EVALUATING THE BENEFITS OF 3D STEREO IN MODERN VIDEO GAMES

by

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ABSTRACT

We present a study that investigates user performance benefits of 3D stereo in modern video games. Based on an analysis of several video games that are best suited for use with commercial 3D stereo drivers and vision systems, we chose five modern titles focusing on racing, first person shooter, third person shooter, and sports game genres. For each game, quantitative and qualitative measures were taken to determine if users performed better and learned faster in the experimental group (3D stereo display) than in the control group (2D display). A game experience pre-questionnaire was used to classify participants into beginner, intermediate, and advanced gameplay categories to ensure prior game experience did not bias the experiment. Our results indicate that even though participants preferred playing in 3D stereo, for the games we tested, it does not provide any significant advantage in overall user performance. In addition, users' learning rates were comparable in the 3D stereo display and 2D display cases.

Dedicated to my friends and family who showered me with support throughout this process.

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CHAPTER ONE: INTRODUCTION

3D stereo is making a huge push in the entertainment industry. With 13 3D movies released in 2009, another 25 slated for 2010, and 32 scheduled to come to theaters in 2011, as well as new television stations broadcasting entirely in 3D, movies and television are clearly pushing the technology. As the technology has started to become more available to consumers, game designers and hardware makers have started to take notice. Games such as "Avatar" and "Batman: Arkham Asylum" have been released as 3D stereo capable on the Xbox 360 and Sony Playstation 3. Consumers are also in favor of the technology as shown by "The U-DECIDE Initiative," which was an online survey run by Meant to be Seen that sought to determine consumers interest in 3D stereo gaming. The survey concluded that the overwhelming majority of users want game developers to natively support 3D stereo in their games [14]. While it is clear the technology is coming and that consumers are interested in 3D stereo, it remains to be seen whether the technology provides any benefits to users.

Motivation

Research has shown that 3D stereo can be beneficial to user performance in certain, isolated tasks in the context of virtual reality and 3D user interfaces [2,9,18,22]. However, to the best of our knowledge, there has been little, if any, work that explores whether 3D stereo benefits a user

playing video games in terms of performance and learning. Understanding these benefits could provide useful information to help improve serious games with applications to education and training.

Statement of Research Question

We wanted to investigate the possibility of 3D stereo providing an advantage, in terms of performance or learning, to users playing modern video games. To explore this question, we present a study investigating whether users' performance and learning are enhanced when using 3D stereo over a traditional 2D monitor in modern video games. In our work, we define learning as becoming more proficient at the game and the tasks associated with the game. We analyzed several video games that are best suited for use with commercial 3D stereo drivers and vision systems (iZ3D and NVIDIA 3D Vision) and chose five modern titles including Left 4 Dead, Resident Evil 5, Flatout, Madden 2008, and Major League Baseball 2K9 as a representative sample of modern video games. In choosing the games, we sought to have them spread across video game genres as well as have games that included tasks that, in our judgment, may benefit from 3D stereo. To evaluate player performance, we collected both quantitative data based on the tasks associated with each game and qualitative data based on post-questionnaires to gage user perception of their performance. A between subjects design was used where the 2D display group played the games with a 2D monitor and the 3D stereo display group played the games with 3D stereo. We also used a modified version of Newcombe and Terlekie's Video Game

Experience survey [19] to classify participants into beginner, intermediate, and advanced categories to ensure prior game experience did not bias the experiment.

Reader's Guide

This thesis is broken up into a few chapters. Chapter 2 provides information on related work in the areas of 3D stereo benefits and measuring video game performance. Chapter 3 will discuss the games we looked into and how we chose the games that were used in the study. Chapter 4 will cover the research design and methodology of our study, Chapter 5 will present the results and analysis of the data, and Chapter 6 will give a discussion of those results. Chapter 6 will provide possible directions for future work in this area a conclusion to this thesis.

CHAPTER TWO: LITERATURE REVIEW

Benefits of 3D Stereo

There has been a significant amount of work on the topic of the benefits of 3D stereo, especially in the virtual reality and 3D user interface communities, with mixed results [2,9,18,22]. Much of the research to date has focused on simple, isolated tasks in virtual environments, and there has been very little research involving more complex tasks and richer graphical environments, such as games. Menendez and Bernard have hypothesized that stereoscopic viewing would benefit a user in a flight simulation environment, but have yet to test the hypothesis [15]. Another study has concluded that binocular viewing in the real world as well as virtual worlds may benefit the user over monocular viewing, and while 3D stereo has been shown to be useful for depth ordering of objects in a virtual world, it may be impossible to measure how accurate a user's perception of 3D stereo is [20]. Research has also been conducted that looks into how shadows and 3D stereo enhance user's perception of 3D. Positioning and resizing tasks were given to users with shadows on and off and with stereo and mono viewing. The researchers concluded that stereo viewing is more effective than shadows based on accuracy and speed with which users completed the tasks [9]. Stereo has also been found to help users playing a game in which they eliminate targets by moving objects into defined zones. The game was still a simple task of moving a cursor to a target in the virtual world that contains objects that needed to be manipulated. To simplify the task only one object was present during the experiment [5]. This is still quite different than playing a modern video game, in which there is a lot more happening on screen and a lot more visual stimulus.

There have been mixed results when looking for benefits gained from 3D stereo. In one study that sought to separate the interaction technique from the stereo, the interaction technique was found to be significant while stereo was not [13]. This has been somewhat contradicted by Teather and Stuerzlinger, however, who presented different positioning techniques that were dependent on the input devices used. They found that stereo was beneficial for accuracy in the tasks they presented to users, but not speed [18]. Many questions about the effectiveness of stereo exist as the technology is far from perfect and requires more understanding. It has been shown that depth perception tends to be underestimated by users in virtual environments [11], and also that for some selection tasks in 3D space, a one-eved 2D cursor can be more beneficial than a 3D cursor [24]. And while it may show some benefits depending on the task presented, it has also been shown to increase some negative symptoms as well. Stereoscopic viewing can have negative consequences and symptoms, such as additional eyestrain and simulator sickness. There has been research on display techniques to reduce some of these symptoms [8,21]. We wanted to see whether this trend of increased symptoms while viewing in 3D would also hold true while playing a game in stereo on a 3D TV, and we wish to see whether any of the benefits of 3D stereo that have been shown in virtual reality environment for simple tasks will translate to improved performance for users playing modern video games on a 3D TV.

Much of the research that does exist that compares 3D stereo to 2D display and uses very simple tasks to measure performance also focuses on other aspects such as head tracking or display environment. One of the more common display configurations used for this type of research is called Fish Tank Virtual Reality, where there is a desktop system with a stereoscopic display and head-tracking [22]. Ware and Booth used this setup to conduct two experiments that

compared viewing conditions of stereo display versus non-stereo display with head-tracking. In the first experiment, users thought that head-tracking created a more compelling 3D perception than stereo viewing alone. In the second experiment, users performed a tree tracing task. Again, the head-tracking provided the best results. Although head-tracking had better results, the stereo did show significant benefits over normal viewing [22]. Similar results have been found by other research as well. In another study, users preferred head tracking, when isolated, over stereo 3D viewing, and while there were benefits shown for stereo 3D in user performance in a tree tracing task, the benefits were greater for head tracking in the same task [2]. Though these studies have concluded that head-tracking produced better results than stereo alone, we wanted to focus this study specifically on 3D stereo because it is more readily available to consumers.

