	20.0% (3)	1.93	15
				answered question	**15**
				skipped question	**0**

50. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Time seems to kind of standstill or stop	33.3% (5)	**66.7% (10)**	0.0% (0)	1.67	15
				answered question	**15**
				skipped question	**0**

51. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel spaced out	13.3% (2)	**73.3% (11)**	13.3% (2)	2.00	15
				answered question	**15**
				skipped question	**0**

52. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I don’t answer when someone talks to me	0.0% (0)	**86.7% (13)**	13.3% (2)	2.13	15
				answered question	**15**
				skipped question	**0**

53. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I can’t tell that I’m getting tired	26.7% (4)	**60.0% (9)**	13.3% (2)	1.87	15
				answered question	**15**
				skipped question	**0**

54. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing seems automatic	20.0% (3)	**66.7% (10)**	13.3% (2)	1.93	15
				answered question	**15**
				skipped question	**0**

55. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
My thoughts go fast	**46.7% (7)**	40.0% (6)	13.3% (2)	1.67	15
				answered question	**15**
				skipped question	**0**

56. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of where I am	13.3% (2)	**80.0% (12)**	6.7% (1)	1.93	15
				answered question	**15**
				skipped question	**0**

57. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play without thinking about how to play	33.3% (5)	**53.3% (8)**	13.3% (2)	1.80	15
				answered question	**15**
				skipped question	**0**

58. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing makes me feel calm	26.7% (4)	**66.7% (10)**	6.7% (1)	1.80	15
				answered question	**15**
				skipped question	**0**

59. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play longer than I meant to	13.3% (2)	**60.0% (9)**	26.7% (4)	2.13	15
				answered question	**15**
				skipped question	**0**

60. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I really get into the game	**46.7% (7)**	33.3% (5)	20.0% (3)	1.73	15
				answered question	**15**
				skipped question	**0**

61. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel like I just can’t stop playing	20.0% (3)	**80.0% (12)**	0.0% (0)	1.80	15
				answered question	**15**
				skipped question	**0**

62. Please comment or compare your two sessions? (Which one was more fun, any other remarks)

	Response Count
	15
answered question	**15**
skipped question	**0**

Page 1, Q1. Interviewee ID (Ask the interviewing supervisor to fill this out)		
1	B10	Sep 21, 2012 1:06 PM
2	B09	Sep 21, 2012 7:45 AM
3	A09	Sep 21, 2012 5:59 AM
4	A08	Sep 20, 2012 1:28 PM
5	B08	Sep 20, 2012 1:27 PM
6	B07	Sep 19, 2012 10:29 AM
7	A07	Sep 19, 2012 7:44 AM
8	B06	Sep 14, 2012 8:07 AM
9	B05	Sep 13, 2012 9:58 AM
10	A06	Sep 13, 2012 9:53 AM
11	A05	Sep 11, 2012 12:13 PM
12	A04	Sep 11, 2012 8:50 AM
13	B02	Aug 13, 2012 10:13 AM
14	A03	Aug 13, 2012 10:11 AM
15	A02	Aug 10, 2012 8:56 AM

Page 2, Q15. If you answered “Yes”, which console(s) do you currently own (specify all)		
1	Old Xbox	Sep 21, 2012 7:46 AM
2	Nintendo Gamecube, Playstation 2	Sep 21, 2012 5:59 AM
3	Nintendo DS, Gameboy Advance, Gamecube, Nintendo 64, SNES, NES, Sega Genesis	Sep 13, 2012 10:00 AM

Page 47, Q62. Please comment or compare your two sessions? (Which one was more fun, any other remarks)		
1	The 2nd time was more fun	Sep 21, 2012 2:02 PM
2	The 3D was easier to get through but kind of strained my eyes a little	Sep 21, 2012 8:54 AM
3	The second session was more fun, since I had picked up the nuances of the game in the first session. During the first session I had to become familiar with the up-and-down movement of the ship, and how the environment changes to match my elevation (i.e. blocks becoming transparent if I am under them).	Sep 21, 2012 6:46 AM
4	3D was much more fun. Needs to be easier to tell when level of elevation you are at.	Sep 20, 2012 2:25 PM
5	The 3D one was easier to play, but I'm not sure if the settings were just off or something, but it felt like my eyes weren't used to the 3D. The 2D version was insanely hard to play.	Sep 20, 2012 2:25 PM
6	second session was clearly more enjoyable than the first one.	Sep 19, 2012 11:40 AM
7	3D feels more like a tool to be considered when designing mechanics and fun ideas for a game rather than something that is supposed to be more immersive	Sep 19, 2012 8:23 AM
8	3D was over 9000 times better than 2D. One part I would always respawn right beside a wall and would have to quickly move away. I immediately forgot that pushing R3 is bombs, I was stuck trying to use a button.	Sep 14, 2012 8:56 AM
9	Both equally fun. 3D is a bit harder to concentrate on. It seems that only if you really focus on the screen that it is 3D. Vertical height is quite tricky to determine.	Sep 13, 2012 11:09 AM
10	2D mode was evil, yet I had a pressure to keep playing because I was hoping that I could nab the title of "made furthest progression of all testers". I almost completed it, but was so close to facing the boss. Either way, evil evil evil. 3D Mode was more fair, however one frustrating thing that still didn't change from the 2D version, was the altitude that the ship was at. The 3D mode gave me a better visual for which altitude I was at, but not entirely accurately. This is why I still slammed into floors and ceilings whenever I had to adjust my altitude. Besides that, I enjoyed the game's challenge, and I conquered the 3D version. Because of that, I feel accomplished and proud of myself, and now I should probably get on my homework... :/	Sep 13, 2012 11:03 AM
11	The 3D was more fun. In 2D I'm always crashing into the floor...	Sep 11, 2012 1:23 PM
12	The first session was easily a much better experience. The second was much more frustrating when trying to locate where the ship was. I found myself relying on memories of the first session and the "order of operations" of how I got through trickier areas while playing the second time. Without the first playthrough in my head, the second would have been incredibly frustrating. I also thought the boss level was really fun. I couldn't tell if he changed depth though, maybe I just got lucky.	Sep 11, 2012 9:38 AM
13	The game in 3d was more enjoyable than the 2d one. I didn't have idea what level the starship was in some points.	Aug 13, 2012 11:30 AM
14	The 2D session lasted a much longer period of time, and I had a very hard time	Aug 13, 2012 11:16 AM

Page 47, Q62. Please comment or compare your two sessions? (Which one was more fun, any other remarks)		
	figuring out what depth level I was on compared to other blocks. The 2D session was my first one, so I was also learning the game mechanics. The 3D session was much, much easier, as I could distinctly tell where the blocks were compared to me, and therefore how to solve the puzzle. One thing I found confusing is that while your crosshair moves in a discrete manner (1 press = 1 level gone down/up) while the ship was not (lentgh of press determines how much to go up/down). This made it difficult to tell (in both 2D and 3D, although 3D was easier) if I was on the proper level, and therefore would smash into the ceiling/floor sometimes.	
15	3d was a good way to start because the second time around i had very few visual queues for depth, so because i had that knowledge from the first run so i could impulse through the 2d run	Aug 10, 2012 9:59 AM

Appendix C

Demographics and Game Engagement Questionnaire Results for Experiment Three

Zfighter_thesis

SurveyMonkey

1. Interviewee ID (Ask the interviewing supervisor to fill this out)

	Response Count
	48
answered question	48
skipped question	0

2. Are you a Game Development & Entrepreneurship student at UOIT

	Response Percent	Response Count
Yes	62.5%	30
No	37.5%	18
answered question		48
skipped question		0

