Project Number: MLC-GP06

The Effects of Gamma and High Dynamic Range Lighting on Performance and Perception in First-Person Shooters

An Interactive Qualifying Project Report
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
Degree of Bachelor of Science
by

_____
Scott Kolodzy

_____
Kenneth Louf

Date: April 30, 2007

Approved:

_____
Professor Mark Claypool, Advisor

Abstract

The goal of this study was to determine the effects of gamma and high dynamic range lighting on user performance and user perception of image quality in computer games. A user study was run in which participants played four different sessions of Counter-Strike: Source with varying gamma and high dynamic range values, while measuring user performance and gathering user opinions. Analysis of the results found that user performance was not affected by gamma or high dynamic range lighting. In addition, game playability and picture quality were similarly unaffected by these settings.

Acknowledgements

The authors of this paper would like to thank Professor Robert Lindeman for the use of his computers. In addition, we would like to thank Professor Mark Claypool for taking the time every week to meet with us and point us in the right direction.

TABLE OF CONTENTS

1 Introduction

Professional gaming is a multi-million dollar industry and is growing every year. There are multiple leagues for professional gamers to play in, with sometimes hundreds of thousands of dollars as the grand prize. More and more each year, gaming is being accepted as a form of sport competition. Players are more and more concerned with playing at their best, and many know that a computer's hardware, frame rate, and other settings can affect how well they play. These display settings also affect the graphical quality of the game, which can be reduced greatly by these settings. Gamers do care about the look of a game, and if a setting sacrifices too much quality, it likely will not be used. Competitive gamers are always looking to improve their skills, which leads to the question of which settings actually affect users' performances and do not sacrifice too much quality. Higher resolution or better antialiasing will reduce frame rate drastically, while making the game picture look much better. There is a noticeable tradeoff between quality and performance, and finding the right balance is important.

Already known are the properties of the settings provided, in this case *high dynamic range lighting (HDR)* and *gamma*, specialized lighting effects and the amount of ambient light respectively. Lower gamma values result in a darkened environment making it difficult to see; higher values make outside daylight much brighter than normal. Enabling high dynamic range produces an image with more realistic lighting and is presumably highly desired.

The game used to study gamma and HDR was Counter Strike Source by Valve Software. This game is a first-person shooter with two opposing teams, Terrorists and Counter-Terrorists, who battle for control over two locations on the map called

"objectives". The score of a player is tallied up by the number of kills that player has gotten, as well as their subjective rating of quality and playability for reach round, with each round being a variable length of time. The game has highly advanced and customizable lighting settings, as well as being a popular game, with tens of thousands servers running at any one time[6], making it a prime choice for the study. The settings varied were the gamma, from the lowest value of 1.8 to the highest value of 2.6, with 2.1 being the normal, and high dynamic range lighting being either on or off. Twenty users participated in the study, all of them being students or faculty at Worcester Polytechnic Institute. While testing the participants, data was gathered on how well the participants performed during each session with varying lighting qualities. After the study, this data was analyzed and conclusions were drawn.

Several similar conclusions were made from this study, relating to both user performance and perception. It was found that the gamma does not have an impact on the performance of the user as well as the rated level of playability. It was also found that high dynamic range lighting similarly did not make affect the game's visual appearance, user scoring, or the playability of the game.

The rest of this paper is organized as follows. Section 2, Background, details the previous work done. Section 3, Methodology, explains how the study was designed and run, and how all of the data was collected. Section 4, Results, summarizes the aggregate data collected. Section 5, Analysis, looks deeper at the gathered data and describes all of the information discovered in the study. Section 6, Conclusions, summarizes what was drawn from the analysis of the data and also discusses what this study contributes to this

field of media. Finally, Section 7, Future Work, touches on future work that can be done to improve this study and studies yet to come

2 Background

In the area of the effects of graphics settings on user performance and perception, previous studies have been done concerning settings such as frame rate, resolution and antialiasing. A study by Claypool *et al.* (2006)[1] looked at the effects that different frame rates and resolutions have on the performance of users playing a first-person shooter video game. The results show that while the amount of frames per second that the game runs at has a significant effect on user performance, resolution does not; the user's perceived quality of the game does, however, increase as both factors increase. Another study by Connor *et al.* (2006)[2] backed these results up, while also establishing that "a higher frame rate allows a user to perform more reliably to their abilities, rather than be affected by lower quality system settings." This study also found that resolution does, in fact, have an impact on user recognition in first-person shooter computer games, pinpointing "512x384 as the highest resolution at which performance is still hindered by lack of quality system settings." Another study by Booth *et al.* (1986)[3] looked at user perception of low-resolution three-dimensional images of cubes and found that users in their study preferred antialiased images and were able to correctly identify the number of cubes quicker in the images that were antialiased.

To the best of our knowledge, no real studies have previously been done to examine the effects of gamma and HDR. Before the tests were done, it was known only that some gamers choose to play with their gamma and brightness settings turned up, as an increase in both of these settings provide a similar effect that decreases the darkness of an image, giving themselves an advantage in games by being able to more easily see dark areas. The reasoning behind this is that if there are any dark areas on a map, they are able

to see those areas more clearly, allowing for better awareness of the surroundings, and consequently better performance in the game itself. This strategy has long been used by gamers playing casually at home, but is not allowed in the competitive gaming circuit.

It was also not known beforehand what effect high dynamic range lighting would have on a player's performance, as it is a relatively new feature in the gaming world. Half-Life 2: Lost Coast, a single-player level custom-created to showcase high dynamic range lighting in the Source game engine, was released on October 27, 2005[5] and marked one of the first occurrences of HDR in computer games. Soon after, it was introduced to Counter Strike: Source, with the addition of the de_nuke map on December 1, 2005[7]. In addition to not knowing the effects of HDR lighting, it was not known if gamma actually affected the performance of a player. There have always been general arguments and counter-arguments between gamers over what effects these settings have, however no real scientific results have ever been established.

3 Methodology

This section explains in more detail the process that went into designing the study. It also discusses how the study was run as well as issues that were encountered during the process.

3.1 Research

Before a user study could be designed, the exact settings to be tested, the game to test them with as well as the manner in which those settings were tested in that game had to be chosen.

3.1.1 Settings Choice

To start, an extensive list of different graphics settings was compiled from a variety of recently released computer games including, but not limited to, Need for Speed: Carbon (2006), The Elder Scrolls Oblivion (2006) and Counter-Strike (2000), as well as from video card drivers such as the ATI Catalyst drivers (v 6.11). Many of the settings were specific to certain games and their engines/purposes (e.g. Need For Speed Carbon has settings for Car Detail and Motion Blur, The Elder Scrolls IV: Oblivion for Tree Canopy Shadows and Window reflections, etc.). The list was carefully looked over and settings of this nature were removed. From this, five settings were found to be used in a majority of the games looked at with the exception of HDR, which was only found in newer, high-quality games, such as Counter-Strike: Source, with advanced graphics features; these settings were looked into more deeply and hypotheses were formed as to their possible effects:

- **Brightness**: How light/bright or dark/dim the display is; this is usually expressed in terms of percentage, from 0 (black) to 100 (white). For games with darker locations, adjusting the brightness to allow for a brighter image may aid the user and result in a better performance; the effect could be drastic if set to extreme levels either way, perhaps making a game difficult to play.
- **Gamma**: Similar to and often confused with brightness, gamma affects the middle tones of an image, leaving the black and white portions of the image untouched; a lower gamma corresponds to a darker image and vice-versa. There is no set range of values for gamma, the default value on PCs is 2.2, but varies by system. Similar to brightness, a higher gamma in games with poorly-lit

environments may help to improve the user's performance; at the same time, a gamma setting too low may make a game unplayable, significantly affecting a user's performance.

