7-2-2013

IMPACT OF GRAPHICAL FIDELITY ON A PLAYER’S EMOTIONAL RESPONSE IN VIDEO GAMES

Vivianette Ocasio De Jesus

Purdue University

Follow this and additional works at: http://docs.lib.purdue.edu/cgttheses

Part of the Social and Behavioral Sciences Commons

http://docs.lib.purdue.edu/cgttheses/31

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact epubs@purdue.edu for additional information.
This is to certify that the thesis/dissertation prepared

By  Vivianette Ocasio De Jesús

Entitled
IMPACT OF GRAPHICAL FIDELITY ON A PLAYER’S EMOTIONAL RESPONSE IN VIDEO GAMES

For the degree of  Master of Science

Is approved by the final examining committee:

James L. Mohler  
Chair

David M. Whittinghill

Patrick E. Connolly

To the best of my knowledge and as understood by the student in the Research Integrity and Copyright Disclaimer (Graduate School Form 20), this thesis/dissertation adheres to the provisions of Purdue University’s “Policy on Integrity in Research” and the use of copyrighted material.

Approved by Major Professor(s):  James L. Mohler

Approved by:  Craig L. Miller  07/02/13

Head of the Graduate Program  Date
IMPACT OF GRAPHICAL FIDELITY ON A PLAYER’S EMOTIONAL RESPONSE IN VIDEO GAMES

A Thesis
Submitted to the Faculty
of
Purdue University
by
Vivianette Ocasio De Jesús

In Partial Fulfillment of the
Requirements for the Degree
of
Master of Science

August 2013
Purdue University
West Lafayette, Indiana
I dedicate this thesis to my mother, my father, and my family and friends for supporting me all the way through my path, and to my wonderful boyfriend, Larry, for providing me with his love, encouragement, and everything I needed to excel in life. I love you guys more than words can ever describe.
ACKNOWLEDGEMENTS

I would like to express my deepest appreciation and gratitude to my committee, Dr. James Mohler (chair), Dr. David Whittinghill, and Dr. Patrick Connolly, for providing all the support, encouragement, knowledge, motivation and confidence for me to excel in my graduate studies. Without their guidance and persistent help this thesis would not have been completed.

I would also like to acknowledge my friends for providing me with their support, inspiration to find my passion in the CG world, and for spending time with me through countless nights of problem solving and helpful support. I could have not done it without any of you.
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>LIST OF TABLES</th>
<th>vii</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF FIGURES</td>
<td>viii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>ix</td>
</tr>
<tr>
<td>CHAPTER 1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Research Question</td>
<td>3</td>
</tr>
<tr>
<td>1.3 Statement of Purpose</td>
<td>3</td>
</tr>
<tr>
<td>1.4 Scope</td>
<td>4</td>
</tr>
<tr>
<td>1.5 Significance</td>
<td>4</td>
</tr>
<tr>
<td>1.6 Definitions</td>
<td>5</td>
</tr>
<tr>
<td>1.7 Assumptions</td>
<td>6</td>
</tr>
<tr>
<td>1.8 Delimitations</td>
<td>7</td>
</tr>
<tr>
<td>1.9 Limitations</td>
<td>7</td>
</tr>
<tr>
<td>1.10 Chapter Summary</td>
<td>8</td>
</tr>
<tr>
<td>CHAPTER 2. LITERATURE REVIEW</td>
<td>9</td>
</tr>
<tr>
<td>2.1 Introduction</td>
<td>9</td>
</tr>
<tr>
<td>2.2 Graphical Fidelity</td>
<td>9</td>
</tr>
<tr>
<td>2.2.1 Choosing framerate over graphical fidelity</td>
<td>10</td>
</tr>
<tr>
<td>2.2.2 How much does frame rate matter?</td>
<td>11</td>
</tr>
<tr>
<td>2.2.3 Understanding the impact of video quality on user engagement</td>
<td>12</td>
</tr>
<tr>
<td>2.2.4 An engine selection methodology for high fidelity serious games</td>
<td>13</td>
</tr>
<tr>
<td>2.2.5 From gaming to training: a review of studies on fidelity, immersion,</td>
<td></td>
</tr>
<tr>
<td>presence, and buy-in and their effects on transfer in PC-based simulations and</td>
<td></td>
</tr>
<tr>
<td>games</td>
<td>14</td>
</tr>
<tr>
<td>2.3 Emotional Response</td>
<td>15</td>
</tr>
<tr>
<td>2.3.1 The effects of technological advancement and violent content in video</td>
<td>16</td>
</tr>
<tr>
<td>games on players’ feelings on presence, involvement, physiological arousal,</td>
<td></td>
</tr>
<tr>
<td>and aggression</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3.2 Boredom, engagement and anxiety as indicators for adaptation to difficulty in games</td>
<td>17</td>
</tr>
<tr>
<td>2.3.3 Looking for the heart of interaction media</td>
<td>18</td>
</tr>
<tr>
<td>2.3.4 Why we play games: four keys to more emotion without story</td>
<td>18</td>
</tr>
<tr>
<td>2.3.5 Visual attention in 3D games</td>
<td>19</td>
</tr>
<tr>
<td>2.4 Measuring the Player’s Emotional Experience</td>
<td>20</td>
</tr>
<tr>
<td>2.4.1 Galvanic skin response as a measure for emotional arousal</td>
<td>21</td>
</tr>
<tr>
<td>2.4.2 Psychophysiological recordings</td>
<td>22</td>
</tr>
<tr>
<td>2.4.3 Measuring emotional valence during interactive experiences: boys at video game play</td>
<td>23</td>
</tr>
<tr>
<td>2.5 Conclusions</td>
<td>24</td>
</tr>
<tr>
<td>2.6 Chapter Summary</td>
<td>25</td>
</tr>
<tr>
<td>CHAPTER 3. FRAMEWORK AND METHODOLOGY</td>
<td>26</td>
</tr>
<tr>
<td>3.1 Research Framework</td>
<td>26</td>
</tr>
<tr>
<td>3.2 Population and Samples</td>
<td>28</td>
</tr>
<tr>
<td>3.3 Testing Materials and System Specifications</td>
<td>28</td>
</tr>
<tr>
<td>3.4 Instructions and Pre-Questionnaire</td>
<td>33</td>
</tr>
<tr>
<td>3.5 Testing and Post-Questionnaire</td>
<td>33</td>
</tr>
<tr>
<td>3.6 Data Analysis</td>
<td>36</td>
</tr>
<tr>
<td>3.7 Chapter Summary</td>
<td>36</td>
</tr>
<tr>
<td>CHAPTER 4. DATA ANALYSIS</td>
<td>37</td>
</tr>
<tr>
<td>4.1 Processing of Data</td>
<td>37</td>
</tr>
<tr>
<td>4.2 Demographic Results</td>
<td>38</td>
</tr>
<tr>
<td>4.3 Study Results</td>
<td>39</td>
</tr>
<tr>
<td>4.3.1 Crysis High versus Low Graphical Settings</td>
<td>41</td>
</tr>
<tr>
<td>4.3.2 Crysis in High Quality Graphical Settings</td>
<td>43</td>
</tr>
<tr>
<td>4.3.3 Crysis in Low Quality Graphical Settings</td>
<td>45</td>
</tr>
<tr>
<td>4.3.4 Dead Space High versus Low Graphical Settings</td>
<td>49</td>
</tr>
<tr>
<td>4.3.5 Dead Space in High Quality Graphical Settings</td>
<td>51</td>
</tr>
<tr>
<td>4.3.6 Dead Space in Low Quality Graphical Settings</td>
<td>53</td>
</tr>
<tr>
<td>4.4 GSR Results</td>
<td>56</td>
</tr>
<tr>
<td>4.4.1 Crysis</td>
<td>58</td>
</tr>
<tr>
<td>4.4.2 Dead Space</td>
<td>59</td>
</tr>
<tr>
<td>4.5 Chapter Summary</td>
<td>60</td>
</tr>
</tbody>
</table>
CHAPTER 5. DISCUSSION AND FUTURE WORK ......................................................... 61
5.1 Introduction ...................................................................................................... 61
5.2 General Findings ............................................................................................. 61

5.2.1 Crysis ........................................................................................................... 62
5.2.2 Dead Space .................................................................................................. 62
5.3 Limitations ....................................................................................................... 63
5.4 Conclusions and Future Work ......................................................................... 64

LIST OF REFERENCES ......................................................................................... 67
APPENDICES
Appendix A High Quality versus Low Quality Screenshots from Crysis ............ 72
Appendix B High Quality versus Low Quality Screenshots from Dead Space .... 73
Appendix C IRB Approval Letter ........................................................................... 74
Appendix D Consent Form ...................................................................................... 75
Appendix E Pre-Study Questionnaire ................................................................... 77
Appendix F Post-Study Questionnaire .................................................................. 80
Appendix G Levene’s test and GSR ANOVA results for Crysis ......................... 84
Appendix H Levene’s test and GSR ANOVA results for Dead Space ................. 86
Appendix I Subjects’ EDA results via Q Sensor software .................................... 88
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 4.1 ANOVA test results for importance of emotional response in Crysis and comparison of quality settings</td>
<td>41</td>
</tr>
<tr>
<td>Table 4.2 ANOVA test results for importance of graphical fidelity in Crysis and comparison of quality settings</td>
<td>42</td>
</tr>
<tr>
<td>Table 4.3 ANOVA test results on how well graphical fidelity is used in Crysis in comparison to differing quality settings</td>
<td>42</td>
</tr>
<tr>
<td>Table 4.4 ANOVA test results for importance of emotional response in Dead Space and comparison of quality settings</td>
<td>49</td>
</tr>
<tr>
<td>Table 4.5 ANOVA test results for importance of graphical fidelity in Dead Space and comparison of quality settings</td>
<td>50</td>
</tr>
<tr>
<td>Table 4.6 ANOVA test results on how well graphical fidelity was used in Dead Space in comparison to graphical quality settings</td>
<td>50</td>
</tr>
<tr>
<td>Table 4.7 ANOVA test results for physiological response peaks in Crysis</td>
<td>58</td>
</tr>
<tr>
<td>Table 4.8 ANOVA test results for magnitude of peaks in Crysis</td>
<td>59</td>
</tr>
<tr>
<td>Table 4.9 ANOVA test results for physiological response peaks in Dead Space</td>
<td>60</td>
</tr>
<tr>
<td>Table 4.10 ANOVA test results for magnitude of peaks in Dead Space</td>
<td>60</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 2.1 Poll taken by Insomniac Games in regards to frame rate in games............. 11