3. Please indicate your gender:

	Response Percent	Response Count
Male	100.0%	48
Female	0.0%	0
answered question		48
skipped question		0

4. Please indicate your age range:

	Response Percent	Response Count
18-20	27.1%	13
21-23	**56.3%**	**27**
24-26	10.4%	5
27-29	6.3%	3
30-32	0.0%	0
33-35	0.0%	0
35+	0.0%	0
	answered question	**48**
	skipped question	**0**

5. At what age did you start playing video games?

	Response Percent	Response Count
2-5	37.5%	18
6-9	**54.2%**	**26**
10-13	8.3%	4
14-17	0.0%	0
18-21	0.0%	0
22-25	0.0%	0
26+	0.0%	0
	answered question	**48**
	skipped question	**0**

6. Approximately how many hours per week do you play video games?

	Response Percent	Response Count
Less than 5	**22.9%**	**11**
5-10	**22.9%**	**11**
11-15	18.8%	9
16-20	20.8%	10
21-25	8.3%	4
26-30	2.1%	1
More than 30	4.2%	2
	answered question	**48**
	skipped question	**0**

7. Have you ever played a game in stereoscopic 3D before?

	Response Percent	Response Count
Yes	**83.3%**	**40**
No	16.7%	8
	answered question	**48**
	skipped question	**0**

8. For video games, how would you rate the stereoscopic 3D experience (vs traditional 2D games) (1 = 2D is much more enjoyable, 4 = equally enjoyable, 7 = stereoscopic 3D is much more enjoyable)

	Response Percent	Response Count
1	6.3%	3
2	8.3%	4
3	18.8%	9
4	**37.5%**	**18**
5	20.8%	10
6	6.3%	3
7	2.1%	1
	answered question	**48**
	skipped question	**0**

9. Have you ever seen a movie in stereoscopic 3D before?

	Response Percent	Response Count
Yes	**97.9%**	**47**
No	2.1%	1
	answered question	**48**
	skipped question	**0**

10. In the movie theatre, how would you rate the stereoscopic 3D experience (vs traditional 2D movies) (1 = 2D is much more enjoyable, 4 = equally enjoyable, 7 = stereoscopic 3D is much more enjoyable)

	Response Percent	Response Count
1	10.4%	5
2	12.5%	6
3	20.8%	10
4	**27.1%**	**13**
5	14.6%	7
6	10.4%	5
7	4.2%	2
	answered question	**48**
	skipped question	**0**

11. Do you currently own a HDTV

	Response Percent	Response Count
Yes	**72.9%**	**35**
No	27.1%	13
I don't know	0.0%	0
	answered question	**48**
	skipped question	**0**

12. Do you currently own a 3D capable HDTV

	Response Percent	Response Count
Yes	12.5%	6
No	**85.4%**	**41**
I don't know	2.1%	1
	answered question	**48**
	skipped question	**0**

13. Do you currently own a 3D capable PC Monitor

	Response Percent	Response Count
Yes	6.3%	3
No	**91.7%**	**44**
I don't know	2.1%	1
	answered question	**48**
	skipped question	**0**

14. Do you currently own a gaming console

	Response Percent	Response Count
Yes	**89.6%**	**43**
No	10.4%	5
	answered question	**48**
	skipped question	**0**

15. If you answered “Yes”, which console(s) do you currently own (specify all)

	Response Percent	Response Count
Playstation 3	**57.1%**	**24**
Xbox 360	54.8%	23
Nintendo Wii	28.6%	12
Nintendo 3DS	26.2%	11
Other	42.9%	18
	Other (please specify)	18
	answered question	**42**
	skipped question	**6**

16. Approximately how much money have you spent in the last year on console games?

	Response Percent	Response Count
None	11.6%	5
$10-$49	9.3%	4
$50-$99	**30.2%**	**13**
$100-$199	**30.2%**	**13**
$200-$299	11.6%	5
$300-$399	4.7%	2
$400-$499	2.3%	1
$500 or more	0.0%	0
	answered question	**43**
	skipped question	**5**

17. Do you currently play games on your PC?

	Response Percent	Response Count
Yes	**95.8%**	**46**
No	4.2%	2
	answered question	**48**
	skipped question	**0**

18. Are you currently wearing prescription eye glasses?

	Response Percent	Response Count
Yes	**50.0%**	**24**
No	**50.0%**	**24**
	answered question	**48**
	skipped question	**0**

19. In your traditional 2D gaming experience please indicate the importance of the following, 1=not-important, 5 being most important:

	1	2	3	4	5	Rating Average	Rating Count
Multi-Player Mode	8.3% (4)	12.5% (6)	**35.4% (17)**	22.9% (11)	20.8% (10)	3.35	48
Single Player Mode	4.2% (2)	4.2% (2)	16.7% (8)	25.0% (12)	**50.0% (24)**	4.13	48
Realistic Graphics (visuals)	14.6% (7)	20.8% (10)	**35.4% (17)**	18.8% (9)	10.4% (5)	2.90	48
Quality of Audio	0.0% (0)	8.3% (4)	31.3% (15)	**41.7% (20)**	18.8% (9)	3.71	48
Surround Sound Audio	12.5% (6)	**37.5% (18)**	27.1% (13)	16.7% (8)	6.3% (3)	2.67	48
Story	4.3% (2)	8.5% (4)	17.0% (8)	34.0% (16)	**36.2% (17)**	3.89	47
Interactivity	0.0% (0)	2.1% (1)	8.3% (4)	35.4% (17)	**54.2% (26)**	4.42	48
						answered question	**48**
						skipped question	**0**

20. For games in stereoscopic 3D, please indicate the importance of the following:

	1	2	3	4	5	Rating Average	Rating Count
Seeing deeply INTO the screen	6.3% (3)	2.1% (1)	29.2% (14)	**45.8% (22)**	16.7% (8)	3.65	48
Having objects come OUT of the screen	8.3% (4)	12.5% (6)	**37.5% (18)**	33.3% (16)	8.3% (4)	3.21	48
Not wearing glasses while playing	12.5% (6)	16.7% (8)	**33.3% (16)**	18.8% (9)	18.8% (9)	3.15	48
Playing for more than 1 hour	8.3% (4)	14.6% (7)	**35.4% (17)**	16.7% (8)	25.0% (12)	3.35	48
Realistic Graphics (visuals)	8.3% (4)	12.5% (6)	**35.4% (17)**	25.0% (12)	18.8% (9)	3.33	48
Multiplayer Mode	22.9% (11)	25.0% (12)	**37.5% (18)**	6.3% (3)	8.3% (4)	2.52	48
						answered question	**48**
						skipped question	**0**

21. Have you played this game before?

		Response Percent	Response Count
Yes		6.3%	3
No		**93.8%**	**45**
		answered question	**48**
		skipped question	**0**

22. How did you play the game? with..

		Response Percent	Response Count
Stereoscopic 3D		**77.1%**	**37**
Shadows		6.3%	3
HUD		8.3%	4
None of the Above		8.3%	4
		answered question	**48**
		skipped question	**0**

23. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of time	**50.0% (24)**	18.8% (9)	31.3% (15)	1.81	48
				answered question	**48**
				skipped question	**0**

24. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Things seem to happen automatically	16.7% (8)	**75.0% (36)**	8.3% (4)	1.92	48
				answered question	**48**
				skipped question	**0**

25. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel different	20.8% (10)	**66.7% (32)**	12.5% (6)	1.92	48
				answered question	**48**
				skipped question	**0**

26. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel scared	2.1% (1)	**97.9% (47)**	0.0% (0)	1.98	48
				answered question	**48**
				skipped question	**0**

27. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
The game feels real	10.4% (5)	**72.9% (35)**	16.7% (8)	2.06	48
				answered question	**48**
				skipped question	**0**

28. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
If someone talks to me, I don't hear them	6.3% (3)	**64.6% (31)**	29.2% (14)	2.23	48
				answered question	**48**
				skipped question	**0**

29. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I get wound up	**66.7% (32)**	18.8% (9)	14.6% (7)	1.48	48
				answered question	**48**
				skipped question	**0**

30. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Time seems to kind of standstill or stop	27.1% (13)	**62.5% (30)**	10.4% (5)	1.83	48
				answered question	**48**
				skipped question	**0**

31. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel spaced out	27.1% (13)	**62.5% (30)**	10.4% (5)	1.83	48
				answered question	**48**
				skipped question	**0**

32. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I don’t answer when someone talks to me	4.2% (2)	**68.8% (33)**	27.1% (13)	2.23	48
				answered question	**48**
				skipped question	**0**

33. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I can’t tell that I’m getting tired	22.9% (11)	**56.3% (27)**	20.8% (10)	1.98	48
				answered question	**48**
				skipped question	**0**

34. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing seems automatic	25.0% (12)	**62.5% (30)**	12.5% (6)	1.88	48
				answered question	**48**
				skipped question	**0**

35. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
My thoughts go fast	41.7% (20)	**47.9% (23)**	10.4% (5)	1.69	48
				answered question	**48**
				skipped question	**0**

36. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of where I am	20.8% (10)	**62.5% (30)**	16.7% (8)	1.96	48
				answered question	**48**
				skipped question	**0**

37. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play without thinking about how to play	27.1% (13)	**60.4% (29)**	12.5% (6)	1.85	48
				answered question	**48**
				skipped question	**0**

38. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing makes me feel calm	10.4% (5)	**66.7% (32)**	22.9% (11)	2.13	48
				answered question	**48**
				skipped question	**0**

39. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play longer than I meant to	**37.5% (18)**	35.4% (17)	27.1% (13)	1.90	48
				answered question	**48**
				skipped question	**0**

40. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I really get into the game	**68.8% (33)**	12.5% (6)	18.8% (9)	1.50	48
				answered question	**48**
				skipped question	**0**

41. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel like I just can't stop playing	25.0% (12)	**50.0% (24)**	25.0% (12)	2.00	48
				answered question	**48**
				skipped question	**0**

42. How did you play the game? with..

	Response Percent	Response Count
Stereoscopic 3D	**35.4%**	**17**
Shadows	33.3%	16
HUD	22.9%	11
None of the Above	8.3%	4
	answered question	**48**
	skipped question	**0**

43. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of time	34.0% (16)	**57.4% (27)**	8.5% (4)	1.74	47
				answered question	**47**
				skipped question	**1**

44. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Things seem to happen automatically	39.6% (19)	**54.2% (26)**	6.3% (3)	1.67	48
				answered question	**48**
				skipped question	**0**

45. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel different	18.8% (9)	**70.8% (34)**	10.4% (5)	1.92	48
				answered question	**48**
				skipped question	**0**

46. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel scared	0.0% (0)	**100.0% (48)**	0.0% (0)	2.00	48
				answered question	**48**
				skipped question	**0**

47. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
The game feels real	16.7% (8)	**70.8% (34)**	12.5% (6)	1.96	48
				answered question	**48**
				skipped question	**0**

48. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
If someone talks to me, I don't hear them	4.2% (2)	**66.7% (32)**	29.2% (14)	2.25	48
				answered question	**48**
				skipped question	**0**

49. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I get wound up	**50.0% (24)**	43.8% (21)	6.3% (3)	1.56	48
				answered question	**48**
				skipped question	**0**

50. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Time seems to kind of standstill or stop	22.9% (11)	**66.7% (32)**	10.4% (5)	1.88	48
				answered question	**48**
				skipped question	**0**

51. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel spaced out	16.7% (8)	**75.0% (36)**	8.3% (4)	1.92	48
				answered question	**48**
				skipped question	**0**

52. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I don't answer when someone talks to me	4.2% (2)	**68.8% (33)**	27.1% (13)	2.23	48
				answered question	**48**
				skipped question	**0**

53. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I can't tell that I'm getting tired	16.7% (8)	**64.6% (31)**	18.8% (9)	2.02	48
				answered question	**48**
				skipped question	**0**

54. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing seems automatic	**50.0% (24)**	39.6% (19)	10.4% (5)	1.60	48
				answered question	**48**
				skipped question	**0**

55. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
My thoughts go fast	45.8% (22)	**50.0% (24)**	4.2% (2)	1.58	48
				answered question	**48**
				skipped question	**0**

56. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of where I am	29.2% (14)	**66.7% (32)**	4.2% (2)	1.75	48
				answered question	**48**
				skipped question	**0**

57. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play without thinking about how to play	**53.2% (25)**	38.3% (18)	8.5% (4)	1.55	47
				answered question	**47**
				skipped question	**1**

58. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing makes me feel calm	16.7% (8)	**62.5% (30)**	20.8% (10)	2.04	48
				answered question	**48**
				skipped question	**0**

59. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play longer than I meant to	20.8% (10)	**62.5% (30)**	16.7% (8)	1.96	48
				answered question	**48**
				skipped question	**0**

60. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I really get into the game	**58.3% (28)**	18.8% (9)	22.9% (11)	1.65	48
				answered question	**48**
				skipped question	**0**

61. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel like I just can't stop playing	22.9% (11)	**66.7% (32)**	10.4% (5)	1.88	48
				answered question	**48**
				skipped question	**0**

62. How did you play the game? with..

	Response Percent	Response Count
Stereoscopic 3D	**37.5%**	**18**
Shadows	25.0%	12
HUD	22.9%	11
None of the Above	14.6%	7
	answered question	**48**
	skipped question	**0**

63. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of time	27.7% (13)	**68.1% (32)**	4.3% (2)	1.77	47
				answered question	**47**
				skipped question	**1**

64. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Things seem to happen automatically	**43.8% (21)**	41.7% (20)	14.6% (7)	1.71	48
				answered question	**48**
				skipped question	**0**

65. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel different	20.8% (10)	**75.0% (36)**	4.2% (2)	1.83	48
				answered question	**48**
				skipped question	**0**

66. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel scared	2.1% (1)	**97.9% (47)**	0.0% (0)	1.98	48
				answered question	**48**
				skipped question	**0**

67. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
The game feels real	16.7% (8)	**72.9% (35)**	10.4% (5)	1.94	48
				answered question	**48**
				skipped question	**0**

68. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
If someone talks to me, I don't hear them	2.1% (1)	**70.8% (34)**	27.1% (13)	2.25	48
				answered question	**48**
				skipped question	**0**

69. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I get wound up	**47.9% (23)**	45.8% (22)	6.3% (3)	1.58	48
				answered question	**48**
				skipped question	**0**

70. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Time seems to kind of standstill or stop	20.8% (10)	**75.0% (36)**	4.2% (2)	1.83	48
				answered question	**48**
				skipped question	**0**

71. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel spaced out	16.7% (8)	**70.8% (34)**	12.5% (6)	1.96	48
				answered question	**48**
				skipped question	**0**

72. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I don’t answer when someone talks to me	4.2% (2)	**70.8% (34)**	25.0% (12)	2.21	48
				answered question	**48**
				skipped question	**0**

73. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I can't tell that I'm getting tired	16.7% (8)	**70.8% (34)**	12.5% (6)	1.96	48
				answered question	**48**
				skipped question	**0**

74. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing seems automatic	**54.2% (26)**	33.3% (16)	12.5% (6)	1.58	48
				answered question	**48**
				skipped question	**0**

75. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
My thoughts go fast	**54.2% (26)**	41.7% (20)	4.2% (2)	1.50	48
				answered question	**48**
				skipped question	**0**

76. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of where I am	21.3% (10)	**70.2% (33)**	8.5% (4)	1.87	47
				answered question	**47**
				skipped question	**1**

77. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play without thinking about how to play	**64.6% (31)**	31.3% (15)	4.2% (2)	1.40	48
				answered question	**48**
				skipped question	**0**

78. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing makes me feel calm	16.7% (8)	**60.4% (29)**	22.9% (11)	2.06	48
				answered question	**48**
				skipped question	**0**

79. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play longer than I meant to	16.7% (8)	**66.7% (32)**	16.7% (8)	2.00	48
				answered question	**48**
				skipped question	**0**

80. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I really get into the game	**58.3% (28)**	29.2% (14)	12.5% (6)	1.54	48
				answered question	**48**
				skipped question	**0**

81. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel like I just can’t stop playing	20.8% (10)	**72.9% (35)**	6.3% (3)	1.85	48
				answered question	**48**
				skipped question	**0**

82. How did you play the game? with..

		Response Percent	Response Count
Stereoscopic 3D		27.1%	13
Shadows		27.1%	13
HUD		16.7%	8
None of the Above		**29.2%**	**14**
		answered question	**48**
		skipped question	**0**

83. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of time	34.0% (16)	**63.8% (30)**	2.1% (1)	1.68	47
				answered question	**47**
				skipped question	**1**

84. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Things seem to happen automatically	**50.0% (24)**	39.6% (19)	10.4% (5)	1.60	48
				answered question	**48**
				skipped question	**0**

85. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel different	20.8% (10)	**72.9% (35)**	6.3% (3)	1.85	48
				answered question	**48**
				skipped question	**0**

86. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel scared	0.0% (0)	**97.9% (47)**	2.1% (1)	2.02	48
				answered question	**48**
				skipped question	**0**

87. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
The game feels real	14.6% (7)	**75.0% (36)**	10.4% (5)	1.96	48
				answered question	**48**
				skipped question	**0**

88. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
If someone talks to me, I don't hear them	4.2% (2)	**72.9% (35)**	22.9% (11)	2.19	48
				answered question	**48**
				skipped question	**0**

89. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I get wound up	41.7% (20)	**54.2% (26)**	4.2% (2)	1.63	48
				answered question	**48**
				skipped question	**0**

90. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Time seems to kind of standstill or stop	22.9% (11)	**72.9% (35)**	4.2% (2)	1.81	48
				answered question	**48**
				skipped question	**0**

91. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel spaced out	16.7% (8)	**75.0% (36)**	8.3% (4)	1.92	48
				answered question	**48**
				skipped question	**0**

92. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I don’t answer when someone talks to me	6.3% (3)	**68.8% (33)**	25.0% (12)	2.19	48
				answered question	**48**
				skipped question	**0**

93. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I can’t tell that I’m getting tired	16.7% (8)	**64.6% (31)**	18.8% (9)	2.02	48
				answered question	**48**
				skipped question	**0**

94. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing seems automatic	**60.4% (29)**	33.3% (16)	6.3% (3)	1.46	48
				answered question	**48**
				skipped question	**0**

95. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
My thoughts go fast	**47.9% (23)**	45.8% (22)	6.3% (3)	1.58	48
				answered question	**48**
				skipped question	**0**

96. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of where I am	20.8% (10)	**70.8% (34)**	8.3% (4)	1.88	48
				answered question	**48**
				skipped question	**0**

97. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play without thinking about how to play	**64.6% (31)**	25.0% (12)	10.4% (5)	1.46	48
				answered question	**48**
				skipped question	**0**

98. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing makes me feel calm	18.8% (9)	**60.4% (29)**	20.8% (10)	2.02	48
				answered question	**48**
				skipped question	**0**

99. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play longer than I meant to	27.1% (13)	**62.5% (30)**	10.4% (5)	1.83	48
				answered question	**48**
				skipped question	**0**

100. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I really get into the game	**58.3% (28)**	31.3% (15)	10.4% (5)	1.52	48
				answered question	**48**
				skipped question	**0**

101. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel like I just can't stop playing	20.8% (10)	**66.7% (32)**	12.5% (6)	1.92	48
				answered question	**48**
				skipped question	**0**

102. Which session did you enjoy more? Have more fun with?

	Response Percent	Response Count
None	2.1%	1
HUD	12.5%	6
Shadow	35.4%	17
Stereoscopic 3D	**50.0%**	**24**
	Why?	48
	answered question	**48**
	skipped question	**0**

103. Which session do you feel you preformed best in?

	Response Percent	Response Count
None	4.3%	2
HUD	**40.4%**	**19**
Shadow	19.1%	9
Stereoscopic 3D	36.2%	17
	Why?	48
	answered question	**47**
	skipped question	**1**

104. Any other remarks about the differences between each session?

	Response Count
	37
answered question	**37**
skipped question	**11**

105. Any general comments about the game?

	Response Count
	42
answered question	**42**
skipped question	**6**

Page 1, Q1. Interviewee ID (Ask the interviewing supervisor to fill this out)		
1	O06	Aug 27, 2013 4:21 PM
2	V05	Aug 25, 2013 1:07 PM
3	T05	Aug 25, 2013 12:20 PM
4	W05	Aug 24, 2013 12:03 PM
5	U05	Aug 24, 2013 12:03 PM
6	X05	Aug 23, 2013 7:17 AM
7	Q05	Aug 23, 2013 6:34 AM
8	S05	Aug 22, 2013 12:18 PM
9	R05	Aug 22, 2013 12:18 PM
10	P05	Aug 22, 2013 10:47 AM
11	N05	Aug 21, 2013 11:50 AM
12	O05	Aug 21, 2013 11:50 AM
13	M05	Aug 20, 2013 12:06 PM
14	L05	Aug 20, 2013 11:46 AM
15	K05	Aug 20, 2013 10:51 AM
16	I02	Jul 30, 2013 11:09 AM
17	G02	Jul 30, 2013 8:41 AM
18	H02	Jul 26, 2013 11:05 AM
19	J02	Jul 26, 2013 11:03 AM
20	F03	Jul 24, 2013 11:12 AM
21	T03	Jul 24, 2013 11:12 AM
22	U02	Jul 24, 2013 11:11 AM
23	E03	Jul 24, 2013 11:11 AM
24	W02	Jul 18, 2013 10:43 AM
25	V01	Jul 17, 2013 2:31 PM
26	X01	Jul 17, 2013 2:31 PM
27	D04	Jul 13, 2013 8:44 AM

Page 1, Q1. Interviewee ID (Ask the interviewing supervisor to fill this out)		
28	A04	Jul 13, 2013 8:42 AM
29	B04	Jul 13, 2013 8:42 AM
30	C04	Jul 13, 2013 8:41 AM
31	R01	Jul 12, 2013 2:04 PM
32	S01	Jul 12, 2013 2:01 PM
33	Q01	Jul 12, 2013 1:59 PM
34	N01	Jul 10, 2013 1:38 PM
35	M01	Jul 10, 2013 1:36 PM
36	P01	Jul 10, 2013 1:34 PM
37	L03	Jul 9, 2013 12:51 PM
38	K01	Jul 4, 2013 10:08 AM
39	I01	Jul 3, 2013 8:28 AM
40	J01	Jul 3, 2013 8:28 AM
41	H01	Jul 3, 2013 8:28 AM
42	G01	Jun 28, 2013 9:37 AM
43	F01	Jun 28, 2013 8:57 AM
44	E01	Jun 28, 2013 8:57 AM
45	A01	Jun 27, 2013 11:54 AM
46	D01	Jun 27, 2013 11:53 AM
47	B01	Jun 27, 2013 11:50 AM
48	C01	Jun 27, 2013 11:47 AM