- **Antialiasing**: The process of removing or reducing the jagged distortions in curves and diagonal lines so that the lines appear smooth or smoother[4]. Possible values for an antialiasing setting may include 2x, 4x and 6x, indicating that each full frame is rendered at double (2x), quadruple (4x) or six times (6x) the display resolution, and then down-sampled to match the display resolution. At lower resolutions, antialiasing could be especially helpful and may in fact have a significant effect on user performance, while its effects at higher resolutions may not be as noticeable.
- **Vertical Sync**: When enabled, allows the frame rate of the game to be matched to the refresh rate of the monitor. On a monitor with a low refresh rate, user performance may decline with this setting turned on.
- **High Dynamic Range**: A relatively new setting found only in some of the more high-end games, this is a lighting procedure designed to emulate the way that light levels in the real world vary over an enormous range. Different games have varying values for this setting; a general on/off setting is the basis, with some games adding in-between values that serve as a toned-down, less resource-intense version of the on setting. While it may increase a user's subjective rating of image quality in a game, it is unlikely to have a significant effect on user performance as it does not affect the picture in a way that would make the game more difficult or easier for the user.

3.1.2 Pilot Study

To look into these five settings even deeper and understand their effects on the user's experience and performance in a game, a small pilot study was conducted in which we went and played a set of games we felt were suitable for testing out the aforementioned settings. These included games such as Counter-Strike: Source (2004), Doom III (2004) and The Elder Scrolls IV: Oblivion (2006). While playing, the chosen settings were changed to various values, both in the games and via the video card driver's control panel. After thoroughly testing out these settings and discussing the results, it was decided that for our user study the effects of both gamma and High dynamic range would be investigated.

We felt that the effects of brightness were overly obvious and testing the effects of it in a game would not lend much insight on player performance in video games. As previously explained, while gamma is similar to brightness, it only affects the mid-tones of an image, leaving the black and white portions untouched. While it produces a similar effect to brightness, lightening or darkening the image as its value is increased or decreased, the effect is not identical and therefore we felt that the results of altering its value would be of more interest.

The resolutions at which games are played have increased from the past as technology has improved; as a result of this, antialiasing is needed less and less, as the visibility of its effects decrease as resolution increases. We decided not to test the effects of antialiasing, as we had planned on using a high-enough resolution in our tests that the effects of antialiasing would not be seen. Similarly, modern computer monitors frequently support refresh rates greater than what is generally discernable by the human

eye. Therefore, enabling vertical sync and matching the game's frame rate to the monitor's refresh rate would presumably have no effect on user performance, as the frame rate would still be high enough that it would not have an effect.

As for the decision to evaluate the effects of high dynamic range, the fact that is a new technology, coming out and being introduced in games starting around a year ago, was a large factor. When it first appeared in computer games starting last year, only those with the most high-end computers were able to experience its effects. Now, more computers can handle this setting being turned on without drastically affecting the frame rate and possibly hindering the user's performance and its effects can be more accurately observed.

3.1.3 Hypotheses

After deciding to test gamma and high dynamic range, our ideas and speculations as to their effects were gathered together and formulated into hypotheses. Separate hypotheses were formed relating to user performance and user perception for each setting:

- **Gamma**
  - **Hypothesis 1:** Lower gamma values will adversely affect user performance, while higher values will improve user performance.
  - **Hypothesis 2:** Higher gamma values will be preferred over lower ones
- **High Dynamic Range**
  - **Hypothesis 3:** Enabling HDR will not have an affect user performance.
  - **Hypothesis 4:** HDR-enabled sessions will be preferred over those without HDR.

3.1.4 Game Choice

After deciding on the settings to test, we were able to narrow down the list of games we would use in our user study to only a few – namely those that support High dynamic range. From this list, it was decided that the game Counter Strike: Source (CS:S) would be used for a couple reasons. CS:S is a highly popular game of the first-person shooter genre, with players collectively contributing to over 1.833 billion minutes of playing time each month[6]. Also, CS:S has a relatively easy learning curve, so that a user who may never have played this game before would easily be able to start playing in a matter of moments, as opposed to a game such as The Elder Scrolls IV: Oblivion, which has a much higher learning curve and requires much more time to start playing. Our study was open for anyone to contribute, regardless of prior experience with computer games, so this was an important factor. Configuration scripts for CS:S can easily be written to allow for automatic changing of nearly all of the settings related to the game. Also, sessions of CS:S can be recorded onto disk in the form of 'demos', which provide for easy record keeping.

3.2 Testing Process

3.2.1 Design

To test the effects of the chosen settings, a user study was designed and tested before running. The gamma setting in CS:S has possible values from 1.6 to 2.6, with 2.1 being the default; **Error! Reference source not found.** shows the effects of gamma at these values. Testing all possible values was clearly not a possibility, so the minimum, default and maximum values were chosen to be tested. The HDR setting has 3 possible

values: Off, Bloom and Full; shows example images of these effects. Setting HDR to Bloom is a less-resource-intense and more widely-supported effect which spreads out

(a) 1.6

(a) Off

(b) 2.1

(b) Bloom

(c) 2.6

Figure 3.1

(c) Full

Figure 3.2

light sources, causing bright lights in the background to appear to bleed over onto objects in the foreground, for example. Setting HDR to Full produces the most realistic lighting effects, using calculations in a larger dynamic range. Keeping the amount of time required in order to participate down was important so as to attract as many people as possible and so a target of around ten minutes was desired. To fully test the effects of both settings, both independent of each other and concurrently, 9 tests would have been required. From previous experience with CS:S, it was known that the amount of time required to launch the game was approximately one minute. Having a user launch and play the game nine times with sessions of at least one minute each would have required a study that would have taken eighteen minutes to complete. It was determined that this was too much time and that something would have to change.

It was then decided that the effects of concurrently varying gamma and HDR values did not need to be tested and also that HDR could be tested with just the values of Off and Full, reducing the number of sessions to four, as displayed in Table 3.1. This only required a time of approximately twelve minutes, using two-minute sessions, which was determined to be more appropriate for scoring purposes.

	Gamma	HDR
1	1.6	Off
2	2.1	Off
3	2.1	Full
4	2.6	Off

Table 3.1

To keep track of the statistics for each user and session, demo videos were initially planned to record for each session. However, this would have required launching the game every time a playback was wanted, so instead, screenshots of the statistics screen, which are automatically brought up, were taken at the end of each session. These actions were bound to the F8 key in a configuration file that was loaded every time the game was launched.

To launch the game, a batch file was created that executes the path to the game executable multiple times, pausing and waiting for the user to hit any key on the keyboard after each session. Initially, it was planned to change the gamma and HDR settings for each session via different configuration files, but an easier, simpler approach was taken instead. Settings were changed in the batch file by passing them as parameters to the executable for each session of the test. In the game, the map de_dust was chosen to be used in the study, partly in reason that it is a commonly played map that is relatively small in size and easy to navigate for any person who has not played the game. A larger factor in choosing this map was that it is one of only a few maps in CS:S supporting HDR. The user played against two computer controlled opponents, or "bots", for each of the four two-minute sessions. The user played as the Counter-Terrorist team, while the two bots, which were set to normal difficulty, were automatically assigned to the Terrorist team. This was determined to be a fair number of opponents for one person to face without giving an advantage to either the user or the computer in terms of scoring.