Research has been conducted on how well users perform with different types of 3D displays as well. Grossman and Balakrishnan looked at volumetric displays and concluded that for the simple tasks that were presented to users, stereo 3D always helped over simple perspective and though volumetric displays were more helpful for simple scenes, there was no benefit over normal 3D displays in more complex scenes [6]. Fully immersive virtual environments have also been shown to be more effective than stereoscopic desktop environments for certain tasks. In comparing a real world scenario of oil well path editing, researchers found that a fully immersive environment, such as a CAVE, was more effective than a stereoscopic desktop environment [7]. A similar study showed results that also suggested the immersive environment provided benefits to the user in analyzing data; however, it also concluded that users were more comfortable using the interaction techniques on the desktop environment [1]. Still more research has been done that concluded identifying if a target exists in a virtual world

has benefited more from an immersive virtual environment over a desktop system [16]. Stereo has been shown to increase the size and amount of abstract data that can be viewed and understood, and the benefits were only increased with a higher resolution stereoscopic display [23,25]. We used a desktop setup for viewing the games in stereo 3D on a 3D TV with a 1080P resolution. While some of the research may suggest that stereo 3D on different display types may be more effective, the desktop setup of a 3D TV with a computer and 3D glasses is more readily available for in-home use.

Evaluating Video Game Performance

In order to test if the 3D stereo was benefiting a user, we needed a way to measure the user's performance in the game. We decided to look at other research in the area of video game performance so that we could determine the best way to measure performance in the games we were going to use. Studies have been run in an effort to explore whether immersion in games can be quantified. It has been determined that immersion can be measured qualitatively, through user's responses, and quantitatively, through measures such as task completion time and eye movement [10]. These studies indicate that reduced time taken in a task can correlate to an enhanced sense of immersion [17]. There have been different types of questionnaires developed to help measure qualitative data [10, 19].

We also looked into different ways of measuring performance as some would say that measures taken from the study and user responses are not enough to measure user experience. There have been experiments exploring the use of physiological data from the user to measure user experience [12]. Setups have been designed to measure user's emotional responses to virtual characters. Experiments have been designed to test whether stereo has any impact on the emotions of the user [4]. While the physiological responses could be a good measure of the user's immersion, we were more interested in the user's performance and perception of their performance. We used some similar measures of performance as some previous research such as task completion time and accuracy adapted to each game individually. We also wished to measure users perception of how they performed through their responses to questions about the experience.

CHAPTER THREE: SELECTING THE GAMES

In order to look into possible benefits that 3D stereo provides to modern video games, we wanted to get a good sample of different game genres. We also wanted to make sure the games we used were highly rated for their use of 3D stereo. The technology we had available were iZ3D monitors and the NVIDIA 3D Vision kit, which are both products currently on the market. Both of these technologies provided a list of modern games that are most compatible. We looked through both lists and picked 21 games that were rated highly for both systems. We then played through sections of the 21 games in 3D stereo, taking notes about how they looked, any glitches that occured, and any tasks we thought may benefit from 3D stereo. Some of the information we took away from our time playing the games follows.

Batman: Arkham Asylum was a third person action game by Rocksteady Studios Ltd. On our test setup, this game suffered from bad aliasing and many of the on screen information was rendered at screen depth which caused some eye strain. There did appear to be some interaction that could benefit from depth perception, such as throwing a grappling hook, but the character locked onto all objects that could be hit, negating any need for it.

Assassin's Creed is another third person perspective action by Ubisoft. This game was another one in which all things that may have benefited by the added depth perception of stereo 3D were negated because the character locked on for interactions and did not have to judge distances because the game only allowed the user to jump the correct distance onto roofs and other objects.

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Demigod is a real-time strategy game developed by Gas Powered Games. We found that there were not really any interactions in the real-time strategy games that we played that would seem to benefit from the additional depth perception gained from 3D stereo. Movement in these games was accomplished by simply clicking on the map where the character needed to move. All interactions were of this variety in the game. It seemed like more of a 2D map or board game being played in 3D. Titan Quest by THQ and Empire: Total War by SEGA were games that fell into the same category with very limited interactions.

Devil May Cry 4 is a third person perspective action game by Capcom. This game did a lot with the 3D stereo as far as depth and objects coming out of the screen at the person playing the game. It did look somewhat odd when an object would appear to pop out of the screen, but then get cut off by the edge of the screen. This game was more of a button masher where different button combos were used to create different moves and it did not appear that any of the interrelations would benefit from the 3D stereo viewing. Prince of Persia is a third person perspective action game from Ubisoft that falls into a similar category as Devil May Cry 4.

Tomb Raider: Underworld by Eidos is a third person shooter. There did appear to be more freedom in movement in this game compared to some of the others, but as far as shooting the weapons, it was a lock-on style aiming again which takes away the opportunity for the 3D stereo to aid a user with aiming.

Pure is an off-road racing game by Disney Interactive Studios. This appeared to be a pretty standard racing game with simple controls for gas, break, and steering. There were also buttons used to perform tricks in the air, but it was more button masher style and did not seem like stereo 3D would provide any benefit.

Spiderman 3 is a third person perspective action game by Activision. This game presented the onscreen status and information in 3D, which was somewhat unique and seemed to make it a little easier for the eyes. This game was another one in which any benefit 3D stereo may seem to provide was taken away by the locking on for interaction.

Half Life 2 is a first person shooter by Valve Corporation. This game provided free controls for running, jumping, and aiming. In a first person shooter, however, any benefit that may be gained for aiming is somewhat limited as there are cross-hairs in the middle of the screen and the shot is always fired toware the center of the screen.

From our analysis, we decided to first remove the real-time strategy games as the 3D wasn't very convincing and it did not seem like any advantage could be gained in that genre. Based on our analysis, we felt a first person shooter, a third person shooter, a racing game, and sports games would be the most appropriate genres to explore. Of the 21 games that we tested, we found Left 4 Dead, Resident Evil 5, Flatout: Ultimate Carnage, MLB 2K9, and Madden NFL '08 performed the best in terms of visual quality and had tasks that we felt could benefit from 3D stereo. Our analysis of these games and reasons for choosing them follow.



Figure 1: Left 4 Dead Screen Shot.

Left 4 Dead is a first person shooter by Valve. A screen shot of the game can be seen above in Figure 1. Though we didn't expect to see any difference in the shooting aspect of the game due to cross hairs being displayed on screen, which make aiming easier by just placing the cross hairs over the target, we wanted to explore the genre to see if 3D stereo may improve performance by helping with navigating the world or providing better sense of which enemies are closer and thus pose a more imminent threat.



Figure 2: Resident Evil 5 Screen Shot.

Resident Evil 5 is a third person shooter by Capcom. It provided a mode in which the user is required to shoot with a bow and arrow that did not provide any cross hairs on the screen as can be seen in Figure 2. This made targeting an enemy more difficult as the user is required to aim the arrow in 3D space. Third person perspective also adds to the aiming difficulty as the aiming is no longer only in the center of the screen as it is with first person shooters. We hypothesized that the added depth cue provided by 3D stereo may help the user with accuracy.



Figure 3: Flatout: Ultimate Carnage Screen Shot.

Flatout: Ultimate Carnage is a racing game by Empire Interactive. Though we didn't expect to see any performance difference in racing games, we wanted to explore the possibility that the added depth perception of 3D stereo could aid maneuvering the course or help in judging corners. A screen shot of the game can be seen above in Figure 3.



Figure 4: MLB 2K9 Screen Shot.

MLB 2K9 is a major league baseball game by 2K Sports that can be seen in Figure 4. In the baseball game we wanted to see if stereo 3D would help the user better judge where the ball was located in space as it came from the pitcher toward the batter in order to swing the bat at the appropriate time. We thought that the added depth perception could help users' timings when hitting the ball.



Figure 5: Madden NFL '08 Screen Shot.

Madden NFL '08 is a football game by EA Sports. There was a punting mini-game in Madden that required the user to aim an arrow in 3D space to kick the ball in a desired direction toward a target that can be seen above in Figure 5. Because the aiming of the arrow was free in 3D space, we thought that 3D stereo may boost the user's performance in successfully hitting the targets.