Figure 3.1 The Q Sensor ........................................................................................................ 29

Figure 3.2 Screenshots of graphical quality differences in *Crysis*................................. 32

Figure 3.3 Screenshots of graphical quality differences in *Dead Space*......................... 32

Figure 3.4 Instruction Page ................................................................................................... 33

Figure 3.5 Post- Study Questionnaire .................................................................................. 35

Figure 4.1 Emotional responses while playing *Crysis*....................................................... 43

Figure 4.2 Thoughts on impact of graphical quality in *Crysis* ........................................ 44

Figure 4.3 Emotional responses while playing *Crysis*....................................................... 46

Figure 4.4 Thoughts on impact of graphical quality in *Crysis* ........................................ 47

Figure 4.5 Emotional responses while playing *Dead Space*............................................. 51

Figure 4.6 Thoughts on impact of graphical quality in *Dead Space* .............................. 52

Figure 4.7 Emotional responses while playing *Dead Space*............................................. 54

Figure 4.8 Thoughts on impact of graphical quality in *Dead Space* .............................. 55

Figure 4.9 GSR measurements from a subject during testing. .......................................... 57

Appendix Figure

Figure A.1 Screenshots of *Crysis* .................................................................................... 72

Figure A.2 Screenshots of *Dead Space* .......................................................................... 73
ABSTRACT

Ocasio-De Jesús, Vivianette. M.S., Purdue University, August 2013. Impact of Graphical Fidelity on a Player’s Emotional Response in Video Games. Major Professor: James Mohler.

Higher quality computer graphics in the areas of virtual reality and games is generally assumed to create a more immersive experience for the end user. This assumption was examined by testing to what degree graphical fidelity was associated with physiological arousal as measured by a galvanic skin response (GSR) sensor. Thirty-six subjects played two different video games, Crysis and Dead Space, at the highest and lowest graphical quality settings while their GSR activity was measured. No significant difference in GSR was observed as associated with graphical quality. However, when asked how the user would rate graphical fidelity usage in Dead Space, the ANOVA result suggests there is a statistical difference. The findings of this study suggest that graphical fidelity is an important factor in survival-horror shooters however there is not enough evidence to support any claims that it is the definitive factor for creating greater emotional response in the games that were tested. Overall, it was concluded that, for video games in which a strong emotional response is desired, development focus only upon increased graphical quality alone, is not likely to lead to a noticeable physiological arousal response in the player.
CHAPTER 1. INTRODUCTION

This chapter introduces the research by presenting the research question and the statement of purpose. The chapter concludes by defining the assumptions used, limitations and delimitations, as well as the scope and significance of this particular research thesis.

1.1 Introduction

As gaming continues to rise in popularity, cross gender and social boundaries, and expand in what defines a gaming experience, artists of all types will be in high demand to provide all the visual elements we as game consumers expect and at the quality we demand,’ says Nick Heitzman, a game developer and member of the faculty at the Guildhall graduate game development program at Southern Methodist University (Snider, 2011, para. 2).

Artists are needed to conceptualize characters and environments as well as produce visual effects, all while meshing the art style with the programming of the game. In addition, game designers are constantly investigating methods of improving the gaming experience through immersion, graphical improvements through technological advances, story and development, and emotional experience elicited by the game.
The video game industry in particular frequently markets their games’ graphics as “pulse pounding” and likely to cause an “adrenaline rush.” Hyperbolic marketing phrasing aside, these descriptors express the assumption that an immersive, engaging experience is one that induces physiological responses in the user that are associated with emotional arousal. It is unclear, however, whether the increases in graphic fidelity do in fact facilitate heightened states of emotional arousal in end users. Game developers have been taking advantage of advances in real-time rendering technology to create more and more graphically sophisticated virtual environments with each new hardware breakthrough. However, producing higher graphical quality digital assets is quite expensive due to the significantly longer time it takes to produce them (Potanin, 2009). Similarly, rendering these higher quality assets at real-time frame rates increases the need for more expensive graphical systems at run time (Potanin, 2009). Despite these advances in capability, development budgets remain necessarily finite. Due to the high cost of producing higher resolution digital assets, fewer resources are therefore left to focus on other aspects of the game production pipeline such as user interaction, art design, narrative, sound, and many other critically important aspects of virtual environment creation.

Researchers have explored techniques for increasing the perception of graphical quality while still using lower fidelity digital assets. Chalmers, Cater, and Maflioli (2003) discusses visual perception exploitation methods through visual attention and saliency maps to avoid “significant computational expense without affecting the perceptual quality of the resultant image or animation” (p. 1). By exploiting these characteristics of the
human visual system, they produced high graphical fidelity renderings of scenes efficiently and at lower expense (Chalmers et al. 2003). Given the cost of high resolution digital asset creation, more must be known as to whether they are worth the increased production value; do these higher resolution assets in fact have a greater impact on the subjective user experience than do lower resolution assets?

This chapter introduces the topic and its significance in the game developer community by presenting the statement of purpose and research question. The chapter concludes by defining the assumptions used as well as the scope and significance of this particular research thesis.

1.2 Research Question

This research focused on a single research question:

Would a higher graphical fidelity in video games elicit a stronger emotional impact on the player compared to lower graphical fidelity?

1.3 Statement of Purpose

The purpose of this research was to determine if graphical fidelity has a greater emotional impact in video games. There has been constant debate in determining the exact importance concerning graphical fidelity and video games. “Since the dawn of recorded history, the stories we find entertaining have followed a consistent template: genres. And the interesting thing about genres is most of them happen to coincide directly with specific emotions: Suspense, Romance, Comedy, Horror, Adventure, Drama and
Tragedy. While this isn't a comprehensive list of human emotion, it does appear to be a comprehensive list of emotions we explicitly seek for entertainment” (Ventricre, 2011, p. 2). Many industry professionals believe that video games can elicit an emotional response and that these responses are significant enough to impact the player’s subjective experience. By increasing graphical fidelity in specific game genres, is there the possibility to get greater emotional responses? Can higher graphical quality in a horror themed game increase the player's emotional response of fear or tension? Would lower graphical settings make a difference in a player’s emotional response to an action-based video game? By researching this idea of graphical fidelity and its relationship to emotional responses, we will further expand our understanding of player physiology and help us refine the game development and design process.

1.4 Scope

This research was limited to determining if graphical fidelity causes a greater user emotional response in video games. The research will measure the impact of how high-end graphics causes various emotional responses in different game genres using galvanic skin response (GSR) sensors. Additionally, the scope of this research is to observe only the emotional responses via visual stimuli.

1.5 Significance

Exploring innovative methods on how to enhance the gaming experience of users is a significant aspect of today's gaming industry. Game designers and producers implement various game mechanics, character lore, story and art in an attempt to enhance the overall
experience of their consumers. According to Tony Ventrice (2011), “Emotion is a difficult element to instill into games. It tends to be highly contextual and not usually pursued as an explicit objective beyond the scope of traditional story-telling” (p.3). In game design, multiple emotions often end up woven together in complex plots and storytelling but there is a lack of knowledge on how graphics impact player response and satisfaction while playing a video game.

Despite the push toward higher fidelity art assets in game environments, there is a lack of direct physiological measurement in regard to its effect on physiological arousal and resulting emotional response. Surveys and post-study questionnaires give us an incomplete, or even inaccurate understanding of human physiological responses since “emotional experiences are not primarily language-based: cognitive effort is required to put emotional experience into words, and this effort can contaminate measurement” (Isbister & Schaffer, 2008, p. 190). This research will provide more information to the fields of game design and psychology, as well as explore new concepts in higher-end graphical usage and human visual perception in game.

1.6 Definitions

Avid Gamer: a person who plays video games on a regular and/or frequent basis.

Frame rate (in video games): the speed at which the image is refreshed in frames per second (FPS).
**Graphical fidelity**: degree of similarity between a game’s recommended graphical settings and the game’s optimized graphical settings.

**High-end graphics**: graphical parameters at the highest available settings, providing the best graphical imagery resolution.

**Low-end graphics**: graphical parameters at the lowest available settings, providing the worst graphical imagery resolution.

**Shooter**: is a video game genre that centers the gameplay on a gun and projectile weapon-based action through a first-person or third-person perspective. The player may experience the encounter through the eyes of a protagonist (first-person) or through a camera positioned right behind the protagonist’s back (third-person).

### 1.7 Assumptions

This research was performed and conclusions have been drawn using the following assumptions:

- The range of graphical fidelity in the study was one that is typically seen in current video games. Games made before 2007 were not tested due to higher graphical fidelity advances in video cards and processing power.
- The range of frame rate in the study was one that is typically seen in various video games. The frame rate had a range from 30 fps to 60 fps.
• The visual style in game levels in the study was one that is typically seen in various video games. Games with an extremely stylized texture design were not chosen for the study.

• All computer hardware and software used to collect data worked accurately and consistently over the complete production of the testing materials.

• A controlled testing environment improved the accuracy and precision of the data collection process.

• The participants answered all questions truthfully.

• The subjects did not have visual defects.

1.8 Delimitations

This research was performed acknowledging the following delimitations:

• No other video game genres were tested other than suspense/horror or action-based.

• Only visual stimuli were measured in the study. All audio and physical stimuli, such as rumble/vibration functions were not tested in this experiment.

• No users under 18 years of age were considered in the study.

1.9 Limitations

This research was limited by the following:

• The study only included research in the areas of player psychology and game development. The results should not be applied to all areas in field of computer graphics.
- The study only focused on visual stimuli and graphics in players.
- Results were interpreted as psychological responses and may have been subject to bias and errors in understanding.
- Research subjects were limited to all Purdue University students above the age of eighteen without compensation. In addition, professors and other faculty were invited to participate in the study.
- This study was not fully generalized across all video games, but was only a guideline to help explore visual design options in video games while maintaining acceptable graphical quality for gaming experience.