3.2.2 Setup and Process

To carry out the tests, two computers capable of running Counter-Strike: Source were borrowed and used. The specifications for each are as follows:

	Computer 1	**Computer 2**
CPU	2.8 GHz Pentium 4	2.4 GHz Pentium 4
Memory	1 Gb	512 Mb
Video Card	nVidia GeForce 7300 GT (512 MB Video memory)	nVidia GeForce 7300 GT (512 MB Video memory)
Hard Drive Type	ATA	ATA
Monitor (Resolution)	17" CRT (1024x768)	17" CRT (1024x768)
Sound	Integrated audio chip, Creative 2.1 Stereo speakers	Integrated audio chip, Headphones

OS	Windows XP SP2	Windows XP SP2
Accessories	Microsoft PS/2 mouse, keyboard	Microsoft PS/2 mouse, keyboard
Game	Counter-Strike: Source updated as of March 26, 2007	

The computers were set up in a private lab, side by side. Two computers were used for user convenience in the case that multiple users wanted to participate in the study at the same time. Although the computers were positioned next to each other, the distance between them was far enough apart so as to avoid distraction from other users during participation. Monitoring of users' participation was done locally, so as to provide any assistance that may have been needed as promptly and helpfully as possible.

For this study, users were solicited in a variety of ways. First, test subjects were found through friends and classmates. Faculty and staff in the Computer Science department also participated. Additional users were procured through CS courses, where students were encouraged by the faculty to take part in the study, rewarding those who participated with extra credit points. Also, posters and advertisements were placed around campus. All users were entered into a raffle for a $25 gift card.

To start the study, each user was given an instruction sheet and a survey sheet (see Appendix). The survey sheet contained a demographics survey on the front side of the sheet and questions pertaining to the playability and picture quality of each session on the reverse side. The demographics survey was anonymous; only a testing number was issued for each participant to be able to keep track and map the answers to the questions pertaining to each session to the correct result set. The instructions contained information about what the user would be doing as well as some basic controls for the game. Specific information about what was being tested was not given, only that different settings would be used for each session. Users were allowed to ask questions at any point during the

process, but no specific information relating to what was being tested or any information that could potentially have an effect on the outcome of the users' performance was given.

As previously stated, the test batch file ran CS:S four separate times, with different settings enabled each time, pausing in between executions, allowing the user to play the session and quit each time. The order that the different settings were enabled was static and is displayed in Table 3.2.

After two minutes of playing the game with each set of settings, the user was notified to press the pre-mapped F8 key, which displayed the statistics screen, took and saved a screenshot and quit the game. The time was kept track of by the test operator(s), using a watch timer. This approach was used for a couple of reasons. While a specific round time can be set via configuration file, if the round ends because one of the teams has achieved the objective for the map before the time is up, a new round will begin with the timer being reset. In addition, even if the round does not end before the timer expires, when the timer does expire at the end of two minutes, no way was found to automatically perform the wanted actions at that time. After each user test, the screenshots generated were placed in a folder corresponding to the testing number issued at the beginning of the test.

Round	Gamma	HDR
1	2.1	Full
2	2.6	Off
3	1.6	Off
4	2.1	Off

Table 3.2

3.2.3 Issues

Throughout the course of the study, there were a few issues that came up that could have possibly affected the results of the study. First, while the setup of the computers being side-by-side with no divider and the operator(s) in the same area was assumed to not affect each user, there was no way to tell ahead of time what, if any,

affect this may have on the overall results. Also, during each test factors such as not being able to automatically quit each session and having to time each user with a watch timer as well as user error in not following directions posed potential problems. However, after collecting and analyzing the resultant data, it turned out that the integrity of the data was unharmed, as there were clear trends in the data with few outliers.

4 Results

The user study ran for one week and results were gathered for 20 individuals, all of them being WPI students, staff or faculty.

4.1 Demographics

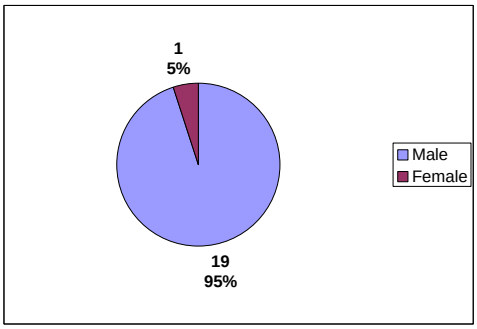
The collected demographics information is displayed graphically in Figure 4.1. Only one female participated in the study. As expected, most of the users participating were under the age of 25, play video games at least a few times a week (first-person shooters at least once a week) and rate their performance at first-person shooters as at least average.

4.2 Session Data

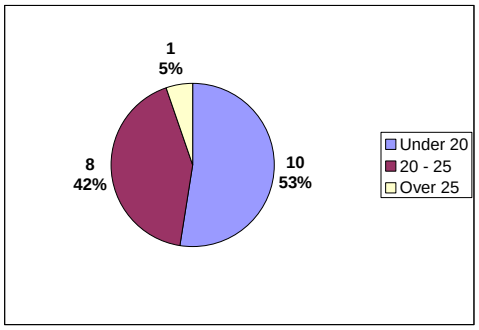
Overall, there was a variety of data of collected about user scoring and user ratings of playability and picture quality. In terms of user scoring (the number of kills a user made), the minimum score was 0, occurring multiple times, and the maximum was 8, occurring only once when HDR was set to full. The average and median scores were between 1 and 3, with standard deviations between 1 and 2, for all sessions. In terms of playability and picture quality ratings, both the minimum rating given was 1 and a

maximum rating of 5 were given multiple times. The average and median ratings given were in the range of 3 to 4, with standard deviations of around 1.

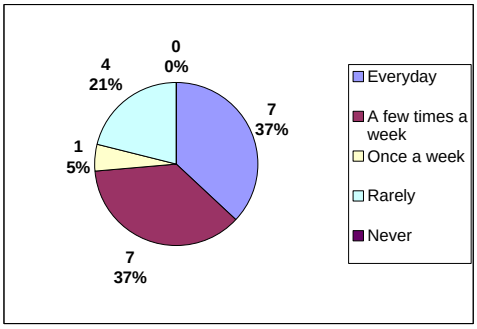
At a first glance, this data tells that there was not much variance, both in scoring



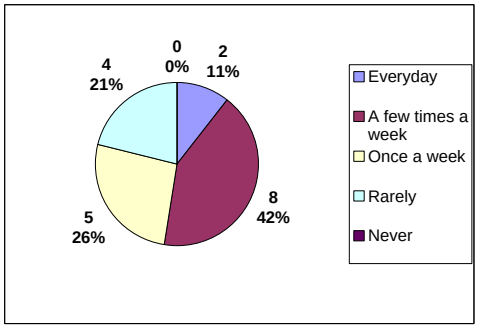
(a) Gender



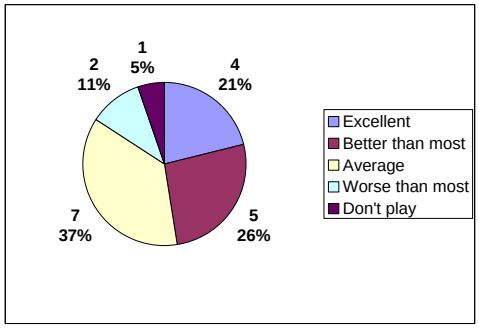
(b) Age



(c) How often do you play video games?



(d) How often do you play first-person shooters?



(e) How would you evaluate your performance in first-person shooters?