CHAPTER FOUR: RESEARCH DESIGN AND METHODOLOGY

User Study

To explore whether there are any performance benefits to using 3D stereo with the video games we selected (discussed in the previous section), we conducted a usability evaluation where participants played each game using 2D display (control group) or with a 3D stereo display (experimental group). We examined both quantitative metrics based on each game's goals and tasks and qualitative metrics based on whether participants preferred playing the games in 3D and whether they perceived any benefits. Based on our analysis of the games, we hypothesized that users would prefer playing in 3D stereo because of the increased sense of immersion. However, there would not be any significant performance improvements in overall performance or in learning since the games were not specifically designed with 3D stereo in mind.

Participants and Equipment

Forty participants (30 males and 10 females ranging in age from 18 to 36 with a mean age of 23.15) were recruited from the University of Central Florida. We ranked the participants based on a modified version of Newcombe and Terlekie's Video Game Experience survey [19] that was used as a pre-questionnaire in which they answered questions about their previous gaming experience. Of the 40 participants, 9 were ranked as beginners, 23 as intermediate, and 8 as advanced. The experiment duration ranged from forty-five minutes to an hour and a half depending on how long the participants took to complete the tasks presented to them in the

games and how much time was spent on the questionnaires. All participants were paid 10 dollars for their time.



Figure 6: The experimental setup.

The equipment used for the study consisted of a quad-core desktop PC with an NVIDIA GTX 260 graphics card and a Samsung 50 inch DLP 3D HDTV display, using the NVIDIA 3D Vision kit for the3D stereo gaming as can be seen in Figure 6. We decided to use the NVIDIA 3D setup over the iZ3D monitors because early pilot testing showed the NVIDIA solution had higher stereo quality with limited ghosting. In addition, the iZ3D monitors had variables that would need to be setup differently for each game and each user, where as the NVIDIA solution

worked seamlessly with the games. The Xbox 360 Controller for Windows was used as the input device for the games.

Experimental Task

The participants were tasked with playing through sections of the 5 games that we selected. For each game, they were presented with a task specific to that game and a goal for completing each task.

Left 4 Dead

Participants had to finish the first section of "The Apartments" level. The goal was to finish the level as fast as possible. They were given three attempts with a goal of making it through the level faster each time.

Resident Evil 5

The task participants were given for Resident Evil 5 was to eliminate as many zombies as possible. The participants were instructed that the only weapon they could use was the bow-and-arrow. The moderator kept track of the time and the participants were given 6 minutes to play the game. They were told that deaths did not count against them.

Flatout: Ultimate Carnage

Participants were given a goal of finishing a lap in one minute and fifteen seconds. We determined that this was a challenging, but attainable goal through our time playing the game. They were given five attempts to reach the goal.

Madden NFL '08

Participants took part in a punting mini game. They were given five attempts to reach the goal of a gold medal, a score of 900 points. There were 3 zones in the targets they were aiming for: a 50 point zone, an 100 point zone, and a 200 point bull's eye. Each attempt consisted of 6 kicks to reach the desired point total.

MLB 2K9

Participants' tasks in this game were to hit 20 home runs in as few swings as possible during a home run derby. Participants controlled two hitters, both a right and left-handed batter that alternated every 3 outs. The pitcher would throw the ball and the participant would have to time the swing correctly to hit a home run.

Design and Procedure

We used a between subjects design where the independent variable was display mode (2D display or 3D stereo display) and the dependent variables were the various scoring metrics used in each game. In order to group the participants into experience levels based on the pre-

questionnaire data, we scored the questionnaire by assigning points to each question. Particular questions were given more points based on how the results fit within the context of our experimental setup. For example, participants who were familiar with the Xbox 360 controller or whose favorite games were first and third person shooters were considered to have a higher experience level. We then used the raw scores from adding up the points for each question to group the participants into the appropriate category. Both the quantitative and qualitative data was explored collectively as well as according to the three groupings.

	Summary of Metrics
Left 4 Dead	 Time for each run Number of kills for each run Kills per second
Resident Evil 5	AccuracyNumber of Player deaths
Flatout: Ultimate Carnage	 Time for each attempt Number of crashes If a shortcut was attempted
MLB 2K9	 Number of swings taken to reach 20 HRs Number of swings missing the ball
Madden '08	 Score for each attempt Number of kicks hitting each target zone Number of kicks missing target

Table 1: Summary of Quantitative Metrics.

Quantitative Metrics

For each game, we tracked quantitative data that we felt was a good indication of how well the user performed. A summary of the quantitative metrics can be viewed in Table 1.

Left 4 Dead

We collected times for each attempt at the level as well as the number of kills for each run. The number of kills could differ from run to run because there were three AI controlled friends helping the user in the game by shooting enemies, and the number of enemies spawned would change based on how long it took to get through certain areas of the level. We also looked at the ratio of kills per second.

Resident Evil 5

We tracked each shot the participant fired in Resident Evil 5, so we had the ability to look at the overall accuracy as well as the accuracy over the course of the participant's time playing the game. We also decided to break up the number of shots into thirds so we could track the participant's accuracy at the beginning, middle, and end of the gaming session. The number of deaths was also tracked.

Flatout: Ultimate Carnage

The time for each lap attempted was recorded along with the number of crashes, and whether or not a short-cut (i.e., a specific corner in the lap) was attempted.

<u>MLB 2K9</u>

The quantitative data we were tracking for MLB 2k9 was the total number of swings needed to reach 20 home runs. Each swing was tracked, so we also looked at the number of misses, both earlier and late.

Madden NFL '08

We recorded the score for each attempt, as well of the number of kicks that hit each section of the target and the number of kicks that missed the target completely.

Table 2: Participants answered these questions on a 7 point Likert scale after each game.

Postgame Questions			
To what extent did the game hold your attention?			
How much effort did you put into playing the game?			
Did you feel you were trying your best?			
To what extent did you lose track of time?			
Did you feel the urge to see what was happening around you?			
To what extent did you find the game challenging?			
How well do you think you performed in the game?			
To what extent did you feel emotionally attached to the game?			
To what extent did you enjoy the graphics and the imagery?			
How much would you say you enjoyed playing the game?			
Were you disappointed when the game was over?			
Would you like to play the game again?			

Qualitative Metrics

Our initial approach for the qualitative aspects of the study was to provide each participant with a post-questionnaire after they played all 5 games. From early pilot studies, we determined that we should reduce the number of qualitative questions and give the survey after each game rather than one larger questionnaire at the end of playing all the games. After playing each game, participants filled out a short, 12 question survey that was based on an immersion questionnaire

from Jennet et al. [14] (see Table 2) aimed at gathering their ideas on how involved or immersed in the game they became. The questions were the same for each game and responses were measured on a 7 point Likert scale (1 = most negative response, 7 = most positive response). An additional 11 question survey was also given to participants in order to gather their opinions on how playing the games in 3D stereo affected their experience. These questions included whether they preferred to play the games in 3D stereo and whether 3D stereo helped or hurt their performance when playing the games.

Procedure

The experiment began with the participant seated in front of the computer and the moderator seated to their side. Participants were given a standard consent form that explained the study and what they would be asked to do. They were then given a pre-questionnaire that focused on their gaming experience. Participants were then presented with the games, in random order. Half the participants played the games in 2D display mode (control group) and half played in 3D stereo (experimental group). The moderator would present the game and give instructions to the participant as to what they needed to accomplish in the game and what their goals were. After each game, the participant filled out a post-questionnaire with questions about their experiences with the game. If the participants played the five games in the 2D display group, they then selected one game to play in 3D stereo. Thus, all participants were given a final post-questionnaire about their experiences with the 3D stereo display.

CHAPTER FIVE: RESULTS AND ANALYSIS

To analyze the performance data, we used independent samples t-tests to look for significance between groups. We also wanted to see whether there was learning taking place in the form of gameplay improvement. We looked at the improvement in the performance measures for each game from the first user run to their last run using a repeated measures ANOVA. Finally we wanted to look at the participant's perception of their performance through the post questionnaires. To analyze this Likert scale data, we used the Wilcoxon Signed Rank test. For all of our statistical measures, we used α =0.05.