1.10 Chapter Summary

This chapter introduced the research by outlining the key research question and significance. The chapter concluded by noting the limitation and delimitations of the chosen scope, and its contribution to the body of knowledge by clarifying the importance of the research. The following chapter will have a review of the literature on the subjects of graphical fidelity, physiological activity as a proxy for emotional response, and human perception via the human visual system.
CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

This chapter provides a summary of recent research literature in the areas of graphical fidelity, emotional response, and how physiological activity can be measured using biometrical equipment. This provides a base understanding of the methods in the focus area as well as motivation going forward to new methodology.

2.2 Graphical Fidelity

This section addresses how video quality and graphics are utilized, recognized, and implemented in various computer graphic related fields. There is constant debate between the importance of graphics versus frame rate immersion, and user engagement. By researching how graphics affect these and other areas within a game, developers and designers can best use their resources to maximize graphical fidelity.
2.2.1 Choosing framerate over graphical fidelity

Game programmer and co-founder of id Software, John Carmack, prioritized frame rate over graphics in development for game title *Rage*. Carmack argues that the user “is going to get more value out of running at a higher frame rate than me making the pixels pretty” (Cifaldi, 2011, p. 1). Carmack states that the game could have been made with higher-end graphics at 30 hertz; however, the decision to focus on refresh rate consistency at 60 hertz would create a greater visual impact than graphical fidelity. Numerous experiments were conducted to investigate if players could distinguish any visual differences between 60 hertz and 120 hertz in two demos of *Rage*. Results suggest that the majority of the participants could not differentiate between both demos. In addition, results suggest that 60 hertz is the appropriate target frame rate for maximal user satisfaction and experience (Cifaldi, 2011).

Unfortunately, the article does not provide any statistical data suggesting conducted research and results. Nonetheless, this indicates that frame rate over graphical fidelity is a problem currently under investigation in the gaming industry. It would be interesting to find out why experiments were conducted between different frame rates and not between impact in user satisfaction or gameplay between frame rate and graphical fidelity.
2.2.2 How much does frame rate matter?

Mike Acton explains Insomniac’s decision to increase graphical fidelity and maintain frame rates of 30 fps in their games. Insomniac investigates the possibilities of frame rates over graphical fidelity impact on sales and reviews of a game. During development, the company performed numerous experiments into the question of frame rate. Results suggest that higher frame rates do not “significantly affect sales of a game” as shown in Figure 2.1 (Acton, 2009, p. 1). In addition, higher frame rates do not directly affect a game’s reviews (Acton, 2009). However, Insomniac found a correlation between graphics and overall game reviews and did not find a correlation between frame rates and game reviews.

Figure 2.1 Poll taken by Insomniac Games investigating importance of frame rates in games (Acton, 2009).
In addition, Acton explains that the company performed polls and surveys asking players how much does frame rate matter to them in console games. Out of 834 self-reported participants, 62 percent of the sample does not care, as long as it does not affect their gameplay. Only 16 percent of the sample really cares about fps. Nineteen percent of the sample does not have a problem with the current frame rate of 30 hertz. Results suggest that frame rate is important, but not significant enough to hinder graphical quality. There is no evidence proving 60 hertz affects game reviews and sales over a game with 30 hertz. With these results, Insomniac Games will continue to produce games in 30 fps. The problem with their poll results is that responses are self-reported and this convenience sample will not likely provide good results that are typical of the population. The quality of the results in the survey does not necessarily reflect the quality of the convenience sample in general. There is no statistical data supporting claims, except for Figure 2.1.

2.2.3 Understanding the impact of video quality on user engagement

Dobrian, Sekar, Stoica, and Zhang (2011), investigate how video quality affects user engagement and the degree of the impact on user engagement. As virtual video distribution gains popularity and becomes mainstream, user expectations increase considerably. Watching television as anything lower than the standard definition quality is not acceptable. Thus, this research approach is a step towards answering this question: How much does quality matter? Additionally, “do different metrics vary in the degree in which they impact the user engagement? These results have key implications on how to best use resources to maximize user engagement” (Dobrian et al., 2011, p. 362). The
researchers use unique datasets that span short videos on demand, long videos on demand, and live footage. Five quality metrics were tested, including buffering ratio, rate of buffering, join time, rendering quality, and average bit rate. “Using client-side instrumentation, we measure quality metrics such as the join time, buffering ratio, average bitrate, rendering quality, and rate of buffering events” (Dobrian et al., 2011, p. 362). Results suggest that the amount of time spent buffering video has the largest impact on user engagement across all content (Dobrian et al., 2011). In addition, quality has a substantial impact on the user’s engagement. Viewers are more sensitive to the quality of live video footage, however, there is a need to do further research to explore both viewer and view level engagement impact). This study suggests the importance of video quality on user engagement and need for further research to understand the relationship between graphics and user engagement for other types of content, including 3D games.

2.2.4 An engine selection methodology for high fidelity serious games

“This paper highlights some of the differences between the technical requisites of high-fidelity serious and leisure games, and proposes a selection methodology based upon these emergent characteristics” (Petridis et al. 2010, p. 27). This article deals very little with the idea of graphical fidelity and user response but what it does mention provides interesting findings. Petridis et al. (2010) states that high fidelity in games is often seen as desirable in specific situations when the subject has a need of transfer process that must be learned between the game and the real world. Another interesting finding is the significant negative impact on immersion induced by low frame rate discontinuity. In addition, “preliminary studies have also shown this demographic
responds poorly to low-fidelity games” (Petridis et al., 2010, p. 27). Overall the article addresses the idea that fidelity is important to the player. However, this article mostly addresses game engine selection for serious games. Therefore, this paper suggests a need for further investigation in the importance of graphical quality and user satisfaction for modern 3D games.

2.2.5 From gaming to training: a review of studies on fidelity, immersion, presence, and buy-in and their effects on transfer in PC-based simulations and games

Alexander, Brunyé, Sidman, and Weil (2005) talks about the different areas that have a major impact on simulations in the sense of improving the amount of skill transfer from a simulation to the real life situation. One area they address is fidelity. Fidelity is broken down into three types within the article: Physical, Functional and Psychological. Physical fidelity deals with graphical fidelity and how real the environment looks. Functional fidelity is how well the simulation mimics the actions of the environment and psychological fidelity is how well the program simulates the situation. In certain simulations graphical fidelity is rated as extremely important, while in some simulations functional fidelity is more significant. The example of a sniper simulation was given where the idea of having a high physical fidelity was not nearly as important and functional fidelity when dealing with trajectory, velocity, gravitational pull, wind shear, etc. However, in a medical simulation high graphic fidelity would be important in the training of triage or combat medical practices (Alexander et al., 2005).
Overall the article does address the idea that fidelity is important to the amount of skill transfer from a simulation to real life. However it is dependent on the purpose of the simulation as to what type of fidelity would be most important. Therefore, this review suggests the importance of graphical quality and need for further research to understand the interaction between graphical quality and user transfer for other types of content, including 3D games.

2.3 Emotional Response

“To evoke in oneself a feeling one has once experienced, and having evoked it in oneself, then, by means of movements, lines, colors, sounds or forms expressed in words, so to transmit that feeling that others may experience the same feeling—this is the activity of art.” (Tolstoy, 1896, Chapter 5)

During the British Academy of Film and Television Arts (BAFTA) Annual Video Game Lecture in 2011, game developer BioWare’s co-founders Drs. Ray Muzyka and Greg Zeschuk discuss key concepts in Tolstoy’s beliefs and how BioWare has been implementing them into their production pipeline and games. Drs. Muzyka and Zeschuk believe that in order to create art there must be a canvas and that canvas could convey emotions. That canvas can be a painting, a play, a novel, or even a video game. The game is the tool to illustrate the emotion to the audience (BAFTA, 2011). “Without the emotional response our experiences of fictions would not be the rich and satisfying things they are” (Tavinor, 2005, p. 201). This section addresses how video games elicit an emotional response.
2.3.1 The effects of technological advancement and violent content in video games on players’ feelings on presence, involvement, physiological arousal, and aggression

Ivory and Kalyanaraman (2007) tested whether or not advancements in gaming technology actually increases a player’s aggression while playing a violent video game. They covered certain ideas that dealt greatly with immersion, such as presence, involvement, and arousal; particularly when trying to measure aggression in the test subjects. Testing was conducted to 120 participants to measure a user’s physiological responses while playing two sets of games; a newer and older version of a non-violent and violent video game (Ivory & Kalyanaraman, 2007). The study measured physiological response using skin conductance equipment and self-reported post-questionnaires. Their results suggest that technological advancements in games increased participants’ involvement, sense of presence, and physiological arousal. While the study suggests some evidence suggesting a relationship between violent game content and aggression, there is no statistical significance claiming that advancements in technology or violence had an impact on a player’s aggressive thoughts (Ivory & Kalyanaraman, 2007). Even though the study did not focus on fidelity, it did show that there is more of a physiological response from players while playing the newer test game than the older test game. Therefore, this review strongly suggests interplay between higher quality graphics and player emotional response and the need for further investigation.
2.3.2 Boredom, engagement and anxiety as indicators for adaptation to difficulty in games

Chanel, Rebetez, Bétrancourt, and Pun (2008) researched emotion recognition as indicators for game difficulty adaptation. Three hypotheses were tested. The first hypothesis questioned whether playing at different levels of difficulty would elicit different emotional responses. The second hypothesis stated that the emotions elicited can be “assessed using central and peripheral signaling” (Chanel et al., 2008, p. 14). The third hypothesis questioned player engagement levels through skill adaptation (Chanel et al., 2008). A total of 20 participants were selected to play Tetris at randomly selected difficulty settings. Based on the difficulty selected, participants were observed and their physiological responses were measured using skin conductance equipment, such as “galvanic skin response sensors to measure skin resistance, a plethysmograph device to record blood pressure, a respiration belt measuring abdomen extensions, and temperature sensors to measure a change in temperature” on participants’ palms (Chanel et al., 2008, p. 14). Participants played six 5 minute sessions of Tetris at different difficulty settings at random. Each difficulty setting was repeated twice to eliminate bias; the participant’s goal was to perform the high score. Results showed different difficulty levels elicited different emotional responses. Playing the same difficulty level a number of times showed that participants felt bored. Due to the scope of this study, there was not enough evidence supporting claims on their hypotheses and modern 3D games. A further study exploring the effects of game difficulty adaptation and emotion recognition on more modern video games would expand knowledge of modulating the graphical fidelity of the game according to the emotions of the player.
2.3.3 Looking for the heart of interaction media

Craveirinha and Roque (2010) hypothesized on the interplay between elements of traditional games and their elicited emotions. The paper describes different studies conducted investigating emotions and player engagement in video games. A significant amount of people believe video games do not seem to be capable of eliciting a wide range of emotional responses, and thus are perceived as emotionally shallow. Through much research, it was concluded that the reward system in goal-oriented type games accidently supports this bias that video games are incapable of eliciting a wide range of emotions. The study raised awareness for game developers to create games that elicit emotions to its players. However, graphical quality was not considered in these studies and in the overall conclusion of this paper.