Figure 4.1

and ratings. This would indicate that the changing of settings did not affect user performance or perception a lot. The next section will delve deeper into these numbers and provide a clearer understanding of the results.

5 Analysis

In this section, the result data is analyzed in a couple ways. First, user scores are analyzed against the change in settings to see the exact impact made. After that, user ratings of playability and picture quality are analyzed against the change in settings to see how the users' perceptions were affected.

5.1 Score Analysis

We begin by analyzing user performance in terms of scoring over related sessions. In the first two figures, the values of each setting tested (1.6, 2.1 and 2.6 for gamma; off and full for HDR) are depicted on the x-axis and score, measured in points, is on the y-axis; mean user scores for each value are plotted with 95% confidence intervals. As mentioned in the previous section, the mean score was similar and did not vary much for each session. Figure 5.1, which depicts Score vs. Gamma Setting, confirms this, but also provides us with more information. The mean scores are close in value, only varying around

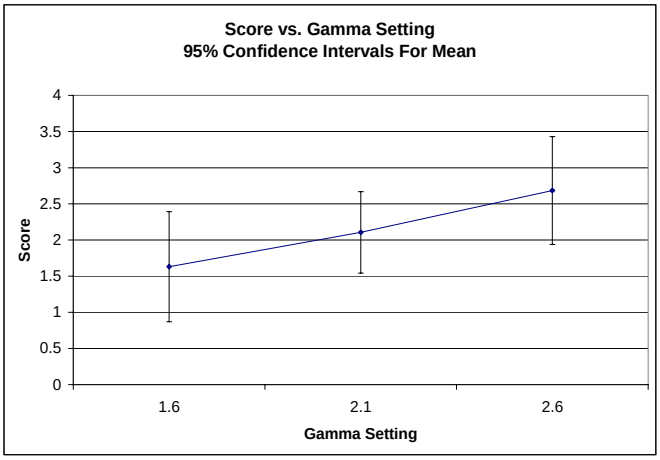


Figure 5.1

1 point from 1.6 at gamma value 1.6 to 2.7 at gamma value 2.6, and the 95% confidence intervals overlap to some extent, indicating that there is no statistical difference between them. This means that while this graph shows that there is a slight increase in mean score, it can not be said that a lower gamma value in fact has a negative effect on player performance and vice-versa. As a result, Hypothesis 1 can not be confirmed.

Similar to the gamma setting, Figure 5.2 shows Score vs. HDR Setting and shows that the mean values are even closer, with less than one half of a point separating the values and both of the confidence intervals fully overlapping. While the graph does show a slight dip with the change in setting, it is not enough of a difference to be of statistical significance; the confidence intervals make this clear. In this case, Hypothesis 2 has been confirmed in that enabling or disabling HDR does not have a statistical effect on a user's performance.

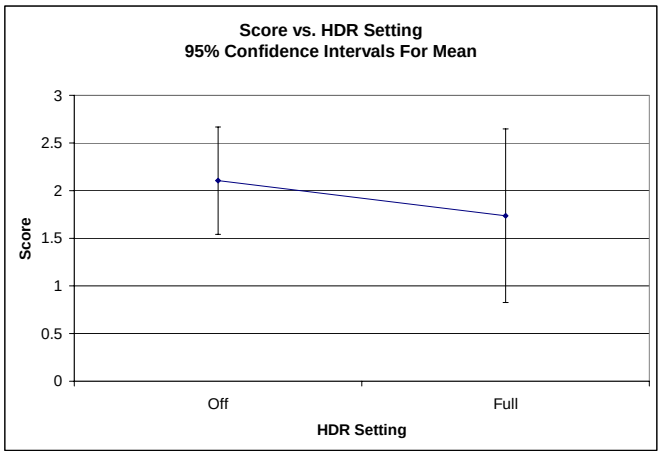


Figure 5.2

5.2 Playability Rating Analysis

Moving on to user playability rating, we find once more that the average rating does not vary much in value. Figure 5.3 shows Playability, measured as a rating from 1 to 5, on the y-axis and values tested for the gamma setting on the x-axis; similar to the previous graphs, mean values are plotted with 95% confidence intervals. Like Figure 5.1, it shows that, although there is a small increase between the settings, especially between

the default gamma value of 2.1 and the maximum value of 2.6. However, because the confidence intervals overlap, it is not enough to suggest that the users believed that the environment with a higher value is more playable than one with a decreased gamma value. Figure 5.4, which shows the frequency of playability ratings given for each gamma value, shows the shift in ratings from lower to higher as the setting changed. Not only does it display that the most common ratings for each setting were those of the 3 and 4 values, it clearly shows a much higher frequency of rating 5 for the session with gamma value 2.6.

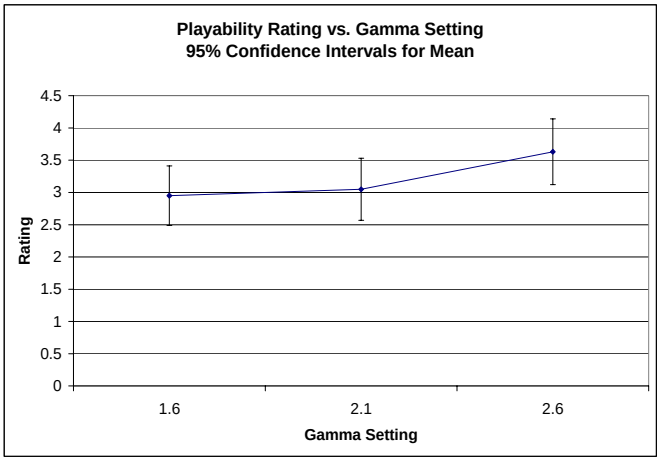


Figure 5.3

In contrast to the results dealing with scoring, average playability rating for HDR sessions did not fluctuate much. Figure 5.5, which displays the plot of mean user playability rating for the two HDR values with 95% confidence intervals and Figure 5.6, which shows the frequency of playability ratings given for each HDR value, suggest that enabling HDR results in a more playable environment for the users. While the two 95%

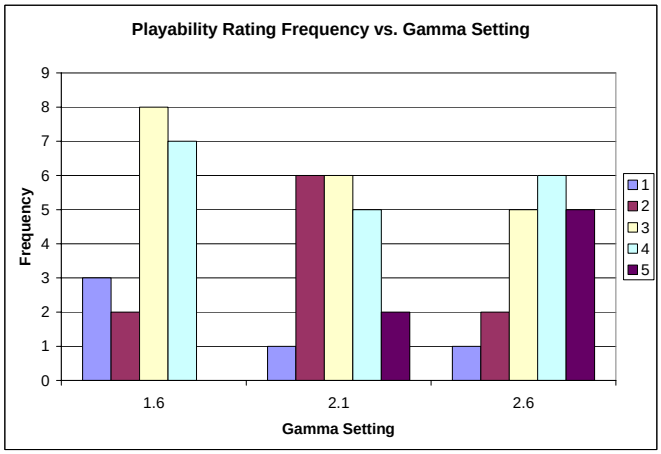


Figure 5.4

confidence intervals do not entirely overlap, the fact that they do overlap indicates that there is no statistical difference between the mean ratings. The histogram backs up the increase shown in Figure 5.5, showing that the number of ratings with a value of 2 is significantly less in the session with HDR turned off, as well as the number of ratings with the value of 5 being slightly more in the session set to full.