Page 2, Q15. If you answered “Yes”, which console(s) do you currently own (specify all)		
1	Colecovision Hockey 4-Can-Play	Aug 27, 2013 4:22 PM
2	N64, Super Nintendo, NES, Master system, Xbox, Game Boy, Game Boy Color, Game Boy Advance, PS2	Aug 24, 2013 12:05 PM
3	psp	Aug 24, 2013 12:03 PM
4	PC	Aug 23, 2013 7:17 AM
5	Nintendo Wii u	Aug 22, 2013 10:47 AM
6	Gameboy Advance, Nintendo 64	Aug 21, 2013 11:50 AM
7	N64, Super Nintendo, NES, Master system	Aug 20, 2013 10:52 AM
8	Sega Dreamcast and N64	Jul 30, 2013 11:10 AM
9	PC	Jul 30, 2013 8:42 AM
10	PC	Jul 17, 2013 2:32 PM
11	PC	Jul 17, 2013 2:32 PM
12	PC	Jul 13, 2013 8:43 AM
13	Nintendo	Jul 13, 2013 8:41 AM
14	Xbox	Jul 3, 2013 8:28 AM
15	PC	Jun 28, 2013 8:58 AM
16	Playstation 2	Jun 27, 2013 11:54 AM
17	N64, Gamecube	Jun 27, 2013 11:53 AM
18	PC	Jun 27, 2013 11:48 AM

Page 89, Q102. Which session did you enjoy more? Have more fun with?		
1	I personally had difficulty discerning depth in the Stereoscopic 3D experience (but I also have terrible depth perception),so it made the game almost like trial and error in a sense. In the shadow experience, the shadowing made it much easier to see where I needed to go. The HUD experience was almost too easy.	Dec 12, 2013 7:25 PM
2	HUD was distracting. Shadow provided a better, natural depth gauge. HUD implementation would have been better served in later test for fine tuning than a distraction on understanding the early rhythm of the game.	Aug 27, 2013 5:07 PM
3	Easy to tell height difference	Aug 25, 2013 2:02 PM
4	It was easiest	Aug 25, 2013 1:50 PM
5	Because it was an additional tool to help me figure out where I was because I didn't realize the HUD was there before and could be beneficial.	Aug 24, 2013 1:05 PM
6	it's easiest, don't need to look away from where I'm going. I just play.	Aug 24, 2013 12:57 PM
7	The HUD was extremely useful when navigating through the level and was useful to determine when to go up or down	Aug 23, 2013 8:17 AM
8	It was much easier to determine where the ship was positioned	Aug 23, 2013 7:16 AM
9	S3D was a lot easier than the other conditions. The other conditions made me feel frustrated and negative. I did not always understand why I died in the HUD condition, and sometimes the shadow condition because I miscalculated the height of my ship. The stereoscopic condition was more fun, more enjoyable, and I would play it for a lot longer if I could due to its enjoyability. I would not want to play the HUD condition at all. The shadow condition was better than the HUD condition, but not as good as stereoscopic 3D condition.	Aug 22, 2013 1:24 PM
10	I felt like judging distance felt more natural, and not have to switch between judging distance and moving	Aug 22, 2013 1:20 PM
11	I think that S3D made the spatial awareness much faster than looking at the HUD, so I believe that is why I enjoyed it the most. It was pretty well applied to the game.	Aug 22, 2013 11:38 AM
12	The other three options were extremely frustrating. In particular, the None and HUD ones were hard to play. The stereoscopic 3D variant felt natural and the mazes seemed solvable.	Aug 21, 2013 1:23 PM
13	It felt the most natural. This condition and the HUD one were definitely the best for me, but the HUD one required you to direct attention away from the main action while with 3D I could immerse myself more in the action of "flying" the spacecraft.	Aug 21, 2013 1:20 PM
14	If it weren't for the fact that I learned the level by heart the first two times through, I doubt I'd have beaten the game. I would have said the HUD but it was pretty poor to use as I couldn't see columns beside me. Also the combo of having learned where the platforms roughly were and learning to just go up and down until I hit the cylinders rendered the HUD useless. That said the shadows were better than nothing so didn't mind them too much.	Aug 20, 2013 1:10 PM

Page 89, Q102. Which session did you enjoy more? Have more fun with?		
15	Most noticibly different than the others. Easiest to play, although it was my 3rd go. 3D was a very close 2nd.	Aug 20, 2013 12:25 PM
16	Of all the methods, it gives you the best perception of where you are vertically, while not as intuitive, the second level has a really tight fit at the end, and the HUD was the one that made it the easiest, though i got hang of the timing near the end.	Aug 20, 2013 11:42 AM
17	fun game play.	Jul 30, 2013 12:31 PM
18	The shadow session was the most enjoyable for me because it was the least frustrating. With the 3D ones, it's a bit harder to tell your height relative to the boxes and bombs.	Jul 30, 2013 9:52 AM
19	Because I could experience depth much easier than with the other sessions.	Jul 26, 2013 11:55 AM
20	it was easier to see blocks that were in the way. Also easier to see how high things might be.	Jul 26, 2013 11:55 AM
21	Hud was the only version of the game that was actually playable without the feeling of having an aneurism	Jul 24, 2013 12:52 PM
22	It was my 4th time playing the lvl and I knew how to play it. Plus the shadows were a nice touch a lvl which I had seen 4 times	Jul 24, 2013 12:43 PM
23	The Hud one was the most fun as it made the game mechanics feel better.	Jul 24, 2013 12:39 PM
24	It was the most fun to play and it ended up being pretty easy to figure out the depth quickly.	Jul 24, 2013 12:22 PM
25	Was the easiest to distinguish height at a glance	Jul 18, 2013 11:46 AM
26	I could tell where I was but also didn't have to look at the HUD, which took away from some of the immersion. I also liked it more than 3D because the image looked more crisp, which I felt made it easier to move around.	Jul 17, 2013 3:22 PM
27	BECAUSE I COULD CLEARLY SEE MY SHIPS HEIGHT!	Jul 17, 2013 3:21 PM
28	Practice made it easiest	Jul 13, 2013 9:50 AM
29	Looks awesome!	Jul 13, 2013 9:41 AM
30	It looked the best.	Jul 13, 2013 9:29 AM
31	I could differentiate with depth so I could easily know how close I was to powering the ship and make better judgement calls when moving to forward blocks. Also, HUD mode was really interesting but a little overpowering so it takes second place.	Jul 13, 2013 9:28 AM
32	When playing the game in stereoscopic 3D it was much easier to differentiate depth. It was still harder to play than with the HUD, but it was more of a fun challenge.	Jul 12, 2013 3:13 PM
33	I was most successful with this one. It made it really easy to finish the last drop	Jul 12, 2013 3:05 PM