2.3.4 Why we play games: four keys to more emotion without story

Lazzaro (2004) and XEDesign investigated the relationship between emotion in games and identified ways to create emotions other than in a game’s cut scenes. A total of fifteen hardcore gamers, fifteen casual gamers, and fifteen non-players participated in this research study. The study analyzed the data through video recordings of players playing the games while answering questions, self-reported questionnaires, and observation of verbal and non-verbal emotion cues during the testing. Based on recordings and observations, Lazzaro (2004) established a list of common themes and triggers used by games to elicit different emotions. The company came up with four key factors to emotion without story involvement. These four key factors are called “hard fun”, “easy fun”, “altered states”, and “people factor” (Lazzaro, 2004, p. 3-8). “Hard fun” represents a player’s emotions elicited from meaningful challenges, strategies, and
puzzles. “Easy fun” grabs the player’s attention with elements of ambiguity, incompleteness, and detail. “Altered States” refers to generated emotions through perception, thought, behavior, and other people. Lastly, “People factor” creates opportunities for player interaction and competition, cooperation, performance, and spectacle (Lazzaro, 2004). Results suggest video games that are goal-oriented do not typically elicit emotional responses from players. Players in groups elicit emotions more frequently and with more intensity than those playing by themselves. There were many interesting findings in this study; however, there was no mention about graphical fidelity or the interplay between graphics and emotions. Therefore, this paper suggests a need for further investigation in the importance of graphical quality and user emotional response for 3D games.

2.3.5 Visual attention in 3D games

El-Nasr and Yan (2006) investigate visual attention processes in video games searching for further understanding on how to decrease frustration, increase a player’s engagement, and overall further enhance the design of a game’s environment. The study explores bottom-up visual elements such as color and motion and how these elements affect player’s perception of a 3D video game environment, and their effectiveness in obtaining the player’s attention. Top-down visual elements are more efficient in obtaining a player’s attention. Their hypothesis focused on investigating the following: “We believe that eye movement patterns reveal the way players visually perceive the 3D environment… that different game genres stimulate different visual attention patterns depending on the tasks the player is engaged in” (El-Nasr & Yan, 2006, p. 2). A total of
six subjects participated in the study with a variety of gaming knowledge. Participants were asked to interact with two games on the XBOX console; an action adventure game called *Legacy of Kain Blood Omen II* and a FPS called *Halo II*. Results suggest evidence of both top-down and bottom-up visual attention patterns used within the gaming environment. Top-down processing was more appropriate for action-adventure game genre due to the player’s scanning tendencies at the whole screen. Bottom-up is used in first-person shooters more often due to the stimulus driven responses implemented in the game as well as the overall eye focal point located at the center of the screen (El-Nasr & Yan, 2006). Due to the scope of this study, graphical fidelity or emotional responses were not investigated. A further study testing the effects of graphical fidelity on visual attention in 3D games is recommended for further knowledge in the field.

### 2.4 Measuring the Player’s Emotional Experience

It has been observed that certain physical behaviors are linked to emotional states. For instance, when a person is feeling excitement, his body’s heart rate and breathing increases. When people are happy, they smile, and when they are feeling upset or annoyance, they typically frown. If these physical reactions in subjects are measured while playing video games, the experiment can provide insight on how the gamer is interacting or reacting to the game (Isbister & Schaffer, 2008).
“The advantage of physiological measurement is that it can provide a biometric marker that accompanies changes in emotional state, and doesn’t [sic] require cognitive effort or memory to produce” (Isbister & Schaffer, 2008, p. 190). This section addresses how well physiological arousal is measured as a proxy for emotional response.

2.4.1 Galvanic skin response as a measure for emotional arousal

Electrodermal activity, also referred as galvanic skin response (GSR), pertains to the electrical components of the skin. Being easily measured as “skin resistivity or conductance”, it is “the most common measure for physiological responses in psychophysiologic research and in computing systems that integrate body responses” (Isbister & Schaffer, 2008, p. 212). There are two properties to GSR: the tonic baseline and the phasic responses. A tonic baseline is the general conductance of the skin, which greatly varies over different individuals. In contrast, phasic responses are deviations from the tonic baseline. In other words, phasic responses are arousal peaks responding to a stimulus (Stern, Ray, & Quigley, 2001). Humans have eccrine sweat glands which are measured for skin conductance. They are located in the palms of the hands and soles of the feet. Eccrine sweat glands respond “to psychic stimulation instead of simply to temperature changes in the body” (Isbister & Schaffer, 2008, p. 212). An example is given when a person has “clammy hands” and that physical trait associated with the state of nervousness. Individuals do not have to physically sweat in order to distinguish the differences in skin conductivity.
This is because the eccrine sweat gland “acts as a variable resistor on the surface. As sweat rises in a particular gland, the resistance of that gland decreases even though the sweat may not overflow onto the surface of the skin” (as cited in Isbister & Schaffer, 2008, p. 212). There is a linear relationship between GSR and arousal (Lang, 1995). “Increases in psychological arousal are best measured by increases in GSR, but can also be seen in increased respiration, decreased blood volume pulse (BVP), and increased heart rate (HR)” (Isbister & Schaffer, 2008, p. 210). Although GSR is widely recognized as a measurement for emotional arousal, many factors can influence the EDA of a subject. These factors include “age, sex, race, temperature, humidity, stage of menstrual cycle, time of day, season, sweating through exercise, and deep breathing” (as cited in Isbister & Schaffer, 2008, p. 213)

2.4.2 Psychophysiological recordings

In regard to understanding a user’s emotional state in a gaming experience, the use of GSR, heart rate (HR), and smiling and frowning expressions measured with muscle electromyography (EMG), provide a representation of a subject’s experience in emotional valence space. This provides an objective and quantitative approach to the measurement of emotional experience when playing video games and other entertaining technological applications (Isbister & Shaffer, 2008). From this method, it is possible to convert arousal-valence space data to emotions, such as “boredom, excitement, frustration, and fun” (Isbister & Shaffer, 2008, p. 208). This method could be used to compare the similarities and differences between biometrical data to subjective, self-reported measures.
2.4.3 Measuring emotional valence during interactive experiences: boys at video game play

Hazlett (2006) uses facial EMG as a measure for positive and negative emotional valence with subjects playing a car-racing game. Thirteen boys played *Juiced*, on an Xbox console while facial EMG data was measured. Facial EMG primarily focuses on two muscle groups in the face: the corrugator supercilli group that is associated with frowning, and the zygomaticus major muscle group which is associated with smiling. The game allows the player to customize their racing vehicle and pick from various racing courses and level of difficulty. The subjects competed with the game’s AI, circuit-style, for several laps. Upon completing the race, subjects were asked to identify positive and negative events in the game. Positive events identified included passing enemy cars, causing enemy cars to crash or wipeout, advancing to the next highest placement in a race, and winning a race. Negative events included being passed by other enemy cars, wiping out, and running off course.
After reviewing video footage, they found out that zygomaticus EMG had significantly greater results during the positive events. In addition, the corrugator muscle EMG data collected resulted in significantly greater difference when negative events were present (Hazlett, 2006). “This study demonstrated that positive and negative emotion can be measured in real time during video gameplay” (Isbister & Schaffer, 2006, p. 193).

2.5 Conclusions

The gaming industry is constantly looking into ways to improve the gameplay experience. Companies are creating more graphically intensive video games enabled by technological advances; however, they are considering sacrificing graphical fidelity for fps consistency. This results in games with an understood standard base for graphics across different games, instead of maximizing graphical fidelity and output. Some researchers have raised awareness of the importance of further investigation on emotional response and how to bring these emotions to the players. Despite the existing push toward higher fidelity art assets in video game environments, there is a lack of direct physiological measurement in regard to its effect on physiological arousal and resulting emotional response. Surveys and post-study questionnaires provide an incomplete, or even inaccurate understanding of human physiological responses since “emotional experiences are not primarily language-based: cognitive effort is required to put emotional experience into words, and this effort can contaminate measurement” (Isbister & Schaffer, 2008, p. 190). This literature raises a new concern: Can greater quality graphics cause a greater emotion response from the player? The more that can be
researched in the focus area, the closer the industry is to improving the overall game play experience and user satisfaction. By exploring these existing studies, new methodologies can be implemented in the area of focus.

2.6 Chapter Summary

This chapter summarized existing literature on graphical fidelity, emotional responses, and the physiological response measures. A summary for each experiment was provided, followed by conclusions of the importance of researching new methods in the focus area.
CHAPTER 3. FRAMEWORK AND METHODOLOGY

The intent for this research was to observe and identify if greater graphical fidelity can cause a stronger emotional impact in players while they interact with video games. This chapter will cover the research framework, sample set, and testing methodology used in this thesis.

3.1 Research Framework

This thesis presents a quantitative approach on the best methods to elicit emotional responses through high quality computer graphics imagery in video game environments over low quality graphical settings. The research follows an incomplete block design (Liu, 1968) model that will manipulate highest and lowest graphical settings as the independent variables. The dependent variables observed throughout the experiment were the number of arousal spikes, and the spike magnitude as recorded by the GSR sensor. An arousal spike indicates an increase in electrodermal activity (EDA) event as measured by the sensor, thus a physiological measurement as a proxy for emotional response. The size of the spike is also recorded and analyzed. There are four possible treatments:

- Game 1 – High Graphics
- Game 1 – Low Graphics
- Game 2 – High Graphics
- Game 2 – Low Graphics
Additionally, the scope of this research was to observe only the emotional responses via visual stimuli. Therefore, in order to control covariates by having sound present, there was no audio from either game during the study. Having no audio eliminated the possibility of the McGurk Effect occurring (McGurk & MacDonald, 1976). The McGurk Effect is best described as the “perceptual phenomenon that occurs when the auditory component of one sound is paired with the visual component of another sound, leading to the perception of a third sound”. It is an interaction between hearing and visual cues in perception (McGurk & MacDonald, 1976, 746). It is important to note that not everyone experiences the McGurk Effect.