Left 4 Dead

There was a significant difference in average time ($t_{37} = -2.626$, p < 0.05) and average kills per second ($t_{37} = 2.334$, p < 0.05). The 2D display group was actually faster in this game with a mean completion time of 214.36 seconds (σ =116.73), compared to 329.14 seconds (σ =152.74) for the 3D stereo group. In addition, participants had significantly more kills per second for the 2D display group as well with a mean of 0.204 (σ =0.063) kills/sec to the 3D stereo display group's mean of 0.155 (σ =0.066). There was no statistical difference in the average number of kills ($t_{37} = -0.981$, p = 0.333). After looking at the overall average of the three runs, we decided to look at the third and final run in an attempt to remove some of the experience factor, as by this time everyone would have knowledge of the level and the controls. We thought that this might be a good judgment of raw performance for the two groups. As we had originally expected for

Left 4 Dead performance, there was no statistically significant difference in the completion times $(t_{37} = -1.89, p = 0.067)$ or number of kills $(t_{37} = -0.268, p = 0.79)$ for the last attempt.

When isolating the three gamer ranks, the beginner group and the advanced group showed no differences for any of the statistics. However, the 2D display group performed significantly better for participants in the intermediate rank for worst time ($t_{10.48} = -2.875$, p < 0.05), best time ($t_{21} = -2.432$, p < 0.05), average time ($t_{11.37} = -3.021$, p < 0.05), average kills per second ($t_{21} = 2.351$, p < 0.05) and the third attempt's kills per second ($t_{21} = 2.29$, p < 0.05).¹ Because 22 out of the 40 participants had played Left 4 Dead previously, we separated the participants based on whether or not they had played the game. This resulted in no significant differences for any of the metrics. Since this result is what we originally expected, previous game experience may have affected the overall performance statistics.

Participants significantly improved their times between the 3 runs for both 2D display $(F_{2,17} = 16.64, p < 0.05)$ and 3D stereo display groups $(F_{2,18} = 14.00, p < 0.05)$. This shows that there was some learning taking place between runs for both groups. The 3D stereo display group improved their time from 499.54 (σ =281.42) seconds to 220.82 (σ =97.90) seconds while the 2D display group improved their run time from 269.09 (σ =141.38) to 164.64 (σ =87.08) seconds. This translates to a 55.8% improvement for the 3D stereo display group compared to a 38.8% improvement for the 2D display group (see Figure 7).

¹ For worst time and average time, Levene's test for equality of means was significant so a correction was used.


Figure 7: Left 4 Dead Improvement.

When broken down based on the gamer ranks, the beginning 3D stereo display ($F_{2,3} = 8.448$, p = 0.059), beginning 2D display ($F_{2,1} = 17.59$, p = 0.166), the advanced 3D stereo display ($F_{2,3} = 4.452$, p = 0.127), and the advanced 2D display ($F_{2,1} = 0.586$, p = 0.679) participants showed no significance in improving their times, while the intermediate 3D stereo display ($F_{2,8} = 10.88$, p < 0.05) and 2D display ($F_{2,11} = 13.99$, p < 0.05) groups appeared to show the same results as the overall learning. As with the overall learning rates, the intermediate 3D stereo display group appeared to outpace the intermediate 2D display group by about the same amount with a 57.8% improvement in time compared to the 2D display group's 38.7% improvement.

Participants in the 3D stereo display group who had not played the game previously saw a significant improvement in their times ($F_{2,11} = 13.72$, p < 0.05) from 610.16 (σ =255.44) seconds to 257.16 (σ =91.83) seconds (σ =91.83), a 57.8% improvement. The 2D display group who hadn't played the game previously showed no statistically significant improvement between runs ($F_{2,2} = 7.92$, p = 0.112). For participants who had previously played the game, both the 3D stereo display group ($F_{1.04,6.26} = 6.10$, p < 0.05) and the 2D display group significantly improved their times ($F_{2,13} = 12.18$, p < 0.05).² The 3D stereo display group saw a 47.86% improvement with their average time improving from 294.07 (σ =211.02) to 153.33 seconds while the 2D display group improved from 258.25 (σ =136.12) to 148.16 seconds (σ =60.94), a jump of 42.6%.

There were not many statistically significant differences in the qualitative data. Overall, the game was found to be significantly more challenging (Z = -2.394, p < 0.05) for the 3D stereo display group ($\bar{x} = 4.90, \sigma = 1.25$) than the 2D display group ($\bar{x} = 4.05, \sigma = 0.89$). This would be in line with the overall average time being worse for the 3D stereo display group. For those participants that had played the game before, the game significantly held the attention more (Z = -1.981, p < 0.05) for the 3D stereo display group ($\bar{x} = 6.86, \sigma = 0.38$) than the 2D display group ($\bar{x} = 6.2, \sigma = 0.86$). The same trend was seen for participants in the advanced rank where the game significantly held the attention more (Z = -2.049, p < 0.05) for the 3D stereo display group ($\bar{x} = 6.8, \sigma = 0.45$) than the 2D display group ($\bar{x} = 6.0, \sigma = 0.00$).

 $^{^2}$ The 3D stereo display group's test violated the sphericity assumption, therefore, we applied a Greenhouse-Geisser correction.

Resident Evil 5

Contrary to what we expected to see in Resident Evil 5, there was very little difference between the groups. There was no overall difference in the number of player deaths($t_{38} = -0.62$, p = 0.539) or accuracy ($t_{38} = 0.024$, p = 0.981). This also held for the beginner player deaths ($t_7 = -0.743$, p = 0.482) and accuracy ($t_7 = -0.779$, p = 0.461) as well as the intermediate group's player deaths ($t_{21} = 0.206$, p = 0.839) and accuracy ($t_{21} = -0.617$, p = 0.544). While there was also no difference ($t_6 = -1.067$, p = 0.327) for the advanced group in player deaths, the group did show a difference ($t_6 = 2.794$, p < 0.05) in accuracy, but it was the opposite of the difference we thought we may see. The 2D display group displayed a higher accuracy of 71.8% compared to that of the stereo 3D group at 59.2%.

In order to test for improvement in accuracy throughout the participant's time playing the game, we divided each user's attempted shots into the first, second, and third group of shots, with each grouping of shots being equal in number for the participant. We then looked at the accuracy change from the first third to the second third to the last third. There were no significant differences found for either the 2D display ($F_{2,18} = 0.898$, p = 0.425) or the 3D display group ($F_{2,18} = 0.651$, p = 0.533) in the changes of the user's accuracy over the course of their time playing the game. This trend held for each gamer rank, both 2D display and 3D stereo display groups.

The only difference found for the qualitative data for Resident Evil 5 was in the group that had not played the game before. In this group, there was a difference (Z = -2.104, p < 0.05) for the question about how much they enjoyed playing the game. The 2D display group actually rated that they enjoyed playing the game more ($\bar{x} = 5.33$, $\sigma = 1.54$) than the 3D stereo display group ($\bar{x} = 4.41$, $\sigma = 1.32$).

Flatout: Ultimate Carnage

As we expected from this genre, in all of the quantitative data that we tracked for Flatout, which included average time, average time in runs without a crash, number of crashes, and best time, there were no differences found between the 3D stereo display and 2D display groups overall or at any experience level.

From looking at the difference in times from the first attempt through the fifth attempt, there did appear to be significant learning taking place in both the 2D display ($F_{2.85,51.26} = 12.35$, p < 0.05) and 3D stereo display groups ($F_{1.72,29.29} = 5.85$, p < 0.05).³ As with Left 4 Dead, the rate of learning did look to be slightly higher in the stereo group who improved their time from 90.47 (σ =12.54) seconds to 81.49 (σ =5.51) seconds, compared to an improvement from 88.71 (σ =5.44) to 82.36 (σ =4.44) seconds for the 2D display group. The 3D stereo display group showed more improvement with a 9.93% gain compared to a 7.16% gain for the 2D display group (see Figure 8). When broken down by game ranks, the only significance shown in learning was for the intermediate 2D display group ($F_{4.9} = 20.55$, p < 0.05) who improved their time time by 6.20%.