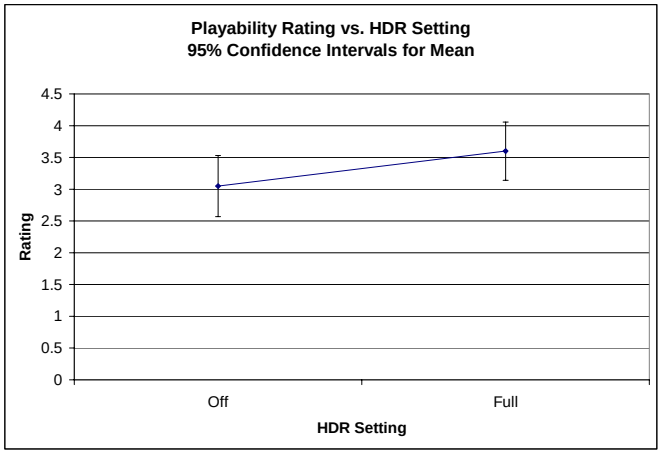


Figure 5.5

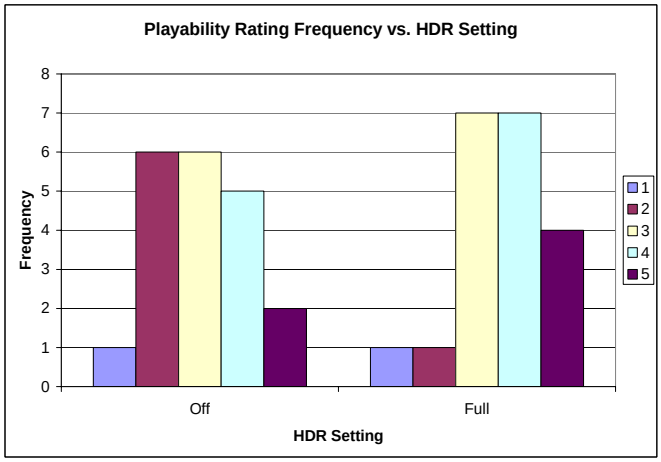


Figure 5.6

5.3 Picture Quality Rating Analysis

The last two graphs display Picture Quality, measured as a rating from 1 to 5, on the y-axis and display setting values on the x-axis. Mean user ratings are graphed with 95% confidence intervals for each display setting value along with a trend line indicating any pattern in the data. Average picture quality ratings for all sessions, both gamma and HDR, were almost equivalent to one another, differing no more than a fraction of one

point. Figure 5.7 and Figure 5.8 show this, with lines going almost straight across from setting to setting. This shows that, although the users performed better and deemed certain sessions more playable than others, they did not feel that the picture quality changed at all, even with the change in settings. The stationary data tells us that the users' opinions of picture quality didn't change even though the HDR and gamma settings did.

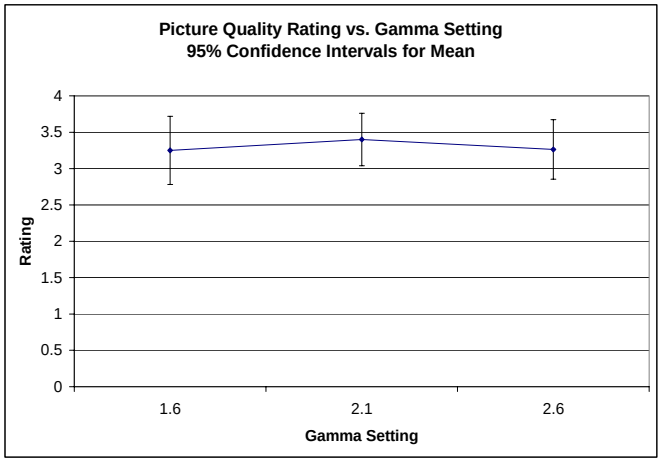


Figure 5.7

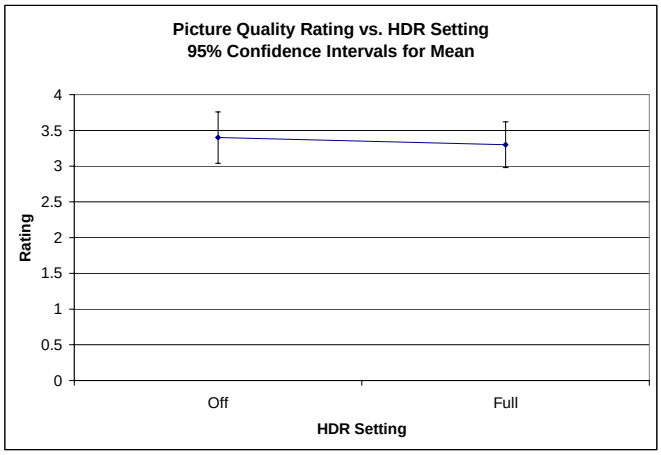


Figure 5.8

6 Conclusions

In today's world, technology, both in hardware and software, is changing at an ever-increasing pace. As a result, display settings are also changing and these settings are being incorporated into computer games. Knowing the effects of these settings on game players allows developers to create better games by allocating their time and resources

where they are appropriate. At the same time, it allows users to get the best possible experience from a game by knowing what to adjust their game settings to.

In our study, we looked at the effects of gamma and high dynamic range (HDR) graphics settings on user performance and perception in Counter-Strike: Source. Using custom configuration scripts and a standard map, we tested these effects. In total, twenty users participated in our study, each playing four two-minute sessions: one session with gamma set to a value of 1.6 and HDR turned off, a second session with gamma 2.1 and HDR off, a third session with gamma 2.1 and HDR set to Full, and finally a fourth session with gamma 2.6 and HDR turned off. After analyzing all of the data collected, the following conclusions can be made.

As to the effects on user performance, it was found that changing the gamma value from the default value of 1.6 did not have an effect on user performance. Lowering the gamma value, which results in a darker image, caused users' performance to decrease slightly. Similarly, a slight increase in performance was found when increasing the gamma value. However, these changes were not enough to be of statistical significance, proving Hypothesis 1 to be false. Similarly, a slight dip in user' performance was found when changing the HDR setting, however, there was no statistical difference. In contrast, however, this confirms Hypothesis 3.

Concerning user perception, the same conclusions were found regarding all of the areas we looked into. First, it was found that user perception of game playability is not affected by changing of both gamma and HDR settings. Although there was an increase in playability rating that coincided with the increase of the gamma value setting, it was not statistically significant. This was also the case when changing the HDR setting from

off to full. Second, it was also found that user perception of game picture quality was similarly not affected by the changing of settings. This both proves Hypothesis 2, which stated that higher gamma values will be preferred over lower ones, to be false and confirms Hypothesis 4, which stated that HDR-enabled sessions will be preferred over those without HDR.

In all of these cases, the confidence intervals were quite large and often overlapped, making the trends in the data not statistically significant. Because confidence intervals decrease in size as the number of samples increases, it is believed that with a larger sample size, possible trends would have been clearer for all of the tests, allowing us to make more confident conclusions.

These results complement the results of other tests and studies, such as those from Claypool *et al.* (2006)[1], which found that both increased frame rate and resolution settings result in an increased user perception of game (picture) quality. The result is a broader knowledge of what effects graphics settings have on user perception in first-person shooters.

The conclusions that we have found will allow both players and developers to make better decisions regarding settings for first-person shooter computer games. Players can use this data to make better-informed decisions about graphics-related settings in games they play. Developers can use it to more appropriately allocate their time and resources towards providing a more user-desirable game. For example, a game designer could take the result that user scoring is not affected by HDR and then choose to spend the time to include HDR lighting in their game, knowing that it will not have an unwanted effect.