Page 89, Q102. Which session did you enjoy more? Have more fun with?		
	on the second level. This was a real difficulty with the other sessions.	
34	Seemed the most intuitive. I was the most involved without relying on HUD.	Jul 12, 2013 2:34 PM
35	I felt like I could actually see the difference in height when it came to 3D, With the others I actually couldn't see what was going on.	Jul 10, 2013 2:40 PM
36	The particle effects, cubes and ship felt more 'real', and seemed to be 'inside' of the screen. This helped me navigate the depth mazes and was more entertaining to experience. The laser particle effects were also much more noticeable with 3D, which helped me orient myself in relation to other cubes.	Jul 10, 2013 2:39 PM
37	The shadow makes it much easier to navigate tight vertical spaces.	Jul 10, 2013 2:23 PM
38	Shadows is hard to judge the height/depth and HUD is challenging to multitask with the actual game.	Jul 9, 2013 1:44 PM
39	The shadows provided a frame of reference to how high or low each object was, and that information was available for all rows at a glance rather than having to look at the HUD or make guesses based on 3D without shadows.	Jul 4, 2013 11:15 AM
40	It gave the most information about the environment. It was as useful as the HUD but better because I didn't have to look off-screen, and it was easier to perceive than the 3D	Jul 3, 2013 9:27 AM
41	It was the easiest to identify depth and where my spaceship was - less frustrating!	Jul 3, 2013 9:09 AM
42	could tell the placement of the ship the best in that mode	Jun 28, 2013 10:34 AM
43	the 3d one as it felt the best	Jun 28, 2013 9:46 AM
44	The game felt very real, and judging depth felt natural and was easy.	Jun 28, 2013 9:37 AM
45	I could easily tell the depth of all the objects.	Jun 27, 2013 12:57 PM
46	Having the shadow in the first round was actually good because it have me a good sense of where all of the objects were located. Having never played the game before, the shadows provided a good depth cue to help me learn about the environment. Also the shadows seemed the most realistic because that is what we have as a depth cue in reality.	Jun 27, 2013 12:51 PM
47	Was fun to use the shadows to try and tell the heights of different things; especially the ship's shadow.	Jun 27, 2013 12:41 PM
48	Looked better.	Jun 27, 2013 12:35 PM

Page 89, Q103. Which session do you feel you preformed best in?		
1	Because I died significantly less than the other experiences.	Dec 12, 2013 7:25 PM
2	HUD offered the best way to understand how to get through the levels and where you were failing. It would be a way to train players rather than a full implement.	Aug 27, 2013 5:07 PM
3	easy to tell height difference	Aug 25, 2013 2:02 PM
4	It was easiest	Aug 25, 2013 1:50 PM
5	Once I figured out how to get through the last section of the last puzzle. (The number of clicks required to drop the ship it became easy.) Had I attempted to use the HUD more it probably would have helped me out earlier on.	Aug 24, 2013 1:05 PM
6	Same reasons as above, I could look at where I was going and adjust as needed.	Aug 24, 2013 12:57 PM
7	The HUD allow me to navigate through the level successfully	Aug 23, 2013 8:17 AM
8	It was much easier to determine where the ship was positioned	Aug 23, 2013 7:16 AM
9	I could tell the height of my ship very easily in this condition. This condition did not frustrate me at all.	Aug 22, 2013 1:24 PM
10	It gave an easy way to tell distance from the ground	Aug 22, 2013 1:20 PM
11	However, sometimes, even with S3D, I felt a bit lost in regards to the spatial location of the ship, by a slight height. Using the HUD solved this problem varioustimes.	Aug 22, 2013 11:38 AM
12	Because I was fastest in these and it was the last one I played. So, I knew how the levels were structured.	Aug 21, 2013 1:23 PM
13	I feel I performed best in 3D. Again, HUD and 3D actually allow you to see where you are. However HUD requires constant redirection of attention whereas in 3D I could keep focused on the spacecraft.	Aug 21, 2013 1:20 PM
14	It was all motor memory here and the 3D didn't really hinder my game play.	Aug 20, 2013 1:10 PM
15	My 3rd run, beat both levels on the first try. Already knew the levels and how the game worked. Shadows were nice visual touch that helped me get immersed more.	Aug 20, 2013 12:25 PM
16	Of all the methods, it gives you the best perception of where you are vertically, while not as intuitive, the second level has a really tight fit at the end, and the HUD was the one that made it the easiest, though i got hang of the timing near the end.	Aug 20, 2013 11:42 AM
17	I was horrible at the game at first. I had trouble figuring out what to do. I eventually got the hang of it but I was still terrible at the game!	Jul 30, 2013 12:31 PM
18	Same reasons as before.	Jul 30, 2013 9:52 AM
19	Because level of depth was much more natural and organic.	Jul 26, 2013 11:55 AM

Page 89, Q103. Which session do you feel you preformed best in?		
20	It was a lot easier to see the layout of the level.	Jul 26, 2013 11:55 AM
21	Game was able to be completed in a reasonable amount of time without having to do anything gargantuan as having to pause the game and adjust heights	Jul 24, 2013 12:52 PM
22	It was my 4th time playing the lvl and I knew how to play it. The shadows though didn't really help too much	Jul 24, 2013 12:43 PM
23	The HUD as it made it so much easier to avoid obstacles reducing the amount of difficult there was.	Jul 24, 2013 12:39 PM
24	I think I started doing really well in this stage, I played the shadow stage after but both of them were just as easy because I had played the game a fair bit and memorized most of the levels and techniques to complete them.	Jul 24, 2013 12:22 PM
25	I knew the levels and was able to clearly see	Jul 18, 2013 11:46 AM
26	I could tell easier what was ahead of me and could maneuver in between obstacles much better than in any other mode.	Jul 17, 2013 3:22 PM
27	BECAUSE I COULD SEE THE HEIGHT OF MY SHIP	Jul 17, 2013 3:21 PM
28	Used it to avoid collision	Jul 13, 2013 9:50 AM
29	The HUD really threw me off. I misunderstood some of the mechanics.	Jul 13, 2013 9:41 AM
30	The mini map for the depth really helped	Jul 13, 2013 9:29 AM
31	I had already run through the game so I new generally where everything was and then with this I could easily tell distance between key blocks and objects.	Jul 13, 2013 9:28 AM
32	I preformed best with the HUD when it came to seeing if I was going to crash into the floor. Shadows did help in this case, but it helped much more to see the actual depth through the HUD. Though when it came down to finding things above the ship, the HUD was not needed.	Jul 12, 2013 3:13 PM
33	The HUD helped with the 3D aspect of the game.	Jul 12, 2013 3:05 PM
34	I played it last, and the part I kept dying at (in the end) was very easy with a shadow	Jul 12, 2013 2:34 PM
35	It was the last session and I memorized the levels. I could also see the most and felt more at ease with the button mapping	Jul 10, 2013 2:40 PM
36	I had practice from earlier sessions, so I knew the level by then, but the 3D session, I feel, was my fastest. It was the easiest thing to comprehend in relation to the other methods. With shadows/HUD, you had to either look at specific spots (the shadows the cube was making) or look at a general place on the screen (the HUD), this distracts you for a brief moment, one that usually causes you to fail shortly after. With the 3D effect, everything you look at is constantly giving you cues, which leaves you to focus on what you are doing, and therefore perform better at the game.	Jul 10, 2013 2:39 PM
37	The shadow makes it much easier to navigate tight vertical spaces.	Jul 10, 2013 2:23 PM