³ For these tests, the sphericity assumption was violated, therefore, we applied a Greenhouse-Geisser correction.



Figure 8: Flatout: Ultimate Carnage Improvement.

Like the previous games, there was not much difference in the answers received for the qualitative questions. The only differences came when divided into the 3 game ranks. For the intermediate rank, the 3D display group put significantly more effort (Z = -2.35, p < 0.05) into the game ($\bar{x} = 6.5$, $\sigma = 0.73$) than the 2D display group ($\bar{x} = 5.77$, $\sigma = 0.73$). In addition, the 3D display group gave significantly higher ratings (Z = -2.344, p < 0.05) for trying their best ($\bar{x} = 6.6$, $\sigma = 0.70$) than the 2D display group ($\bar{x} = 5.85$, $\sigma = 0.80$).

MLB 2K9

As we expected due to the task being more of a timing task than a spatial 3D task, , there was no significant difference in the performance data for missing early ($t_{38} = 0.214$, p = 0.832), missing late ($t_{38} = -0.908$, p = 0.370), outs ($t_{38} = -0.141$, p = 0.889), and total number of swings ($t_{38} = -0.593$, p = 0.556). This trend held across the gamer ranks as well.

Similar to what we did for Resident Evil 5, we broke the swings into thirds to evaluate the presence of any learning that may have been happening. Overall there didn't appear to be any improvement as far as the number of home runs from the first third of the swings to the last third for either the 2D display ($F_{2,18} = 1.878$, p = 0.182) or 3D stereo display groups ($F_{2,18} = 1.277$, p = 0.303). There was significant improvement for both groups, 2D display ($F_{2,18} = 8.078$, p < 0.05) and 3D stereo display ($F_{2,18} = 7.811$, p < 0.05), when we looked at the number of swing-and-misses in each third. This time, the non-stereo group had a slight advantage in the improvement as they went from 3.6 to 2.0 misses while the stereo group dropped to 3.0 misses from 4.2. This translated to a 44.4% improvement for the 2D display group compared with a 28.6% improvement for the 3D stereo display group (see Figure 9). When broken down by gamer ranks, however, the intermediate stereo 3D participants were the only group that exhibited this learning ($F_{2,8} = 5.954$, p < 0.05) on the number of misses decreasing throughout their swings with a 26.3% improvement.



Figure 9: MLB 2K9 Improvement.

In line with what we have seen in other games, there was not much difference in the user's responses to the qualitative questions. The only significant difference (Z = -0.488, p < 0.05) was seen for the intermediate rank, where the 3D stereo display group was less likely to be distracted by what was happenin around them ($\bar{x} = 1.70$, $\sigma = 0.67$) than the 2D display group ($\bar{x} = 2.85$, $\sigma = 1.34$).

Madden NFL '08

Going against what we expected to see from the task in Madden, there was no difference between the groups in number of kicks that missed the target ($t_{38} = 0.64$, p = 0.526), the number of 200 point target hits ($t_{38} = -0.534$, p = 0.597), 100 point target hits ($t_{38} = -0.337$, p = 0.738), 50 point target hits ($t_{38} = 0.525$, p = 0.603), best score ($t_{38} = -0.858$, p = 0.396), worst score ($t_{38} = -0.135$, p = 0.893), or average score ($t_{38} = -0.62$, p = 0.539). This held across the gamer ranks when broken down, there was no difference.

Overall, there did appear to be some learning happening when we looked at the difference in the user's score from the first try to the fifth and final try for both the 2D display $(F_{4,13} = 4.604, p < 0.05)$ and 3D stereo display groups $(F_{4,12} = 3.495, p < 0.05)$. As with Left 4 Dead and Flatout, the stereo group demonstrated a more drastic change in this game as their scores grew to 406.25 (σ =297.7) from 171.87 (σ =146.02), a 136.4% improvement, while the 2D display group demonstrated a 103.2% improvement, increasing their score from 185.29 (σ =189.37) to 376.47 (σ =222.28) (see Figure 10). The only group that demonstrated significant improvement when isolated was the intermediate non-stereo group ($F_{4,8} = 4.53, p < 0.05$). They made a 170% improvement as the increased their score from 170.83 (σ =151.44) points to 470.83 (σ =187.64).



Figure 10: Madden NFL Improvement.

Madden NFL '08 actually did show some differences in the qualitative section. Overall, the 3D stereo display group gave significantly higher ratings (Z = -2.279, p < 0.05) for trying their best ($\bar{x} = 6.05$, $\sigma = 1.15$) than the 2D display group ($\bar{x} = 5.2$, $\sigma = 1.20$). The 3D stereo display group was also significantly more likely (Z = -2.337, p < 0.05 to want to play the game again (\bar{x} =4.1, $\sigma = 1.41$) than the 2D display group ($\bar{x} = 2.95$, $\sigma = 1.73$). There were no differences for beginning users, but there were differences on 7 questions for intermediate users (see Table 3) and on 1 question for advanced users (Z = -2.037, p < 0.05) in which the 3D stereo display group responded that they enjoyed the graphics and imagery more ($\bar{x} = 4.4$, $\sigma = 0.89$) than the 2D display group($\bar{x} = 2.66$, $\sigma = 0.58$).

Madden NFL '08 Qualitative Results						
Qs	Wilcoxon Signed-Rank Test	3D Stereo Display	2D Display			
Q1	Z = -2.37, p < 0.05	x̄ =5.3, σ=1.70	x̄ =3.9, σ=1.38			
Q2	Z = -1.29, p = 0.20	x̄ =5.9, σ=0.99	x =5.4, σ=0.96			
Q3	Z = -2.15, p < 0.05	x̄ =6.2, σ=1.03	x̄ =5.2, σ=1.07			
Q4	Z = -2.13, p < 0.05	x̄ =4.6, σ=0.84	x̄ =3.2, σ=1.63			
Q5	Z = -2.31, p < 0.05	x̄ =2.0, σ=0.82	x̄ =3.5, σ=1.61			
Q6	Z = -0.38, p = 0.70	x̄ =4.6, σ=1.51	x̄ =4.8, σ=1.54			
Q7	Z = -0.92, p = 0.36	x̄ =4.6, σ=1.78	x =3.9, σ=1.50			
Q8	Z = -2.06, p < 0.05	x̄ =2.9, σ=1.20	x̄ =1.9, σ=126			
Q9	Z = -2.05, p < 0.05	x̄ =4.6, σ=1.07	x̄ =3.2, σ=1.59			
Q10	Z = -1.89, p = 0.06	x̄ =4.5, σ=1.35	x =3.5, σ=1.27			
Q11	Z = -0.22, p = 0.82	x̄ =2.4, σ=1.17	x̄ =2.5, σ=1.66			
Q12	Z = -2.04, p < 0.05	x̄ =4.5, σ=1.51	x̄ =2.4, σ=1.56			

Table 3: Madden NFL '08 Qualitative results for the intermediate group.

Stereoscopic 3D Questions

There were some interesting results from the questions about the experience of 3D on the perceived benefit or hindrance of the technology. Three people from the 2D display group who played the five games in non-stereo and then played one game in stereo thought that the stereo provided them an advantage. Of the 20 participants in the 2D display group, 4 chose to play Resident Evil 5, and of those 4 people, two thought that the stereo 3D helped them. The other

person who thought that stereo helped was one of the 5 people who chose to play Flatout: Ultimate Carnage. Of those same people who played in non-stereo, seven thought the technology hurt their performance when they got the chance to replay a game in stereo. Three of the 7 participants who thought the technology hurt them were playing Left 4 Dead and another 3 of the participants were playing Flatout. The remaining participant who thought stereo 3D hindered their performance was playing Resident Evil 5.