The experimenter collected biometrical data and self-reported responses, analyzed the data to investigate if high graphical fidelity was associated with stronger emotional impact, or if effects were observed between the different chosen video game genres. The research focused on testing a null form hypothesis.

- H_o^1 Higher graphical fidelity in video games does not elicit a stronger emotional impact on the player in action-adventure shooter video games.
- H_a^1 Higher graphical fidelity in video games elicits a stronger emotional impact on the player in action-adventure shooter video games.
- H_o^2 Higher graphical fidelity in video games does not elicit a stronger emotional impact on the player in survival-horror shooter video games.
- H_a^2 Higher graphical fidelity in video games elicits a stronger emotional impact on the player in survival-horror shooter video games.
3.2 Population and Samples

Students and faculty over the age of 18 within Purdue University were tested in this study. The intention was to test on a range of 20-30 students with a wide variety of gaming experience. Participants were avid video game players, thus having a better judgment in graphical quality and gaming. The study was promoted through mass student undergraduate and graduate emailing systems across the Computer Graphics Technology’s department and via word of mouth.

3.3 Testing Materials and System Specifications

The physical testing environment was an unused office near the university department’s computer lab. The lighting and furnishing in the room was held constant and the door was closed for the duration of all experimental test runs. Subjects played two video games of different genres available through the PC. One computer was used during the testing. The laboratory test computer is operated under the following specifications and conditions:

- Intel ® Core™ i7 CPU 930 at 2.80 GHz
- 6.00 GB System memory
- 1.88GHz CPU speed
- NVIDIA GeForce GTX 470 video card
- 3.96 GB video card memory
- DirectX 11
- 1600x900 Display Resolution with 50,000:1 Dynamic Contrast Ratio
- Windows 7 Professional 64-bit operating system
At the time of experimentation these machine specifications exceeded, by a significant margin, the specifications recommended by the game publisher for playing either game at its highest graphics quality settings. To collect GSR recordings the Affectiva Q Sensor (see Figure 3.1) was used; a wearable, wireless biosensor that measures physiological arousal via skin conductance. The Q Sensor records electrodermal activity (EDA) that tends to increase during states such as excitement, attention, or anxiety, and decrease during states such as boredom or relaxation.

Figure 3.1 The Q Sensor
An extensive review of graphical fidelity in FPS games was done to narrow down which games would be appropriate for this experiment. Different games that enabled the player to change the extremes of graphical quality settings were considered. For instance, Bethesda’s *The Elder Scrolls V: Skyrim* offered great textures, great shadow renders, however, when viewed in lowest graphical settings, there was a big difference between the texture quality and shadow renders. Although this game has a first-person perspective view, this game is not a FPS, therefore, it was not chosen for this study. Crytek’s *Crysis 2* had minimal graphical quality changes between highest and lowest graphical settings. DICE’s *Battlefield 3* also had minimal graphical quality changes between both extreme graphical settings.

The games chosen were: *Crysis* and *Dead Space*, both are published by Electronic Arts. Since Isbister and Schaffer (2008) concluded that “different game genres will have different goals for the player’s emotional experience” (p. 188), two different emotional-driven genres were chosen that also had a broad range in high versus low graphical rendering settings. Both *Crysis* and *Dead Space*, though similar in some respects have very different experiential goals for the player. An additional goal of this particular selection of games was to help balance out the influence of camera, mood, narrative, agency, and environment. Though more game types and genres were desired, the time required to conduct even these particular experiments was forty-five minutes to an hour per subject; thus making further demands on subjects’ time was deemed inappropriate by the author.
*Crysis* is a first-person perspective action-adventure game that involves the user navigating a colorful, three-dimensional open environment while holding a firearm and shooting hostile enemies. The player can only see the character’s hands and weapon on the screen. In this game, the character is a powerful soldier wearing a suit used to enhance his physical capabilities and is easily capable of defending himself. See Figure 3.2 for a comparison of image quality in *Crysis*. The graphical fidelity difference between both high and low graphical settings is drastic. Playing the game in the highest graphical settings results in beautiful quality renderings, distinction between landscape textures and enemy textures. Playing the game in the lowest graphical settings results in decent quality graphics; the grass, shadows, and light attributes were subpar. This game provides a drastic difference between both graphical quality settings as shown in Figure 3.2.

*Dead Space* employs a third-person perspective camera that allows the player to see the character on screen with a behind-the-shoulder camera position. *Dead Space* also involves navigating a three-dimensional environment, however the environment in *Dead Space* is dark, claustrophobic, and is intended to be frightening. The character that represents the player is placed in an extreme survival scenario and is constantly hunted by various enemy monsters called Necromorphs. The graphical fidelity difference between both high and low graphical settings is extreme. Playing the game in the highest graphical settings results in beautiful quality renderings, distinction between environment textures, enemy recognition and realistic renders. Playing the game in the lowest graphical settings results in decent quality graphics; the blood, shadows, and enemy geometrical attributes were subpar. This game provides a drastic difference between both graphical quality settings as shown in Figure 3.3.
Figure 3.2 *Crysis* in highest quality graphical settings (left) and lowest settings (right)

Figure 3.3 *Dead Space* in highest quality graphical settings (left) and lowest settings (right)
3.4 **Instructions and Pre-Questionnaire**

Each subject was given a demographic survey prior to the study. Participants received a randomized identification number used to classify the subjects while processing the data. The researcher conducted a verbal tutorial to all of the participants individually (see Figure 3.4). This familiarized the subjects on how the study would be conducted.

![Figure 3.4 Instruction Page](image)

3.5 **Testing and Post-Questionnaire**

Subjects played two different shooter titles, in random order, on the computer with each of the titles categorized under different genres. A review was conducted of many possible video game selections that met the following criteria: the game must
involve navigation through a three-dimensional virtual environment, the game’s graphics must be noticeably different in its low and high quality rendering modes, and the game’s genre must be likely to elicit some form of emotional arousal period, thus the decision was made to study games in the action/adventure and survival/horror genres. The testing procedure was as follows:

- Attach Q Sensor
- Administer pre survey
- Play Game 1 (randomly assigned graphics level)
- Administer Game 1 post survey
- Play Game 2 (randomly assigned graphics level)
- Administer Game 2 post survey
- Remove Q Sensor
- Save and backup biometrical data

Subjects had the Q Sensor on their wrist which collected biometric data using GSR through the entire experiment duration. Subjects played the introductory level of Crysis and Dead Space in random order with either highest graphical or lowest graphical settings, also randomly determined. After ten minutes of play for each game, subjects filled out a specific post-study that was dependent on which order the games were played (see Figure 3.5). Participants were asked about gaming experience, the use of graphics, emotional responses in each level, and overall satisfaction.
Upon completion of the first game, subjects repeated the same process with the remaining game. The entire testing procedure took between 40 to 60 minutes to complete. Upon a subject’s completion of the study, all biometric data and questionnaires were archived for later analysis. Some subjects received more than 10 minutes of gameplay per game because they had to trigger story checkpoints that would convey to the player to react to something. For example, in *Dead Space*, the player had to activate a switch that would trigger an in-game cinematic event that showed the monsters attacking the scientists, triggering the player to react to the event by running away from the scene into the next room.
In *Crysis*, the player had to play up to the moment they would go against enemies spotted along the drop site. If the subjects did not experience these moments in gameplay, the data might not detect any emotions from these scenes. The subject wouldn’t be able to interact with the biggest horror element in the game, which in *Dead Space* are the Necromorphs. A maximum amount of 5 additional minutes of gameplay time was awarded to subjects that did not meet this experiment requirement in 10 minutes.

3.6 **Data Analysis**

Once testing was complete, the data analysis stage of testing was performed. The quantitative data was statistically analyzed using one-way ANOVA for establishing the relationship between the key independent and dependent variables.

3.7 **Chapter Summary**

This chapter provided an explanation of methodology that was used during testing. The next section will provide testing analysis and results.
CHAPTER 4. DATA ANALYSIS

This chapter explains how the data was analyzed for this experiment. The statistical model used to analyze the different data sets was a one-way ANOVA. The data was sorted in Excel spreadsheets then calculated using SPSS. A test of homogeneity of variances (Levene’s test) was used to assess the equality of variances in the different samples. Levene’s test failed to reject that the samples are not homoscedastic.

4.1 Processing of Data

Data collection was conducted over the period of a month. Thirty-six subjects over the age of 18 participated in this study. Though initially 42 were tested, 6 were eliminated from the data analysis due to combinations of overly noisy sensor readings, improper sensor attachment, or subjects fidgeting with sensors (thus contaminating the results); therefore data from a total of 36 subjects were analyzed. No participant was tested more than once and no actual compensation was given to volunteers. Instead, students were given “Cogent”, a token currency unit used in a required Computer Graphics Technology senior course.
4.2 Demographic Results

Participants’ age ranged from 19 to 39 years with 69.44% being males and 30.56% being females. The subjects were asked questions including:

- How many hours a day do you spend playing video games?
- How often do you play survival-horror video games?
- How often do you play action-adventure video games?
- How often do you play first or third person shooter video games?
- How would you rate your knowledge of the game *Crysis*?
- How would you rate your knowledge of the game *Dead Space*?

Surprisingly, none of the individuals had visual impairments that may detract them from enjoying the video game. An average of daily hours spent playing video games was 3.51 hours, 33% of subjects stated they played for more than the calculated average of hours. However, all subjects played at least one hour daily, classifying them as avid gamers. Most subjects expressed that they played more often when school was not in session. Fifty-eight percent of the subjects stated they were more familiar with action-adventure video games and first or third perspective shooter game genres. Forty-four percent were more familiar with survival-horror game genres.
When asked how they would rate their knowledge of the games, 92% classified themselves as novice or beginner in *Crysis* and 80% in *Dead Space*. This is a model population for the study because the majority of the subjects are avid gamers that are very familiar with shooter video game mechanics while being inexperienced and new with of these specific game titles.