Page 89, Q103. Which session do you feel you preformed best in?		
38	At that point, I had practice and memorized the map.	Jul 9, 2013 1:44 PM
39	I feel I performed well in both HUD and Shadow mode. I'm not sure which was clearly a better run, but I feel like I did well because not only did I have a better frame of reference in both, but I had figured out what actions I needed to perform in order to finish each level (eg: move target 2 spaces left -> shoot -> slow ship down -> loop around to the wall -> raise ship height 1 level -> ...). That on combination with the perception of depth helped out a lot.	Jul 4, 2013 11:15 AM
40	Because I played HUD as one of the last playthroughs and at that point I was already good at the game	Jul 3, 2013 9:27 AM
41	It was much easier to see/feel where my ship was in relation to the rest of the level, so it was easier to navigate levels	Jul 3, 2013 9:09 AM
42	Was the last one i played and had the levels memorized	Jun 28, 2013 10:34 AM
43	easy to judge depth	Jun 28, 2013 9:46 AM
44	I didn't have to put any effort into determining the depth of game objects, so I was able to focus more on the other tasks at hand.	Jun 28, 2013 9:37 AM
45	Easiest.	Jun 27, 2013 12:57 PM
46	By the time I got here I had already played the game twice; the HUD is useful because it is an explicit representation of the relative locations of objects. I think this was my fastest round; the practice of the previous two rounds definitely helped but the HUD was just enough to help me make the most informed decisions when changing heights.	Jun 27, 2013 12:51 PM
47	Easiest to tell the ship's specific height in relation to the blocks.	Jun 27, 2013 12:41 PM
48	I could see the depth.	Jun 27, 2013 12:35 PM

Page 89, Q104. Any other remarks about the differences between each session?		
1	I wished I had voted HUD in the first one. I didn't know it would not be featured in other tests.	Aug 27, 2013 5:07 PM
2	easier to play in later playthroughs when use to mechanics/controls	Aug 25, 2013 2:02 PM
3	None was awful	Aug 25, 2013 1:50 PM
4	There wasn't a very big difference between all of them I felt. Except for the 3D was noticeably not 3D. Though it didn't hinder the game-play a lot. I think the use of the HUD, or a re-positioning of the HUD would have made it a more vital asset.	Aug 24, 2013 1:05 PM
5	1st playthrough: I sucked, hard, don't know what I was using but I failed miserably (I put stereoscopic 3D in the survey but I know that's wrong). 2nd playthrough: So much easier, I could tell the depth of stuff, simple, made it through no problem. 3rd: Shadows...I'm guessing. Had a hard time figuring out depth here, feel like a struggled a bit. Made it more challenging. Just couldn't tell anything to save my life, made it challenging though which was kinda fun, if a little frustrating. 4th)This one I had the HUD with. It was bad in the sense that I had to look away from my ship to use it and the HUD sucks (only shows your current column on it) so the info it provided wasn't that useful. But just having it there made me less frustrated than playthrough 3. I even found out that I could go between 2 green blocks on the 2nd level (after you shoot both the red & blue blocks). I didn't figure that out in any other playthrough, and I became more focused on successfully passing through the level with that path than playing the game properly. Probably hurt my time a bit.	Aug 24, 2013 12:57 PM
6	Shadows definitely showed dimension where there was level difference where as in stereoscopic 3D i found it a little difficult to differentiate level differences	Aug 23, 2013 8:17 AM
7	Stereoscopic condition was the best. Followed by shadows. HUD condition was last.	Aug 22, 2013 1:24 PM
8	I thought the first trial was 3D since it had some depth from geometry, only when I saw the 3D stereoscopic trial did I realize how much more information it provides	Aug 22, 2013 1:20 PM
9	Why were there 4 levels for HUD and only 2 levels for the rest of the conditions? Training phase?	Aug 21, 2013 1:23 PM
10	The difference between "None" and "Shadow" did not feel very noticeable. I am honestly not sure which was which; this indicates that shadows didn't help that much.	Aug 21, 2013 1:20 PM
11	-	Aug 20, 2013 12:25 PM
12	My skill level at the controls grew really fast, so the earlier tests are biased towards being harder, at the end I beat it in no time at all because not only was I better at the game, I played those levels already, so even without the indicators such as shadows and 3d I could easily get through as I already knew everything about the level. If I had to play the tests in random order or different levels each time I think it would have been better.	Aug 20, 2013 11:42 AM

Page 89, Q104. Any other remarks about the differences between each session?		
13	Each session became much easier to play. The second session was the easiest because it showed your height relative to the map in the game in case you lost your place.	Jul 30, 2013 12:31 PM
14	I found that the shadows and 3D really made the game. Without it i found myself constantly hitting things that i thought i shouldn't.	Jul 26, 2013 11:55 AM
15	difference between shadow and stereoscopic 3D was minimal. Could barely notice difference	Jul 24, 2013 12:52 PM
16	Shadows made the game look nice but not that much of a difference.	Jul 24, 2013 12:43 PM
17	The none one was the most difficult as that provided almost no aid at all to properly gauge depth and where the positions of the blocks were. In order of easiest to hardest I would say for it went from HUD,Shadow,3D and None.	Jul 24, 2013 12:39 PM
18	The levels got easier each play through, the first time through was really hard, the second wasnt bad, but the 3rd and 4th time I was breezing through them.	Jul 24, 2013 12:22 PM
19	I had a lot of trouble distinguishing depth in the third (HUD) play through.	Jul 18, 2013 11:46 AM
20	During the HUD session I found out the exact heights of certain sections making playing through without anything on easier. Before I had the HUD session There were a few places I had a very hard time completing but became much easier after. I feel like I had the hardest time with the 3D mainly because I was still learning how to play but would be better at it after playing with the other modes.	Jul 17, 2013 3:22 PM
21	Didn't really know if there was a HUD version or a version with nothing, as far as i knew, all versions had a little 3D and a bit of a HUD	Jul 17, 2013 3:21 PM
22	SHADOWS LOOKS AWESOME	Jul 13, 2013 9:41 AM
23	no comment	Jul 13, 2013 9:29 AM
24	- Shadow was difficult as the ground usually wasn't close enough to be useful as to location. - None would have been really hard had it been my first play through. - Stereoscopic 3D and HUD were both fun and would be interesting to see them being used together.	Jul 13, 2013 9:28 AM
25	It became a lot easier once I knew the layout of each level, and understood the controls more. It was really fun once stereoscopic 3d was introduced.	Jul 12, 2013 3:13 PM
26	Having shadows and the HUD made it the easiest to complete the levels.	Jul 12, 2013 3:05 PM
27	I thought that all of them were 3D until I actually got to the session that was in 3D. The one with the HUD confused me because it was my first time playing it and I was not used to the controls. The more complexity that was added to the game the better it felt and I could immerse myself more.	Jul 10, 2013 2:40 PM
28	If I had to rank all of the features from most useful to least useful, it would be: 1. 3D 2. HUD 3. Shadow However, all of these features definitely help when playing a game that focuses on depth as its main mechanic	Jul 10, 2013 2:39 PM
29	The end of the 2D session was frustrating. At the very end of the final	Jul 4, 2013 11:15 AM

Page 89, Q104. Any other remarks about the differences between each session?		
	level,where you need to let the blocks explode underneath you and then lower the ship 2 levels is extremely hard to do without the 3D reference and with the camera being positioned where it is.	
30	Very difficult without some form of depth identification!	Jul 3, 2013 9:09 AM
31	Was really difficult to tell where the ship and landscape were. May haps a cool shading technique to make the difference more distinct	Jun 28, 2013 10:34 AM
32	was one just 2d?	Jun 28, 2013 9:46 AM
33	There was a large different between 3D, and 2D gameplay. I had more to do in 2D, because I had to determine the depth of game objects on my own, which I was sometimes wrong about. In 3D it took no effort to determine the placement of objects, and I was more consistently right.	Jun 28, 2013 9:37 AM
34	Didn't really pay attention to the HUD. Couldn't tell when it was on or not. Same with shadows.	Jun 27, 2013 12:57 PM
35	Thought round 2 was in stereo, but then I realized that round 4 was way more stereo so round 2 must have been nothing.	Jun 27, 2013 12:51 PM
36	Didn't feel very different apart from the shadows and the UI. Game got a lot easier as I played it more (I knew what to do).	Jun 27, 2013 12:41 PM
37	I thought all of the scenes were 3d.	Jun 27, 2013 12:35 PM