Of the participants from the 3D stereo display group, that played all the games in stereo, 10 of them thought that it gave them an advantage in at least one of the games, while seven of them thought that it hurt them in at least one of the games. In this group, 9 participants thought the technology helped them in Left 4 Dead, 8 thought so in Resident Evil 5, 5 felt it benefited their performance in Flatout, and another 5 felt the same in MLB 2K9. In the same group, 3 felt it hurt them in Left 4 Dead, 3 more participants felt it hurt their performance in Resident Evil 5, and another participant thought it hindered them in MLB 2K9. No participants from the 3D stereo display group thought that 3D hurt their performance in Flatout, and no participants thought that it helped or hurt them in Madden.

Despite the fact that 3D stereo did not seem to impact performance and had very little impact on how the participants rated their experience with the games, the participants still preferred to play in 3D stereo. As part of the questionnaire relating to the stereoscopic aspect of the study, participants responded to four statements on a 7 point Likert scale (1 = Strongly Disagree, 7 = Strongly Agree). Participants agreed that 3D stereo improved their experience (\bar{x} =5.13, σ =1.40), they would choose to play video games in 3D stereo over the 2D display (\bar{x}

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=5.13, σ =1.47), and that it enhanced the level of immersion they felt (\bar{x} =5.58, σ =1.11). Though preferred, participants responded that it was not a necessity (\bar{x} =3.85, σ =1.51).

CHAPTER SIX: DISCUSSION

Overall, the results obtained for the quantitative data were in line with what we expected to see, that stereoscopic 3D in its current form would not provide much benefit to the user. But why is that? There seemed to be a few tasks in these games that appeared as though they could benefit from added depth perception, tasks like hitting a baseball and aiming an arrow in 3D space.

One reason this may be the case is that current games may not be built to take advantage of 3D. With almost every game that is on the list of the best games in 3D, there were settings that needed to be adjusted to maximize the 3D aspect or reduce artifacts that it would create. Most of the games needed shadows to be turned off as they would not be rendered correctly with the stereoscopic 3D enabled. We have seen that while not as beneficial as stereo, other depth cues such as shadows can increase the benefits for some 3D tasks [9]. Even with the settings tuned the way they were requested, some games still had noticeable glitches at times. Left 4 Dead would periodically create a flash effect in which the screen would go really bright if a light caught the camera the wrong way, which was hard on the eyes.

Another factor may have been the controls. Studies have shown that the interaction devices can have a significant impact on user performance [13]. This factor was most evident in the beginner group of participants, as it appeared that a lot of times they were struggling much more with manipulating the controls than anything that was being viewed on the screen. In addition, the controller used in our study was a standard Xbox 360 controller. Controlling the action onscreen with this type of input can be somewhat unintuitive, especially for beginning users, and standard 2D controls without special input may become even more unintuitive with

the more immersive 3D stereo environment. Other controllers that provide 3D spatial input such as the Playstation Move or Microsoft's Kinect device could provide users with control mechanics that are more conducive to performing game tasks in 3D stereo.

One possible reason we did not see the benefits that other research has shown to be possible with 3D may be that in video games, the tasks are not as cleanly isolated and evident. There is much more going on in the environment and the scenes are much more complex than most previous research on the topic. Left 4 Dead and Resident Evil 5 are the two notable examples from our study.

Some interesting results did show up when we started to look at the possible learning effects taking place in the games. It was clear that learning occurred in most of the games for users regardless of whether they were viewing in 3D or not. What is interesting is that in 3 of the games, the learning that occurred was greater for users viewing in 3D. So it is a possibility that the 3D may help users in learning the game environments or tasks in the games. Similar results have been shown by other research in which it was determined that 3D stereo allowed users to grasp larger, more complex scenes with more understanding [23,25]. In those studies, the benefits were only increased as the resolution of the display increased. We were running the study on a 1080P TV with 120Hz refresh rate. 3D TVs are starting to come out now with 240Hz refresh rates and higher, so more benefits may occur as display technology advances allowing for more detail to be seen and motion to be cleaner.

Much of the research that has studied the benefits of stereoscopic 3D has compared it to normal viewing as well as viewing with head tracking. It would be interesting to run tests with

head-tracking in these games as well to see if the results where head tracking has been shown to provide more benefit to users than stereo 3D would translate to modern video games.

As for the qualitative data, we had thought we would see more of a difference in the responses for the stereo group. We assumed this based on previous work in which user preference was clearly for 3D such as the U-Decide initiative released my Meant to be Seen 3D [14]. Overall, it did not appear that the user's perception of their performance was affected by the stereo 3D as there were not very many instances where any of the qualitative data was found to be statistically different between the 2D display and 3D stereo display groups. One reason for the difference might be because of the relatively short time that our users played each game. With such short play times, it may have been difficult for them to become immersed in the game whether or not they were viewing it in stereo.

CHAPTER SEVEN: FUTURE WORK AND CONCLUSION

Future Work

Although our study provided a significant amount of data from the games that we tested, and we were able to get some good information from the results, we were not able to get results that some researchers have seen in the virtual reality and 3D user interface communities in which the 3D stereo increases the user's performance. This leads to more questions and areas for further exploration in the area of 3D stereo with modern video games. We present several areas that may benefit from further research and ideas for future studies that take into account some of those areas.

Areas for Further Exploration

Looking at the results from our study, we discussed a few reasons that we thought may have been why we did not seen any advantage from 3D stereo viewing that has been shown in other studies. We suggest a few areas that may have detracted from our results, and these are areas that may aid future studies in providing better results.

Newer Games

Since the time our study was conducted, several more games have been released that support 3D stereo. Battlefield: Bad Company 2, Dead Rising 2, Just Cause 2, and Metro 2033: The Last Refuge are four games that fall into the genres we tested that have been recently released with 3D stereo support. It would be interesting to test some of these games, that are said to provide a

better overall 3D stereo experience, on a similar study as ours. If these games can run with 3D stereo along with some of their more advanced graphical techniques, such as shadows, there is a chance that they may provide better results as depth cues can be additive.

Better Displays

Along with the new games that have been released, there are also new television sets and 3D stereo setups that are now available. These new TVs can have refresh rates of 240Hz and faster. This may provide a better, more detailed, and smoother image throughout the games as display technology has been shown to affect performance in some applications [23,25]. Again, it may be interesting to conduct a similar study to ours that compares results on different display technologies. It may also be useful to try different display sizes in order to explore whether the size of the display may affect performance. A user may be able to see smaller details better on a larger screen, but the pixels are also stretched leading to a less clear, more aliased image.

Isolating Tasks

Although it would be heading more towards simple tasks like previous research, it may be beneficial to develop similar interaction techniques on our own in a game engine, such as Unity, that supports 3D stereo. If this were accomplished, we could isolate the interactions from the controls and also from all of the other action that was taking place in the games. This way, we could see whether 3D benefits a user performing those interactions outside of a game environment. If there were not any benefit provided in that case, it would be reasonable to assume no advantage would be gained inside of a game.

Head Tracking

Since depth cues can be additive, another area for further exploration is whether head tracking with 3D stereo can be beneficial to a user playing video games. The added depth perception from motion parallax that the user would gain from the head tracking may be enough to give them an advantage in some of the interactions provided by modern video games. It would be reasonable to assume that this may be the case as there have been instances where it has been shown to be true by research in other areas [2,22].

3D Input Devices

Interaction devices can play a large role in the performance of a user playing video games. We observed that many of the participants from our study that were classified in the beginner group struggled to control the onscreen action with the input device provided. As noted in the discussion section, a standard Xbox 360 controller was used for input in our study. The tasks that we were looking at in the games we chose to study can be placed into three categories of 3D interaction techniques: selection and manipulation, travel, and wayfinding [3]. With that in mind, it may be beneficial to use 3D input devices and interaction techniques to control the action in these games as this may be more intuitive for users. The Playstation Move and Microsoft's Kinect make it possible to control games with 3D spatial input devices, so games available on these systems that can be played in 3D stereo would be good options for further exploration.