4.3 **Study Results**

Each of the games was presented, at random, in either highest or lowest graphical rendering settings. Subjects were never told that they were playing games at different graphical settings. In order to determine any frustration level that subjects may have had experienced while playing the game, either by using a mouse and keyboard versus a game controller or from the various mechanics of the game itself, the subjects were asked the following questions in a Likert scale format:

- How easy was it to pick up the gameplay mechanics?
- Was it easy to play the game using a keyboard and a mouse?
- How would you rate the difficulty level of this game?
In order to determine the subjects’ thoughts on emotional response and how important it is in gaming, the subjects were asked the following questions in a Likert scale format and short essay style:

- How important would emotional response be in this game?
- How well was action/fear demonstrated by graphics in this game?
- Did you experience any emotions playing this game? If so, please explain what emotions you experienced and what caused them.
- Did you feel any tension/fear/stress during the game’s playthrough? If so, explain.

In order to determine the subjects’ thoughts on graphical quality and how important it is in games, the subjects were asked the following questions in a Likert scale format and short essay style:

- Is graphical quality important in this game?
- If you were to rate this game based on how well graphical quality was used in the game, how would you rate it?
- Do you think higher or lower graphical quality could cause a change of impact on your emotions while playing this game?
4.3.1  *Crysis* High versus Low Graphical Settings

For the game *Crysis*, a one-way ANOVA (F(1,34) = 0.168, p = 0.684) test did not detect a statistically significant difference between the high quality and low quality graphics groups along the dimension of the importance in emotional response (see Table 4.1). Further, a one-way ANOVA (F(1,34) = 1.464, p = 0.235) test did not detect a statistically significant difference between the importance of graphical fidelity in this game (see Table 4.2).

Table 4.1

*ANOVA test results for importance of emotional response in Crysis and comparison of quality settings*

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.111</td>
<td>1</td>
<td>.111</td>
<td>.168</td>
<td>.684</td>
</tr>
<tr>
<td>Within Groups</td>
<td>22.444</td>
<td>34</td>
<td>.660</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>22.556</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4.2

_ANOVA test results for importance of graphical fidelity in Crysis and comparison of quality settings_

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>1.000</td>
<td>1</td>
<td>1.000</td>
<td>1.464</td>
<td>.235</td>
</tr>
<tr>
<td>Within Groups</td>
<td>23.222</td>
<td>34</td>
<td>.683</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>24.222</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lastly, a one-way ANOVA (F(1,34) = 0.000, p = 1.000) test did not detect a statistically significant difference between the how well graphical fidelity was used in the game (see Table 4.3).

Table 4.3

_ANOVA test results on how well graphical fidelity is used in Crysis in comparison to differing quality settings_

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.000</td>
<td>1</td>
<td>.000</td>
<td>.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>19.000</td>
<td>34</td>
<td>.559</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>19.000</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.3.2  *Crysis* in High Quality Graphical Settings

When asked, “Did you experience any emotions playing this game,” subjects that played *Crysis* in high graphical settings reported a wide range of emotions (see Figure 4.1):

- Excitement
- Curiosity
- Confusion
- Suspense
- Fear
- Panic
- Helplessness
- Surprise
- Shock
- Unfamiliarity
- “Fight or Flight” Response
- A sense of adrenaline rush

![Did you experience any emotions playing Crysis?](image)

*Figure 4.1* Emotional responses while playing *Crysis*
Out of 18 participants that played *Crysis* on the high quality graphical settings, five reported to not have experienced an emotion during gameplay. Since they played the game with no audio, these subjects stated that the biggest reason why they did not experience an emotion was due to the lack of sound in the game. Some reported that they felt frustrated with the introductory cinematic and that they just wanted to start playing the game rather than wait for the cinematic to finish. “*A little bit of impatience waiting for the cinematic to end,*” reported Subject 12. When subjects were asked to explain if they felt any fear, stress, or tension during the game’s playthrough, 72% of the subjects experienced those emotions.

![Pie chart showing the percentage of subjects who felt that high/low graphical quality caused a change of impact on their emotions while playing *Crysis*. 78% said no, and 22% said yes.](chart.png)

*Figure 4.2 Thoughts on impact of graphical quality in *Crysis*"
Seventy-eight percent of the subjects that tested using the highest graphical settings agreed that higher or lower graphical quality could cause a change of impact on a player’s emotions while playing *Crysis* (see Figure 4.2). Subjects reported that higher quality graphics would result in an improvement in distinguishing objects and enemies in 3D space, more realistic encounters and environments, and more immersive experiences.

“Yes, the higher graphical quality of this game really drew me in. I would have been far less excited to kill those zombies in the last game [Dead Space] given lower quality because they looked dumb,” reported Subject 12. Participants that disagree reported that graphical fidelity is not the definitive factor in emotional response and that it’s not necessary to have higher resolution imagery. In addition, they also reported that story is the most important aspect in the game, not graphical quality.

### 4.3.3 *Crysis* in Low Quality Graphical Settings

When asked, “Did you experience any emotions playing this game,” subjects that played *Crysis* in low graphical settings reported feeling (see Figure 4.3):

- Excitement
- Curiosity
- Panic
- Helplessness
- Surprise
- Unfamiliarity
- Confidence
- Happy
- Sense of Urgency
- A sense of adrenaline rush
Seventy-one percent of the subjects that tested using the lowest graphical setting experienced an emotional response. “A sense of imminent danger and sense of urgency. I felt the need to remain stealthy and undetected due to the nature of the mission and night time environment. When Aztec began praying, I rushed leaving all pretense of stealth,” reported Subject 29. Out of 17 participants that played Crysis in low quality graphics, five reported to not have experienced an emotion during gameplay. There was no report on why they did not experience an emotional response. When subjects were asked to explain if they felt any fear, stress, or tension during the game’s playthrough, 59% of the subjects experienced those emotions.
"I was under stress to provide aid to my teammates and to stay undetected. I didn't have very much fear because the opening cinematic, where bullets bounce off my suit, assuring me that I was an excellent and dangerous combatant," reported Subject 29. However, Subject 18 disagrees; “Not so much. Maybe a bit of tension/excitement when it came to action sequences."

---

**Figure 4.4** Thoughts on impact of graphical quality in *Crysis*

Fifty-nine percent of the subjects that tested on the lowest graphic setting agreed that higher or lower graphical quality could cause a change of impact on a player’s emotions while playing *Crysis* (see Figure 4.4). Subjects reported that higher quality graphics would result in more realistic encounters and environments, and more immersive experiences, and that lower graphical quality could cause a negative effect by losing the environmental ambiance.
“I believe higher quality would make the world/environment that much more believable and exciting to play. It brings the player that much more involvement in the experience,” reported Subject 18.

Participants that disagree reported that graphical fidelity is not the definitive factor in emotional response and that it is not necessary to have higher resolution imagery. “The gameplay wasn’t really focused around the graphics, and that’s what caused the emotional response,” reported Subject 3. An interesting observation was reported by Subject 29: “Most of my emotional response was a result of the cinematic and the dialogue. If I had not been presented with the feeling of invincibility in the opening or read the dialogue of my teammates I would not have reacted as I did.” Subjects that reported feeling confident did state that it was due to the powers the protagonist’s suit obtained.
4.3.4  Dead Space High versus Low Graphical Settings

For the game Dead Space, a one-way ANOVA (F(1,34) = 0.191, p = 0.665) test did not detect a statistically significant difference between the high quality and low quality graphics groups along the dimension of the importance in emotional response (see Table 4.4).

Table 4.4
ANOVA test results for importance of emotional response in Dead Space and comparison of quality settings

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.094</td>
<td>1</td>
<td>.094</td>
<td>.191</td>
<td>.665</td>
</tr>
<tr>
<td>Within Groups</td>
<td>16.656</td>
<td>34</td>
<td>.490</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>16.750</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Further, a one-way ANOVA (F(1,34) = 0.257, p = 0.616) test did not detect a statistically significant difference between the importance of graphical fidelity in this game (see Table 4.5).
Table 4.5

ANOVA test results for importance of graphical fidelity in Dead Space and comparison of quality settings

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.166</td>
<td>1</td>
<td>.166</td>
<td>.257</td>
<td>.616</td>
</tr>
<tr>
<td>Within Groups</td>
<td>22.056</td>
<td>34</td>
<td>.649</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>22.222</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lastly, a one-way ANOVA (F(1,34) = 7.436, p = 0.010) test suggests a statistically significant difference between the how well graphical fidelity was used in the game (see Table 4.6).

Table 4.6

ANOVA test results on how well graphical fidelity was used in Dead Space in comparison to graphical quality settings

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>5.204</td>
<td>1</td>
<td>5.204</td>
<td>7.436</td>
<td>.010</td>
</tr>
<tr>
<td>Within Groups</td>
<td>23.796</td>
<td>34</td>
<td>.700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>29.000</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.3.5  *Dead Space* in High Quality Graphical Settings

When asked, “Did you experience any emotions playing this game,” subjects that played *Dead Space* in high graphical settings reported a wide range of emotions (see Figure 4.5):

- Excitement
- Curiosity
- Frustration
- Suspense/Fear
- Panic
- Surprise/Shock
- Tension
- Immersed
- A sense of adrenaline rush
- Stress

![Figure 4.5 Emotional responses while playing *Dead Space*](image)

Out of 17 participants that played *Dead Space* in high quality graphics, only one subject reported to have not experienced an emotion during gameplay. Subjects reported feeling emotions such as suspense, fear, and tension due to the vivid textures of blood stains on the walls, the scientists being devoured by the Necromorphs in front of the
protagonist, and the flickering lights and chasing sequence that followed. Most reported that they felt frustrated with the navigation setup using a third person camera view as well as the in-game mouse sensitivity. However, the navigation setup might be an intentional design approach to Dead Space’s horror ambiance. “The control scheme is not completely intuitive, making my first panicked run from the necromorph clumsy and terrifying; every time a door opened I was worried what would be behind it,” reported Subject 25. When these subjects were asked to explain if they felt any fear, stress, or tension during the game’s playthrough, 94% of the subjects experienced those emotions.