From our study, future researchers now have new materials with which to continue studies into this field. To run the experiment again, or similar experiments, researchers can use the same Counter-Strike: Source configuration file to have the game set up in the same manner. Also, the test batch file is available to use, or be modified to fit the needs of future studies. Lastly, our data is also available in its raw form to be analyzed differently, allowing for new and different conclusions.

7 Future Work

The next logical steps to take are testing a player's performance with other game settings and different genres. First-person shooters have long been chosen as primary candidates for competition-caliber games, and will likely remain in the gaming forefront for a long time. Even with these games being the main makeup of professional gaming, and a large share of casual gaming, the effects of these video settings should also be studied on other genres. There are real time strategy, racing, and other types of games waiting to be studied.

As well as other genres, there are settings that were not discussed at all. Some of them include anisotropic filtering, a way of rendering three dimensional "distance" effects, brightness as opposed to gamma, resolution size, refresh rate, and others. These settings are all available and can be changed in a wide range of games on the market today, and some users will change settings where they can be changed. If these settings make any difference in performance or the overall quality of play, users and developers benefit from knowing the results.

References

[1] Mark Claypool, Kajal Claypool, and Feissal Damma. 2006. “The Effects of Frame Rate and Resolution on Users Playing First-person Shooter Games.” *Multimedia Computing and Networking*, San Jose, California.

[2] Tim Connor, Adam Fiske and Ryan Kennedy. 2006. “The Impact of Frame Rate and Resolution on Player Movement in First-Person Shooters.” *Interactive Qualifying Project IQP-MLC-GP05*, Worcester Polytechnic Institute.

[3] Kellogg S. Booth, M. Philip Bryden, Wiliam B. Cowan, Michael F. Morgan and Brian L. Plante. 1987. “On the parameters of human visual performance: An investigation of the benefits of antialiasing.” In *Computer Human Interaction and Graphics Interface Proceedings* 1987 (Toronto, April 5-9). ACM, New York, pp. 13-19.

[4] "Antialiasing." Houghton Mifflin Company. 2004. *The American Heritage® Dictionary of the English Language, Fourth Edition*. 17 Dec. 2006. <http://dictionary.reference.com/browse/antialiasing>

[5] “Steam - News”. Valve Corporation. 2005. Half-Life 2: Lost Coast Available Now. 27 Apr. 2007. <http://www.steampowered.com/v/index.php?area=news&id=472>

[6] “Steam Game and Player Statistics”. Valve Corporation. 2007. Steam & Game Stats. 27 Apr. 2007. <http://www.steampowered.com/v/index.php?area=stats&cc=US>

[7] “Counter-Strike: Source Update History”. Valve Corporation. 2007. Update News - Counter-Strike: Source. 27 Apr. 2007. <http://www.steampowered.com/platform/update_history/index.php?id=240&skin=0>

Formatted: French (France)
Formatted: French (France)
Formatted: French (France)
Field Code Changed
Formatted: French (France)
Field Code Changed
Formatted: French (France)
Formatted: French (France)

Appendix A: Flyer

=

Play Counter-Strike!
Win a $25 Visa Gift Card!

Help take part in a user study by playing 10 minutes of Counter-Strike: Source!

Participants will be entered into a drawing for a $25 Visa gift card!

Head over to FL318 10 A.M. – 2 P.M.
Monday, March 26 – Friday, March 30

Or send an e-mail to klouf@wpi.edu for other times.

Appendix B: Batch File

```
run "C:\Program Files\Steam\steam.exe" -applaunch 240 +map de_dust
+sv_lan 1 +bot_join_team T +bot_pistols_only +bot_quota 2
+mat_hdr_level 2 +mat_monitorgamma 2.1 +name P1221
ECHO. "Please fill out the relevant question on the survey and then"
PAUSE

run "C:\Program Files\Steam\steam.exe" -applaunch 240 +map de_dust
+sv_lan 1 +bot_join_team T +bot_pistols_only +bot_quota 2
+mat_hdr_level 0 +mat_monitorgamma 2.6 +name P1221
ECHO. "Please fill out the relevant question on the survey and then"
PAUSE

run "C:\Program Files\Steam\steam.exe" -applaunch 240 +map de_dust
+sv_lan 1 +bot_join_team T +bot_pistols_only +bot_quota 2
+mat_hdr_level 0 +mat_monitorgamma 1.6 +name P1221
ECHO. "Please fill out the relevant question on the survey and then"
PAUSE


run "C:\Program Files\Steam\steam.exe" -applaunch 240 +map de_dust
+sv_lan 1 +bot_join_team T +bot_pistols_only +bot_quota 2
+mat_hdr_level 0 +mat_monitorgamma 2.1 +name P1221
ECHO. "Please fill out the relevant question on the survey and then"
PAUSE
```

Appendix C: Test Materials

INSTRUCTIONS (READ ALL BEFORE PROCEEDING)

1. Fill out the Demographics survey.
2. Double-click icon on desktop labeled “IQPGO” and follow its directions (See explanation below)
3. At the beginning of each round, please click OK, select the Counter-Terrorist Team and Auto-Select your class.
4. After two minutes you will be notified to please hit the F8 key; this will quit the game for you.
5. Answer the questions related to that round (on the reverse side of the Demographics survey)
6. The map will reload with different settings when you are ready
7. Do this for each round

IQPGO

- This will load a map from Counter Strike: Source with different settings enabled.
- You will play 4 rounds that will each end after 2 minutes.

Controls:

W: Forwards	**Up arrow**: Forwards	**Ctrl (hold):** Crouch
S: Backwards	**Down arrow**: Backwards	**Shift (hold):** Walk
A: Strafe Left	**Left arrow**: Turn Left	**B (in buy zone):** Buy menu
D: Strafe Right	**Right arrow**: Turn Right	**Spacebar:** Jump

Mouse: Looks up, down / Turns left, right
Left-Click: Fire weapon/Throw grenade

DEMOGRAPHICS SURVEY

Please fill in or circle the appropriate responses. _____

Gender: Male Female

Age: _____

How often do you play video games?

Everyday A few times a week Once a week Rarely Never

How often do you play first-person shooters?

Everyday A few times a week Once a week Rarely Never

How would you evaluate your performance in first-person shooters?

Excellent Better than most Average Worse than most Don't play

User Study Survey

Please circle a response after each round. _____

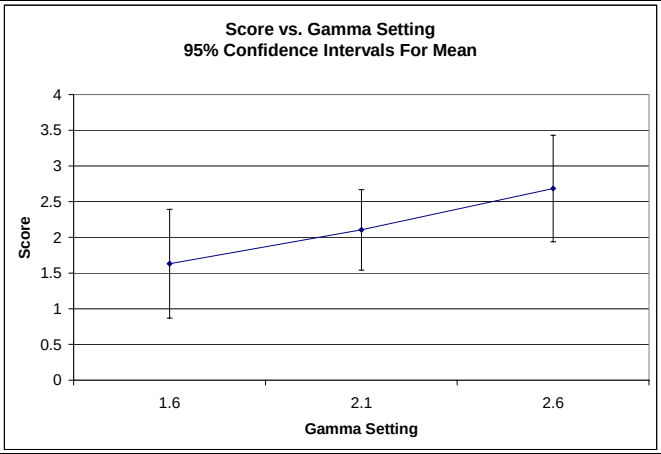
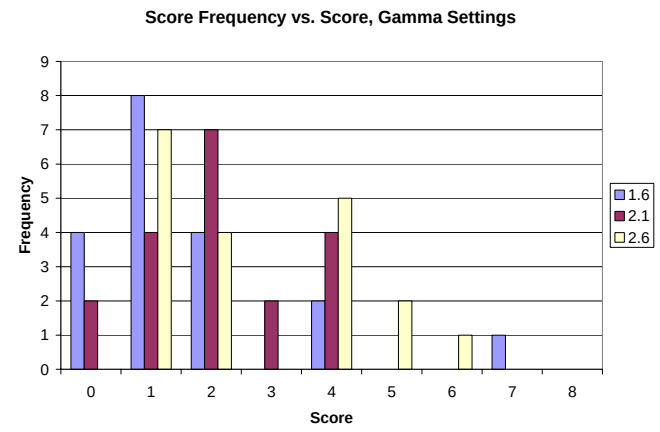
For each round, please indicate the level of playability and picture quality on a scale of 1 to 5, 1 being unplayable/less desirable and 5 being quite playable/most desirable:

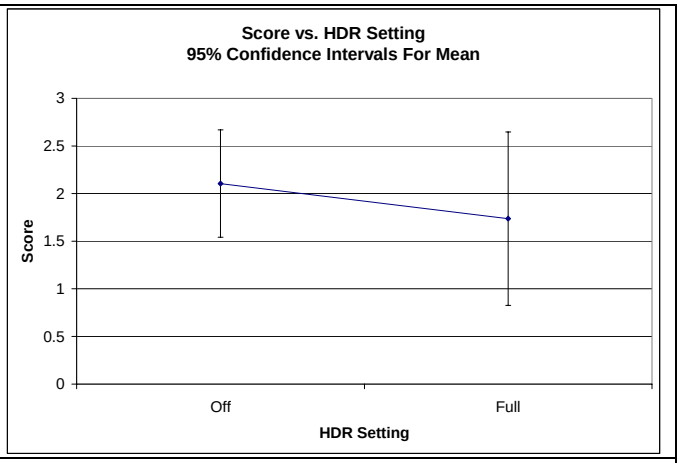
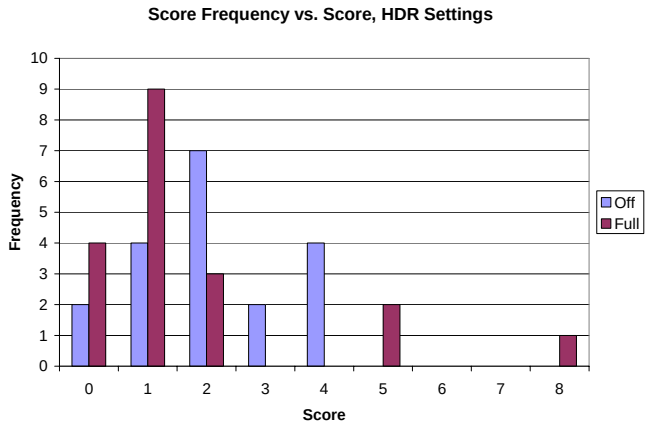
	Playability					Picture Quality				
	Worst				**Best**	**Worst**				**Best**
Round 1	1	2	3	4	5	1	2	3	4	5
Round 2	1	2	3	4	5	1	2	3	4	5
Round 3	1	2	3	4	5	1	2	3	4	5
Round 4	1	2	3	4	5	1	2	3	4	5

Comments:

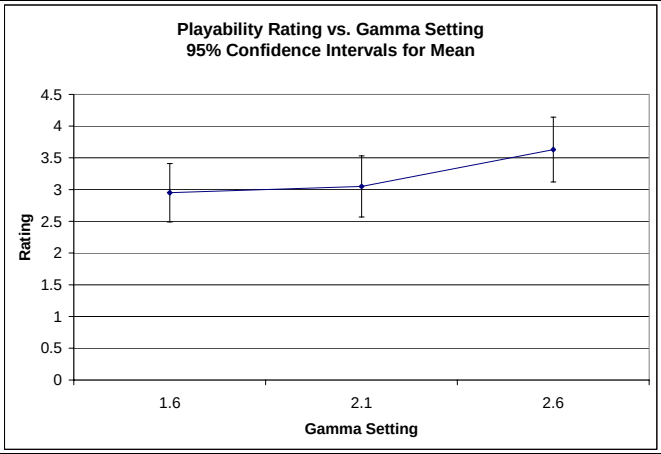
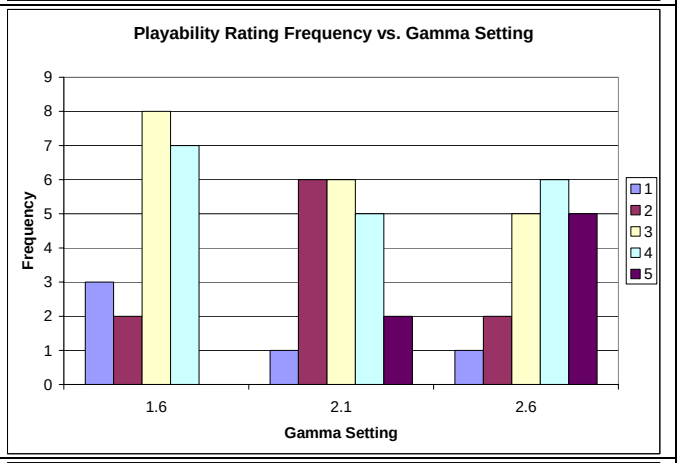
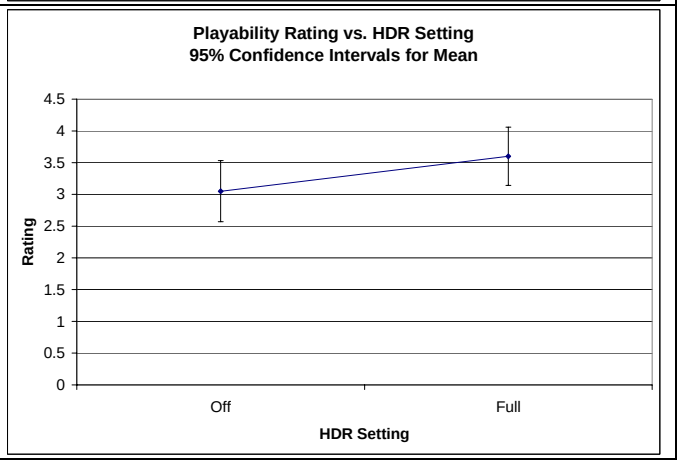
Appendix D: Graphs

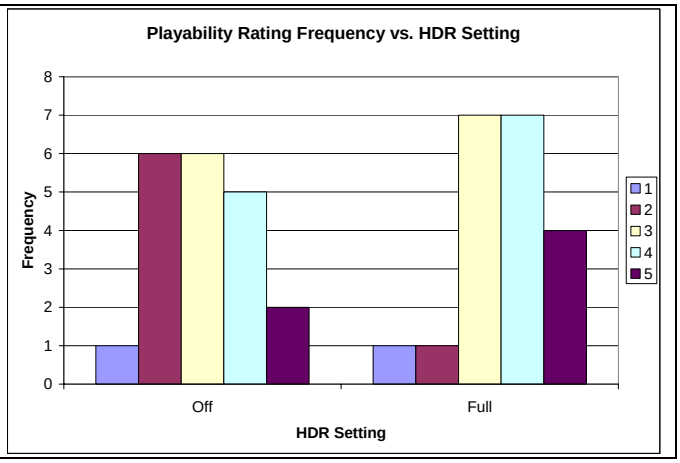
D.1 Scoring

Score vs. Gamma Setting 95% Confidence Intervals for Mean	
Score Frequency vs. Score, Gamma Settings	