More Participants

We used 40 participants to collect our data. We then broke this group of 40 into three groups based on video game experience. We experienced some interesting results when looking at the learning rates in the games, with several games showing the 3D stereo display group improving their performance more throughout their time playing the game than the 2D display group. In some cases, however, there were not enough participants in some of the experience groups for the results to be statistically significant. It would be beneficial to have more participants in each of the groups to see if some of the trends that we saw would continue and be statistically significant with more participants.

Future Studies

To answer some of the questions that arose from our study, and to address some of the possible areas for future work, we would like to propose two more studies that should be conducted. These new studies will take into account some of the learnings from our study and will be geared toward the direction that we would like to see the research take.

Since areas such as display technology and video games are constantly evolving and getting better, the best options from those categories should be taken at the time of the future study. As of now, there are TVs on the market that refresh at 480Hz. This would allow for much smoother motion in 3D as each eye would be getting refreshed at 240Hz. This would be a major improvement from our setup, as the display we had available to use had a 120Hz refresh rate, giving each eye only 60Hz. We chose the highest rated games for 3D at the time of our

study. Since games will continue to come out with better support for 3D stereo, a survey of available games should be taken before each study to assure the best 3D stereo is being used.

Playstation Move

At the time of this thesis, Sony has recently released Playstation Move and Microsoft released the Kinect device. Thus far, there are no games for Microsoft's Kinect that are 3D stereo capable while the Playstion Move provides 3D spatial input for Playstation 3 games that support the technology, and the Sony Playstation 3 also supports 3D stereo. That leaves us with the Playstation 3 and the Move device as the only available option currently on the market to play games with a 3D spatial input device in 3D stereo. The combination of 3D stereo and 3D spatial input allow the opportunity to study whether 3D stereo can provide an advantage to users playing video games when a 3D spatial input device is used.

A subset of Playstation 3 games can be used with Playstation Move and another subset of games can take advantage of 3D stereo. By cross referencing those two sets of games, we come up with a list of 13 games that can be played with the Move in 3D stereo. The list of games includes Dungeon Defenders – a 3^{rd} person action game by Tendy Ent., Dynasty Warriors 7 – a 3^{rd} person action game by Omega Force, The Fight: Lights Out – a 3D fighting game by Coldwood, High Velocity Bowling – a bowling game by SCEA, Hustle Kings – a pool game by VooFoo Studios, Killzone 3 – a first person shooter by Geurilla, NBA 2K11 – a basketball game by 2K Sports, Pain – a game in which users launch their character to inflict damage to the environment by Idolminds, The Sly Collection – a collection of 3^{rd} person action games by

Sanzaru Games, Tron: Evolution – a 3^{rd} person action game by Propaganda Games, Tumble – a 3D puzzle game by Supermassive Games, and Virtual Tennis 4 – a tennis game by SEGA.

Though we haven't had the opportunity to play these games, it seems, from descriptions and videos of the games, that some of them are in the same genres and have similar interactions to the games used in our study. Four of the available game options are 3rd person perspective games. Dungeon Defenders appears to have interactions that include shooting and moving in 3D space while Dynasty Warriors appears to be a similar style of game as Devil May Cry 4. The Sly Collection and Tron: Evolution also appear to have similar 3rd person interactions. Killzone 3 could represent the first person shooter genre. There are a few sports games that are not the same sports that we studied, but may have similar interactions to the games we looked at. Depending on the mechanics to shoot the ball, NBA 2K11 could provide some interesting options as far as 3D interaction and Virtual Tennis 4 would probably have similar opportunities to time a swing and hit a ball as MLB 2K9. Tumble and Pain are also different types of games than anything we looked at and may provide interactions worth looking at.

We would propose playing through these games to determine the best ones to use in a study. For each game selected, metrics should be determined to judge the performance of a user. We would suggest items such as completion times, accuracy in shooting, scores from the games, and goals to attain in the games to be good measures of performance. From our experience, 40 participants seems to be the minimum for this type of study. We believe that a between subjects design is the best option. A between subject design helps eliminates issue of learning the task in the games from playing with one viewing type and using that knowledge to perform better on the second display type. Therefore, a user study with at least 40 participants should be run with

half the participants playing the games with the Playstation Move on a 3D stereo display and the other half playing the games with the Move on a standard 2D display. A study such as this could help determine whether 3D stereo viewing makes a larger impact when 3D spatial input devices are used for the interactions in the games.

3D Interaction Techniques

One issue with using games with the Playstation Move is that the interaction techniques are decided upon by the developer and there is no control on which interaction techniques to use. So another area to be studied would be which 3D interaction techniques may work best with viewing games in 3D Stereo. Since developers are unlikely to open their games for researcher to develop different control techniques for them, it would be up to the researcher to develop "games" that support 3D stereo and different 3D interaction techniques with 3D input devices. Another advantage of developing the interactions would be that the researcher could add support in the games for head tracking to see if the added depth from the motion parallax cue could aid performance with 3D stereo.

One way to accomplish this would be to use a game engine that supports 3D stereo, such as Unity. The researcher would develop interactions in the game engine that mimic the interactions from the games. Although the environment would not be as intricate and detailed as a true video game and this would naturally lead to the tasks being more isolated than in a video game setting, this study would still be beneficial in determining the optimal conditions for 3D stereo. Some interactions could include things like aiming an arrow at targets, moving a character through a type of maze level with obstacles, and timing objects moving through 3D space as they approach pre-defined zones.

While implementing the interactions, the researcher would want to make sure interactions from each class of 3D interaction techniques are included: selection and manipulation, travel, and wayfinding [3]. This way, different types of interaction techniques could be tested to see if some techniques perform better when viewing in 3D stereo than others. Techniques available can be found in 3D User Interfaces: Theary and Practice by Bowman et al. Techniques such as interacting through pointing and direct manipulation should be tested with selection and manipulation tasks, while physical locomotion, steering, route-planning, and manual manipulation techniques could be used with the travel tasks of exploration, search, and maneuvering [3].

Developing the 3D tasks in this manner could lead to multiple studies that provide more insight into the possible benefits of 3D stereo and what tasks may benefit the most from 3D stereo. This could also help answer the question of which 3D interaction techniques, if any, aid in performance while viewing in 3D stereo. Having access to the tasks in this way would also allow for studies to be conducted that look at whether head tracking may provide benefits, and if any benefits from head tracking could be additive with possible benefits from 3D stereo viewing alone.

One possible study could involve participants playing each task in 3D stereo with the different techniques available. The tasks and techniques would be presented in random order in an attempt to counteract the learning that would take place with each task. Such a study could help determine which techniques work best for each task in 3D stereo. After that study, another

study could be conducted in which participants play each task with either a 3D stereo display or a 2D display. The results could be analyzed to see if 3D stereo may provide benefits to the user when they are using the best possible interaction technique for the task presented in 3D stereo. Similar steps could be taken to see if head tracking may provide benefits to the user. This additional research may help provide feedback to game developers on which interaction techniques may be the most beneficial for the tasks that they are presenting in their games.

Conclusion

This research has explored the possibility of 3D stereo providing benefits to a user playing modern video games. Overall, the results were in line with what we expected to see. 3D stereo did not provide any significant advantage in performance over a 2D display and learning rates were comparable between display modes for the games we tested. In addition to the performance and learning results, the qualitative data suggests that overall there was not much difference in perception of the gameplay experience between the 3D stereo display group and the 2D display group. Despite these results, participants indicated that they preferred playing the games in 3D stereo over playing on the 2D display. With many more questions arising from the results produced, we provided a few areas where this research could be further explored in the future and presented formats for a few future studies that could be conducted. These further studies may provide more concrete answers to the question of whether 3D stereo can be beneficial to a user playing video games. The results of such studies may also be beneficial to

game developers seeking to use 3D stereo and 3D spatial input devices for interactions in their games.