Page 89, Q105. Any general comments about the game?		
1	Loved the concept, it was fun in a frustratingly challenging way.	Dec 12, 2013 7:25 PM
2	Repetitive. Well done shadows.	Aug 27, 2013 5:07 PM
3	enjoyed playing the game	Aug 25, 2013 2:02 PM
4	I thought it was a well put together game. It's not the type that I would generally play, but I could see people enjoying it. Especially with timers and leaderboards.	Aug 24, 2013 1:05 PM
5	The more times through it I went the more it became muscle memory rather than actually trying to figure out depth, especially on the 3rd run through, I just memorized how many times I hit the up/down buttons and tried to make my way through like that.	Aug 24, 2013 12:57 PM
6	confusing at first trying to figure everything out but once that is done the game is alot of fun	Aug 23, 2013 8:17 AM
7	was that an arwing	Aug 23, 2013 7:16 AM
8	It seemed very challenging at first, maybe not enough reinforcement of the rules, as the first trial I had to learn by trial and error, even though I had read the rules, I didn't yet really get how they worked.	Aug 22, 2013 1:20 PM
9	The game itself was hard, but I do like hard games.However, once in a while I felt I was struggling with the controls. The visuals and the 3D we good anyway.	Aug 22, 2013 11:38 AM
10	The game only makes sense with stereoscopic 3D vision. Everything else will drive you crazy after some time of playing!	Aug 21, 2013 1:23 PM
11	It seems to have a really steep learning curve. I also feel that the way the possible actions are presented is not ideal. At first, I failed a lot because I was not aware you could decelerate the spacecraft. Still, it was fun and I enjoyed trying to beat it in the first condition (which I think was the "None" one) even though I got frustrated at times.	Aug 21, 2013 1:20 PM
12	It's a fun game concept but if I were to find this as a flash game I doubt I would have played long.	Aug 20, 2013 1:10 PM
13	The HUD didn't show the color changers if they were above or below you. Very very hard first level, takes many tries just to know how to win the large 2nd part.	Aug 20, 2013 12:25 PM
14	I like the concept and found it fun to play	Aug 20, 2013 11:42 AM
15	The game really woke me up and I had fun.	Jul 30, 2013 12:31 PM
16	It was tricky to figure out during the first play-through because it wasn't immediately apparent to me what I was doing was wrong. I'm not exactly sure if I liked the shadow session more than the stereo 3D ones (because the 3D ones came first and lead to the most frustration), but the test was more enjoyable towards the end.	Jul 30, 2013 9:52 AM
17	Cool game, I had a fun time playing it.	Jul 26, 2013 11:55 AM
18	Control scheme is going to give someone carpal tunnel, consider changing for	Jul 24, 2013 12:52 PM

Page 89, Q105. Any general comments about the game?		
	further tests	
19	You should tell the player you can speed up and slow down with how much push down on the stick.	Jul 24, 2013 12:43 PM
20	The game can get very frustrating and difficult when using the up and down mechanic at times as the player has to accurately gauge how much they press.	Jul 24, 2013 12:39 PM
21	I really like the Stereoscopic 3D, much more than I thought I would and would like to play more games with it.	Jul 24, 2013 12:22 PM
22	Hard	Jul 18, 2013 11:46 AM
23	The game is actually a pretty fun concept, I feel like having a HUD that is more in view and integrated with the rest of the game would make the game more enjoyable, compared to when it is off to the side. The shadows are also a good addition and would be nice in conjunction with the HUD.	Jul 17, 2013 3:22 PM
24	MAKE IT SO THE SHIP SNAPS HEIGHT. OMFG I DIED 9001 TIMES CUZ MY SHIP KEPT CRASHING INTO THOSE SHITTY CAGE BOX THINGS THAT IM SPOSED TO BE ABLE TO FLY THROUGH. SO MUCH RAGE. MORE QUESTIONS IN THE SURVEY TO MONITOR HOW MAD I AM. DEFINITELY SPIKE AT THE END.	Jul 17, 2013 3:21 PM
25	Was very confused about both controls and mechanics without additional help	Jul 13, 2013 9:50 AM
26	Looks awesome!	Jul 13, 2013 9:41 AM
27	awesome game! great concept	Jul 13, 2013 9:29 AM
28	Overall interesting game and the mechanics are fun. If the levels were longer I definitely would have wanted checkpoints. But they were just long enough that it worked out fine.	Jul 13, 2013 9:28 AM
29	The controls were at first really hard to get used to, even though I remembered them. I feel that the maneuvering of the ship could be improved when it comes down to moving left, right forward and backward. Moving up and down was not an issue once played with stereoscopic 3D. I feel it would be more fun if the game was not as difficult (at least initially).	Jul 12, 2013 3:13 PM
30	Really challenging game for new players. Had a lot of fun in the end seeing the different ways to help with 3D puzzles such as the shadows and the HUD. Training levels helped a lot for understanding the games mechanics. Wish there were checkpoints in the level because the beginning becomes very repetitive. Would like to play more levels in the future.	Jul 12, 2013 3:05 PM
31	The game was very difficult to pick up. the controls were not mapped very well or I didn't pick up on the instructions very well. I really enjoyed the 3D aspect once I saw it. The mechanics area is a bit weak in the game, but it's nothing some art assets or polish could not fix.	Jul 10, 2013 2:40 PM
32	Keeping track of two separate locations at once (the ship and the target) felt a bit clunky, and once a split-second decision had to be made, it was quite awkward to try to get the target into the right place very quickly.	Jul 10, 2013 2:39 PM

Page 89, Q105. Any general comments about the game?		
33	You should switch up levels so people can't memorize the path to take.	Jul 9, 2013 1:44 PM
34	I think the mechanic of "If the ship is next to or above the current colour, energy doesn't go down; if the ship is on top of its current colour,energy is regained." should be explained a little more explicitly, since much of the game relies on having enough energy remaining to fly to the next colour swap. It's easy, as a player, to just think 'oh, okay, near same color = good, away from same color = bad" and not understand the additional depth to the mechanic and how to use it to your advantage.	Jul 4, 2013 11:15 AM
35	One problem is that the game is difficult, but after much practice you get better at the levels. So I got better at the game and was able to beat the levels much easier near the end, regardless of the advantages of the 3D or HUD	Jul 3, 2013 9:27 AM
36	Challenging, addictive, loved it - I would actually buy a full-version of this, in stereoscopic 3D	Jul 3, 2013 9:09 AM
37	Cool game not relaxing more actiony based. Found the controls at time to be a bit overwhelming and a little hard to control	Jun 28, 2013 10:34 AM
38	Great game! Was a lot of fun to play, especially with 3D enabled.	Jun 28, 2013 9:37 AM
39	Surprisingly fun.	Jun 27, 2013 12:57 PM
40	Pretty good. Previous renditions were very difficult to play with all of the controls not doing what I would expect but this time everything seemed to work harmoniously; greatly improved controls, visuals and mechanics. Overall not too much to manage but still complex and challenging enough to piss someone off when they die a billion times in the same place. Good job! :)	Jun 27, 2013 12:51 PM
41	Would be a lot less irritating if: 1) You could move the targeting circle to the side / behind the ship. 2) You can move the ship backwards (at least to the extent of where the screen is). A lot of the times I would rush forward only to narrowly skip a needed colour-change-cylinder.	Jun 27, 2013 12:41 PM
42	Very fun and challenging.	Jun 27, 2013 12:35 PM