![Figure 4.6 Thoughts on impact of graphical quality in Dead Space](image)

Eighty-two percent of the subjects that tested the higher graphical setting agreed that higher or lower graphical quality could cause a change of impact on a player’s emotions while playing Dead Space (see Figure 4.6). “I think the higher graphical quality would have any great impact on the emotion since everything would look so real
and players would be easier to get fully involved in the game and play for a longer time,” reported Subject 16. “The visceral horror of the crew being torn apart would be lessened, and the scratches and blood on the wall certainly added to my senses of fear,” reported Subject 25. Subjects reported that higher quality graphics would result in more realistic and scarier encounters, as well as more immersive experiences, and that lower graphical quality could cause a negative image on monster appearance. Subjects reported that if graphical quality were any lower, they wouldn’t have been scared. Some of the subjects stated that lower quality graphics would have given them a “funny” experience rather than fear or suspense. Participants that disagreed reported that graphical fidelity is not the definitive factor in emotional response and that it’s not necessary to have higher resolution imagery. They stated that elements such as audio and story development were more important. “I don’t think the horror genre improves that much with better graphics. Old horror games are just as scary without the good graphics,” reported Subject 5.

4.3.6 Dead Space in Low Quality Graphical Settings

When asked, “Did you experience any emotions playing this game,” subjects that played Dead Space in high graphical settings reported feeling (see Figure 4.7):

- Excitement
- Curiosity
- Panic
- Frustration/Stress
- Suspense/Fear
- Tension
- Anxiety
- Sense of Urgency
- Confusion
- Alert
- Surprise
- A sense of adrenaline rush
Out of 18 participants that played *Dead Space* in low quality graphics, only one reported to not have experienced an emotion during gameplay. Subjects reported feeling emotions such as suspense, fear, anxiety, and excitement. Subject 22 reported that she was scared because the necromorphs almost “got through the elevator” and she was unaware this was a scripted scene in preparation for the next level. Many subjects reported feeling frustrated because the game did not allow quick, turn-around movements that are commonly seeing in other FPS games. Others felt frustrated because of the mouse sensitivity and that made them feel a sense of not having complete control over a situation. When subjects were asked to explain if they felt any fear, stress, or tension during the game’s playthrough, 94% of these subjects experienced those emotions.
Eighty-three percent of the subjects that tested the low quality graphical settings agreed that higher or lower graphical quality could cause a change of impact on a player’s emotions while playing *Dead Space* (see Figure 4.8). Subjects felt that if *Dead Space* had lower quality graphics, the game would lose the horror aspect of it because the game would not look as scary. Subject 18 believes higher graphical fidelity “*adds to the game’s atmosphere and overall can be the difference between a great experience to a decent one.*” Subjects reported that higher quality graphics would result in more realism, elicit more emotions, increase engagement and immersion, and increase the overall “creepiness” feel of the game. Subjects reported that if graphical quality were any lower, they wouldn’t have been scared. “*I would feel more immersed if the graphical quality was better. If it were any worse, I probably wouldn’t want to sit through the cinematic at the beginning. When the alien zombie characters came on screen, they looked so dumb*”
"they weren’t scary at all," reported Subject 12. Participants that disagreed reported that graphical fidelity was not the definitive factor in emotional response and that it was not necessary to have higher resolution imagery.

4.4 GSR Results

The sampling rate of the Q Sensor is 8Hz and each sample from the device is represented by a single floating point numeral. These observations are collected in a large single row list. At eight data points collected for each second, this assumes that each user experienced 8 emotional responses per second, which is implausible. We minimized the processing time with writing some reusable code that automatically takes a user’s every 8th emotional response per second and calculated the mean, median, standard deviation, and the number of peaks as well as the magnitude of those peaks. By averaging each group of one-second values we produced a workable time series (Isbister & Schaffer, 2008). A typical response pattern is illustrated in Figure 4.9.
Figure 4.9 GSR measurements from a subject during testing. The rhythmic scalloping that occurs towards the end of the series corresponds to a series of startled events that occurred within the *Dead Space* game.

An arousal spike is defined as a GSR reading that is one standard deviation above the baseline response level, and is sustained in duration (one second or greater). The baseline response level is the median GSR level of the user. As the median statistic is not sensitive to outliers (Groebner, Shannon, Fry, & Smith, 2011) it was chosen over the mean as our baseline measurement. The baseline level represents the resting state of the individual; it is calculated separately for each subject as initial testing revealed different individuals tended to have idiosyncratic absolute resting levels. Spike magnitude is defined as the number of standard deviations an arousal spike is from the baseline. Data were analyzed using SPSS and Microsoft Excel using a one-way ANOVA test.
4.4.1  *Crysis*

For the game *Crysis*, a one-way ANOVA (F(1,33) = 0.407, p = 0.528) test did not detect a statistically significant difference between the high quality and low quality graphics groups along the dimension of arousal spikes (see Table 4.7). Further, a one-way ANOVA (F(1,33) = 1.357, p = 0.252) test did not detect a statistically significant difference between the high quality and low quality graphics groups along the dimension of spike magnitude (see Table 4.8).

Table 4.7

*ANOVA test results for number of physiological response peaks in Crysis in comparison to quality settings*

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>99.442</td>
<td>1</td>
<td>99.442</td>
<td>.407</td>
<td>.528</td>
</tr>
<tr>
<td>Within Groups</td>
<td>8063.529</td>
<td>33</td>
<td>244.349</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8162.971</td>
<td>34</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4.8

ANOVA test results for the magnitude of physiological response peaks in Crysis in comparison to quality settings

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.164</td>
<td>1</td>
<td>.164</td>
<td>1.357</td>
<td>.252</td>
</tr>
<tr>
<td>Within Groups</td>
<td>4.000</td>
<td>33</td>
<td>.121</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4.165</td>
<td>34</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.4.2 Dead Space

For the game Dead Space, a one-way ANOVA (F(1,35) = 0.000, p = 0.986) test did not detect a statistically significant difference between the high quality and low quality graphics groups along the dimension of arousal spikes (see Table 4.9). Further, a one-way ANOVA (F(1,35) = 0.002, p = 0.968) test did not detect a statistically significant difference between the high quality and low quality graphics groups along the dimension of spike magnitude (see Table 4.10).
Table 4.9

ANOVA test results for number of physiological response peaks in Dead Space in comparison to quality settings

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.102</td>
<td>1</td>
<td>.102</td>
<td>.000</td>
<td>.986</td>
</tr>
<tr>
<td>Within Groups</td>
<td>11823.789</td>
<td>35</td>
<td>337.823</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>11823.892</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.10

ANOVA test results for the magnitude of physiological response peaks in Dead Space in comparison to quality settings

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.000</td>
<td>1</td>
<td>.000</td>
<td>.002</td>
<td>.968</td>
</tr>
<tr>
<td>Within Groups</td>
<td>4.866</td>
<td>35</td>
<td>.139</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4.866</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.5 Chapter Summary

This chapter has provided an explanation of the process used to analyze the data collected for this experiment. The following chapter addresses general findings, conclusions, and recommendations for further study.
CHAPTER 5. DISCUSSION AND FUTURE WORK

5.1 Introduction

This chapter discusses the results found across ANOVA and biometrical data analysis in depth, limitations in the study, and conclusions.

5.2 General Findings

In the experiment, a statistically significant relationship between graphical fidelity and subject physiological response was not observed. From these results, there is no support for the notion that increased focus on higher graphical fidelity alone results in a more physiologically, and therefore, more emotionally, engaged experience.

• \( H_0^1 \) Higher graphical fidelity in video games does not elicit a stronger emotional impact on the player in action-adventure shooter video games. **FAIL TO REJECT**

• \( H_0^2 \) Higher graphical fidelity in video games does not elicit a stronger emotional impact on the player in survival-horror shooter video games. **FAIL TO REJECT**
There is no evidence to suggest that graphical fidelity is completely unimportant to the perception of engagement within a video game, however results demonstrate that, all things being equal, graphical fidelity by itself is insufficient to increase physiological arousal in the end user.

### 5.2.1 Crysis

Both groups of subjects that experienced *Crysis* in highest and lowest graphical quality reported similar emotions. Players experienced excitement, curiosity, unfamiliarity, surprise, panic, helplessness, and the sense of an adrenaline rush (fight or flight response). However, based on self-reported and physiological responses, there is no evidence that suggests that playing *Crysis* at either graphical quality settings impacted the emotional response of those tested.

### 5.2.2 Dead Space

Both groups of subjects that experienced *Dead Space* in highest and lowest graphical quality reported similar emotions. Players experienced fear, panic, frustration, excitement, stress, suspense, tension, curiosity, and the sense of an adrenaline rush (fight or flight response). Based on physiological responses, there is no evidence that suggests that playing *Dead Space* at either graphical quality settings would impact the emotional response of those tested. However, when asked how the user would rate graphical fidelity usage in *Dead Space*, the ANOVA result suggests there is a statistical significance.
Therefore, it is presumed that graphical fidelity is important in survival-horror shooters but there is not enough evidence to claim that it is the definitive factor for creating greater emotional response.

5.3 Limitations

The study did not consider games outside of the first and third person perspective adventure and horror genre, nor did it account for the subject's level of familiarity with the input control scheme. Both games used a control scheme that consisted of using the mouse for moving the direction of the game camera and the keyboard for translating the player through the virtual environment. It is plausible that this control scheme itself could have been a source of emotional reaction and in the process overwhelmed the influence of a potential graphical quality factor.

The two games played during the study had different ranges of graphical quality between the two titles. The difference in rendering quality in *Crysis* between its low and high settings was noticeable, but not strikingly so; a cursory glance at low and high quality *Crysis* images did not reveal a glaring difference between the two. *Dead Space* on the other hand did demonstrate a more noticeable difference between its high versus low rendered output.

From a practicality perspective, the timeframe of the study had to be limited to a maximum of 60 minutes. The *Q Sensor* used to gather the GSR data has a recommended waiting resting period of at least 15 minutes of user inactivity prior to the study to accurately record a baseline (Affectiva, 2012). It would be ideal to have had a resting period for 15 minutes, followed by the 30 to 40 minute study. However, since the sample
mostly consisted of students and the testing procedure took place during regular academic
hours, it was not possible to have subjects stay for more than 60 minutes for a more
complete gameplay experience.