APPENDIX A: IRB APPROVAL LETTER



University of Central Florida Institutional Review Board Office of Research & Commercialization 12201 Research Parkway, Suite 501 Orlando, Florida 32826-3246 Telephone: 407-823-2901 or 407-882-2276 www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: UCF Institutional Review Board #1 FWA00000351, IRB00001138

To: Joseph J. LaViola II and Tad R. Litwiller

Date: March 17, 2010

Dear Researcher:

On March 17, 2010, the IRB approved the following human participant research until 3/16/2011 inclusive:

Type of Review:	Initial Review Submission Form
Project Title:	User Performance in Stereoscopic 3D Video Games
Investigator:	Joseph J LaViola II
IRB Number:	SBE-10-06692
Funding Agency:	None

The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form <u>cannot</u> be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu.

If continuing review approval is not granted before the expiration date of 3/16/2011, approval of this research expires on that date. <u>When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate</u>.

<u>Use of the approved, stamped consent document(s) is required.</u> The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Joseph Bielitzki, DVM, UCF IRB Chair, this letter is signed by:

Signature applied by Janice Turchin on 03/17/2010 12:45:02 PM EST

Janui mituchn

IRB Coordinator

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APPENDIX B: PRE-QUESTIONNAIRE

Video Game Experience

Participant Number:			
Gender (please circle one): Male	F	Female	
Age:	Major:		
Directions: Please circle the best a your answer in the space marked	nswer for e "other".	each of the following questions, or write	¢
1. Have you ever played video gan	nes? Yes	No	
2. Do you currently play video gar	nes? Yes	No	
If your answer was "No" to) either que	estion, why don't you play video games	?
a. cost	-		
b. not interested			
c. not enough time			
d. lack of skill			
e. not allowed (parent	ts, teachers,	s, etc.)	
1			

3. How long have you been playing video games?

- a. 6 months
- b. 1 year
- c. 2-5 years
- d. 5-10 years
- e. 10 or more years

4. How often (approximately) do you currently play video games?

- a. daily
- b. weekly
- c. once a month
- d. once in 6 months
- e. once a year

5. How good do you feel you are at playing video games?

- a. very good
- b. moderately good
- c. not very skilled
- d. no skill

6. What consoles do you own (if any)? Please list all.

 7. If you do not own a console, how do you play? a. other friends that own b. online/internet c. arcade d. on my phone 			
e. handheld			
f. other			
8. What are your Top 5 (in order)video games that you like t #1#4	o play?		
#2#5			
#3			
9. Have you played video games in Stereoscopic 3D before?	Yes	No	
 Have you played any of the following games? (circle all t Resident Evil 5 Left 4 Dead MLB 2K9 Madden NFL '08 	hat appl <u>i</u>	y)	
Flatout: Ultimate Carnage			
11. Are you offended in any way by violent video games?	Yes	No	

APPENDIX C: POST-QUESTIONNAIRE

To what extent	did the game	hold your	attention?			
1	2	3	4	5	6	7
Not at al	1		Somewhat			A lot
Commer	nts:					
How much effo	ort did you pu	t into playi	ng the game?			
1	2	3	4	5	6	7
None			Some			A lot
Commer	nts:					
Did you feel that	at you were tr	ying your b	best?	_		_
1	2	3	4	5	6	7
Not at al	1		Somewhat			very much
Commer	nts:					
o what extent	did you lose t	track of tim	ne?			
1	2	3	4	5	6	7
Not at al	1		Somewhat			A lot
Commer	nts:					
Did you feel the	e urge at any	point to sto	p playing and see wl	hat was haj	ppening are	ound you?
1	2	3	4	5	6	7
Not at al	1		Somewhat			Very Much S
Commer	nts:					
l'o what extent	did you find	the game cl	hallenging?	_		_
1	2	3	. 4	5	6	7
Very Eas	зу		Average			Very Difficu
Commer	nts:					
low well do yo	ou think you p	erformed i	n the game?	_	<i>.</i>	-
l	2	3	. 4	5	6	/
Very Poo	or		Average			Very Well
Commer	its:					······································
o what extent	did you feel e	motionally	attached to the gam	ie?	<i>,</i>	-
	2	3	4	5	6	/
Not at al	1		Somewhat			Very Much S
Commer	nts:					······································
lo what extent	did you enjoy	the graph	ics and the imagery?	, ,	<i>(</i>	7
l Na sa	2	3	4	3	0	/
None			Some			A lot
	118:					
10w much wol	nd you say yo	u enjoyea j	playing the game?	=	6	7
l None	2	3	4 S ann a	5	0	/
None			Some			A lot
	118:	diagona sind	ad that the same me	a awaw?		
vnen interrup	iea, were you	disappoint	ed that the game wa	s over:	6	7
l Nonc	Z	3	4 Somo	3	0	/ Vor
INONe			Some			very
	115:					
voula you like	to play the g	ame again?	Λ	5	<i>r</i>	7
l Definited	ے ابر Not	3	4 Wouldr't Mind	3	0	/ Definitely Ver
Definite	iy inol		wouldn't wind			Definitely res
Commer	ns:					

Please answer the following questions by circling the relevant number.

APPENDIX D: 3D STEREO QUESTIONS

Stereoscopic 3D Experience Your Experience of the Game

Please answer the following questions by circling the relevant number. In particular, remember that these questions are asking you about how you felt at the end of the games.

Stereo 3D imp	proved the over	all experienc	e of the game?			
1	2	3	4	5	6	7
Not at a	all		Somewhat		·'	Very Much So
Comme	ents:					
I would choos	e to play video	games in ste	reo 3D over norn	nal viewing.		
1	2	3	4	5	6	7
Strongl	y Disagree		Don't Care		S	trongly Agree
Comme	ents:					
I felt that Ster	eo 3D enhance	d the level of	immersion I felt	in these gan	nes.	
1	2	3	4	5	6	7
Strongl	y Disagree		Don't Care		S	trongly Agree
Comme	ents:					
Stereo 3D is a	necessity for m	y future gan	ning experiences.			
1	2	3	4	5	6	7
Strongl	y Disagree		Don't Care		S	trongly Agree
Comme	ents:					
How much we	uld vou be will	ling to spend	on a device that	enabled you	to play the vi	deo games

How much would you be willing to spend on a device that enabled you to play the video games you have now in stereo 3D? (Circle the best answer)

\$0 Less than \$50 \$50-\$150 Over \$150

Do you feel that viewing any of the games in Stereoscopic 3D helped you to perform better in the tasks that were presented to you? (Circle the best answer)

Yes No

If Yes, Please answer the following two questions.

Which games did you feel that it helped you in? (circle all that apply)

Resident Evil 5 Left 4 Dead MLB 2K9 Madden NFL '08 Flatout: Ultimate Carnage

How do you feel it aided you in these games?

Do you feel that viewing any of the games in Stereoscopic 3D hurt your performance in the tasks that were presented to you?

Yes No

If Yes, Please answer the following two questions.

Which games did you feel that it hurt your performance in? (circle all that apply) Resident Evil 5 Left 4 Dead MLB 2K9 Madden NFL '08 Flatout: Ultimate Carnage

How do you feel it hindered you in these games?

Did you feel any Symptoms from viewing the games in stereo (eye strain, head aches, dizziness, Nausea)?

Please rate the level you felt such symptoms Eye Strain

·	1	2	3	4	5	6	7
	Not at a	ıll		Some			Very Much
Head	Ache						-
	1	2	3	4	5	6	7
	Not at a	ıll		Some			Very Much
Dizzi	ness						
	1	2	3	4	5	6	7
	Not at a	ıll		Some			Very Much
Naus	ea						
	1	2	3	4	5	6	7
	Not at a	ıll		Some			Very Much

Please list any other symptoms you felt from this experience.

Additional Comments:

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