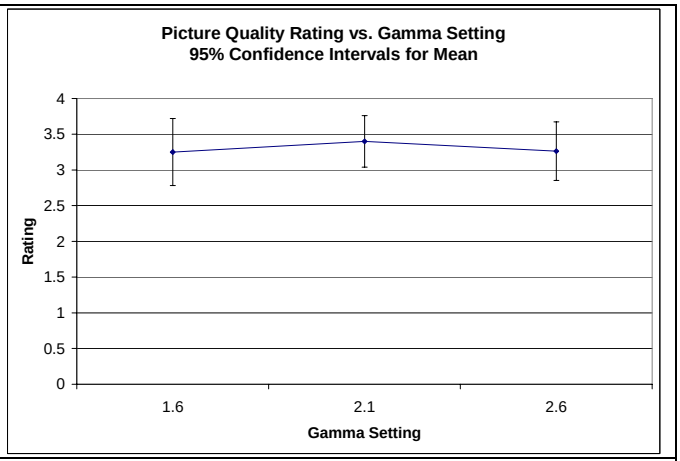
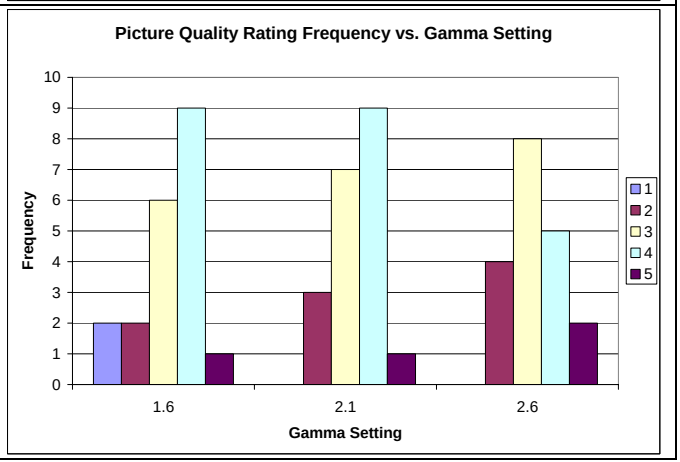
Score vs. HDR Setting 95% Confidence Intervals for Mean	
Score Frequency vs. Score, Gamma Settings, HDR Settings	

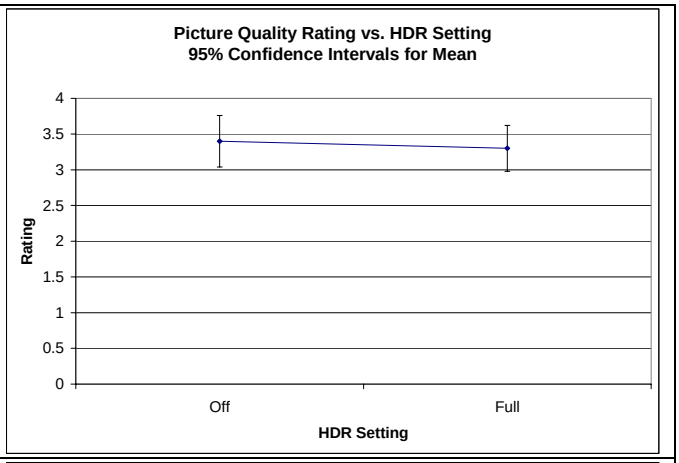
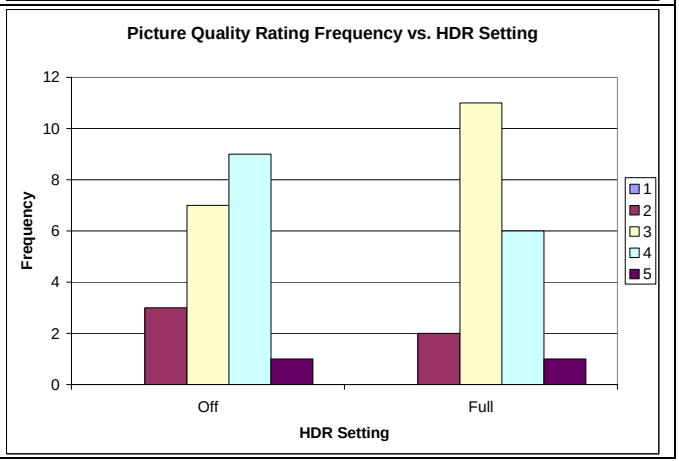
D.2 Playability Rating

Rating vs. Gamma Setting 95% Confidence Intervals for Mean	
Frequency vs. Gamma Setting	
Rating vs. HDR Setting 95% Confidence Intervals for Mean	

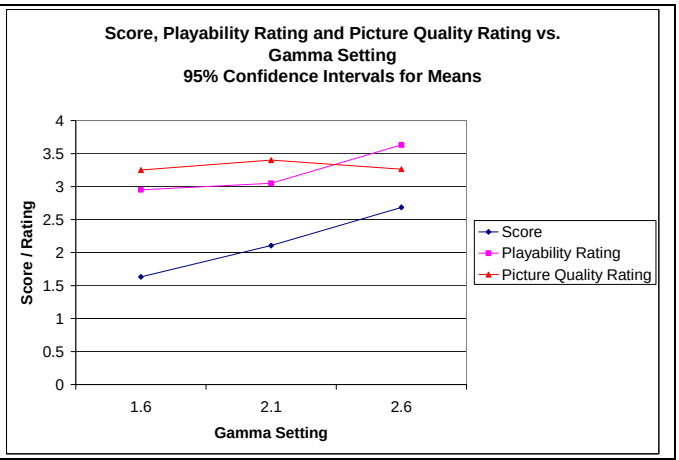
Frequency vs. HDR Setting	

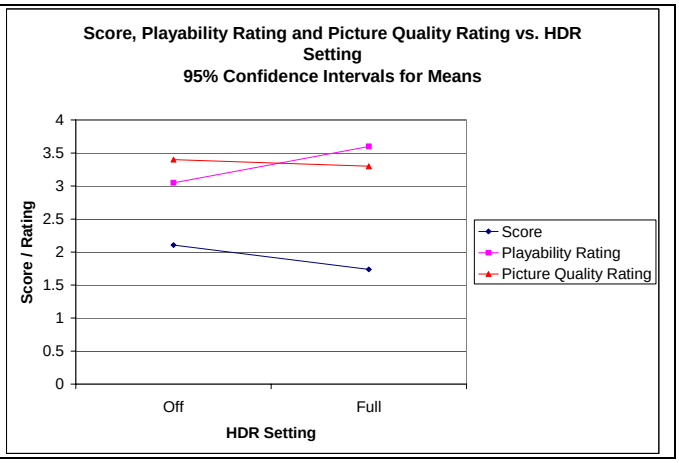
D.3 Picture Quality Rating

Rating vs. Gamma Setting 95% Confidence Intervals for Mean	
Frequency vs. Gamma Setting	

Rating vs. HDR Setting 95% Confidence Intervals for Mean	
Frequency vs. HDR Setting	

D.4 Combined

Score, Playability Rating and Picture Quality Rating vs. Gamma Setting 95% Confidence Intervals for Means	

Score, Playability Rating and Picture Quality Rating vs. HDR Setting 95% Confidence Intervals for Means	

D.5 Other

Mean Score vs. Self-Rating