Though there is ample support in the literature that arousal measured by GSR is
an appropriate proxy for emotional response; furthermore there are many factors that can
affect the data recording process. For example, GSR is sensitive to device movement,
physical activity from user, and the subject’s individual physiological differences
(Isbister & Schaffer, 2008).

If one thing could be changed from this study, the use of EMG instead of GSR
would greatly detect emotional valence, therefore, emotional arousal within the gameplay
experience. However, due to funding limitations, it was necessary to test with more cost
efficient and easily obtainable sensor devices, such as Affectiva’s Q Sensor.

5.4 Conclusions and Future Work

In summary, no statistically significant relationship between graphical quality and
physiological response was observed for either of this study’s test games. Despite the
excitement generated by the steady increase in the sophistication and power of graphics
display hardware, results suggest that creating video games that are immersive and
exciting is dependent on a broad range of factors, of which graphical fidelity is only one.
Attempts to rely solely upon impressive graphics are likely to leave users of video games
and other forms of virtual environments feeling unengaged and aloof from software
creations. Though the study suffered from a few potential confounds, it has been
concluded that these results are nonetheless compelling as these confounds seem unlikely
to explain our lack of observed variance relating to graphical quality. More specifically, if an effect does exist relating to this factor, the fact that it was so easily washed out by the influence of other co-factors indicates that this effect would likely be fairly weak. However, the author has not presumed to have lain to rest the matter of graphical fidelity in regards to video games. The following areas are recommended for future study:

- An examination of the effects of graphical fidelity on physiological response in various video game genres, aside from first and third person shooters.

- Further study that extends our methodology to explore other first person perspective games that focus on different play styles, as well as to allow subjects to play the game longer so they can experience a broader range of emotional responses.

- As this study was limited to video games designed to cause tension, fear, and stress, we feel that it is worth investigating the effect of graphical fidelity on games that are designed to elicit a different range of emotions.

- Repeated testing with different biosensors such as an electroencephalograph (EEG) or electromyography (EMG) may yield compelling new insights into the effect of graphic fidelity on physiological arousal and emotion.

- Further study on different demographical subjects and gamer personas. For example, the comparison between the results of a casual gamer to a professional gamer, the results between males and female gamers, and impact of graphics between different age groups.
This study raises awareness in the need for further scientific research and statistical analysis in player behavior and interaction studies in the gaming industry. Game designers are constantly investigating methods of improving the gaming experience but there seems to be a lack of psychological research that backs up final game design implementations in video games. If there is more investigation done to find ways to make better games with statistical analysis and research, the possibilities to convey certain emotional responses to our players are endless. The use of self-reported data that focus testing and game testers in industry provide are not sufficient for validation of game design choices and implementation. The combination of self-reported and biometrical data for physiological activity as a proxy for emotional response provides more accurate validation. Therefore, it is recommended to expand in psychological and perceptual studies in the field to explore new knowledge in creating better emotionally-engaging video games.
LIST OF REFERENCES
LIST OF REFERENCES


http://doi.acm.org/10.1145/1457199.1457203


Figure A.1 Screenshots of *Crysis* in high graphical settings (top) and low graphical settings (bottom)
Appendix B  High Quality versus Low Quality Screenshots from *Dead Space*

*Figure A.2* Screenshots of *Dead Space* in high graphical settings (top) and low graphical settings (bottom)
Appendix C  IRB Approval Letter

Purdue University

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To: JAMES MOHLER
To: JAMES MOHLER
KNOY 347
KNOY 347
From: JEANNE DICLEMENTI, Chair
From: JEANNE DICLEMENTI, Chair
Social Science IRB
Social Science IRB
Date: 11/05/2012
Date: 11/05/2012
Committee Action: Approval
Committee Action: Approval
IRB Action Date: 11/01/2012
IRB Action Date: 11/01/2012
IRB Protocol #: 1210012787
IRB Protocol #: 1210012787
Study Title: Impact of Graphical Fidelity on Player Emotions in Video Games
Study Title: Impact of Graphical Fidelity on Player Emotions in Video Games
Expiration Date: 10/31/2013
Expiration Date: 10/31/2013

Following review by the Institutional Review Board (IRB), the above-referenced protocol has been approved. This approval permits you to recruit subjects up to the number indicated on the application form and to conduct the research as it is approved. The IRB-stamped and dated consent, assent, and/or information form(s) approved for this protocol are enclosed. Please make copies from these document(s) both for subjects to sign should they choose to enroll in your study and for subjects to keep for their records. Information forms should not be signed. Researchers should keep all consent/assent forms for a period no less than three (3) years following closure of the protocol.

Revisions/Amendments: If you wish to change any aspect of this study, please submit the requested changes to the IRB using the appropriate form. IRB approval must be obtained before implementing any changes unless the change is to remove an immediate hazard to subjects in which case the IRB should be immediately informed following the change.

Continuing Review: It is the Principal Investigator’s responsibility to obtain continuing review and approval for this protocol prior to the expiration date noted above. Please allow sufficient time for continued review and approval. No research activity of any sort may continue beyond the expiration date. Failure to receive approval for continuation before the expiration date will result in the approval’s expiration on the expiration date. Data collected following the expiration date is unapproved research and cannot be used for research purposes including reporting or publishing as research data.

Unanticipated Problems/Adverse Events: Researchers must report unanticipated problems and/or adverse events to the IRB. If the problem/adverse event is serious, or is expected but occurs with unexpected severity or frequency, or the problem/event is unanticipated, it must be reported to the IRB within 48 hours of learning of the event and a written report submitted within five (5) business days. All other problem/events should be reported at the time of Continuing Review.

We wish you good luck with your work. Please retain copy of this letter for your records.
Appendix D  Consent Form

RESEARCH PARTICIPANT CONSENT FORM
Impact on Graphical Fidelity on Player Emotions in Video Games
James L. Mohler Ph.D.
Purdue University
Computer Graphics Technology

Purpose of Research
Many industry professionals believe that video games can elicit an emotional response and that these responses are
significant enough to impact the gaming community. By researching this idea of emotional response with biomarkers we
will further expand our understanding of player responses and help us refine the game development and design process.

Specific Procedures
The testing will be conducted in office room Knoy 347. Experimenter will place the Galvanic Skin Response sensor on
your wrist that monitors skin conductance. You will wear the sensor until the end of the study (after filling out the post-
study). You will start by filling out a pre-study survey and conduct part A of the experiment by playing one game at
random, followed with a post-study survey. This step is then repeated with the remaining game for part B. You will play
two video games of different games available through the PC, Crysis for the action-adventure genre and Dread Space for
the horror genre. You will have 10 minutes to play each game. The order of the games played will also be at random. Once
you have completed the post-study, then the GSR sensor will be removed.

Duration of Participation
The research will take no longer than 35 minutes to complete.

Risks
The research is minimal risk, which is no greater than every day activities. There are no known additional risks to those
who take part in this study. As with all research, there is a chance that confidentiality could be compromised; however,
we are taking precautions to minimize this risk.

Benefits
There is no direct benefit to be gained by the participant. Potential benefits to be gained may include:
- 30 minutes of game time will give students the entertainment they needed in between classes.
- In game design, multiple emotions often end up woven together in complex plots and storytelling but there is a lack
  of knowledge player emotional response and satisfaction while playing a video game. This research will provide
  more information to the fields of game design and psychology, as well as explore new concepts in human visual
  perception in games.

Compensation
There is no real monetary compensation for completing this study. If you are a Computer Graphics student, you will get
cognet compensation after completing the study. Cognet is a fake currency unit used only in CGT's 411/450 course. You
will be asked what major you represent, and if you are in CGT, you will get paid in cognet in the total of $300 cognet
dollars.

Participant's Initials           Date
Confidentiality
We will keep your study records private and confidential. No identifiable data will be collected. By law, anyone who looks at your records must keep them completely confidential. The person who is in charge of this research study is James L. Mohler, Ph.D. However, other research staff may be involved and can act on behalf of the person in charge. Vivianette Ocasio is being guided in this research by James L. Mohler, Ph.D., and will be conducting the study. The project's research records may be reviewed by departments at Purdue University responsible for regulatory and research oversight. When the research is completed, data collected and survey results may be saved for use in future research done by us. We will retain this study information for up to 12 months/years after the study is over.

To minimize the risks to confidentiality, you will receive a tracking number, and that number is what helps us match pre-study, post-study, and GSR data and compare results. However, there will be no way of telling who you are based on tracking numbers and data collected. We will keep your study data as confidential as possible.

Voluntary Nature of Participation
You do not have to participate in this research project. If you agree to participate you can withdraw your participation at any time without penalty.

Contact Information:
If you have any questions about this research project, you can contact Vivianette Ocasio at vocasio1@purdue.edu or 317-946-1197 (primary contact) or James L. Mohler, Ph.D. at jlmohler@purdue.edu or 765-496-6071. If you have concerns about the treatment of research participants, you can contact the Institutional Review Board at Purdue University, Ernest C. Young Hall, Room 1032, 155 S. Grant St., West Lafayette, IN 47907-2114. The phone number for the Board is (765) 494-5942. The email address is irb@purdue.edu.

Documentation of Informed Consent
I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research project and my questions have been answered. I am prepared to participate in the research project described above. I will receive a copy of this consent form after I sign it.

Participant’s Signature  Date

Participant’s Name

Experimenter’s Signature  Date
INTRODUCTION

“Since the dawn of recorded history, the stories we find entertaining have followed a consistent template: genres. And the interesting thing about genres is most of them happen to coincide directly with specific emotions: Suspense, Romance, Comedy, Horror, Adventure, Drama and Tragedy. While this isn’t a comprehensive list of human emotion, it does appear to be a comprehensive list of emotions we explicitly seek for entertainment.”

-Venitce, 2011

Many industry professionals believe that video games can elicit an emotional response and that these responses are significant enough to impact the gaming community. By researching this idea of emotional response with biometrics we will further expand our understanding of player responses and help us refine the game development and design process.

To help us with our study, please fill out the pre-study before conducting the study. You must be at least 18 years old to participate and the survey is completely voluntary. If you choose to participate, you will have play two different shooter video games on the computer categorized as two different types of genres. You will play them at random order. In addition, you will have a sensor on your wrist that collects electrodermal activity using GSR. In this study we will be using the Affectiva Q Sensor (GSR). It is a wearable, wireless biosensor that measures emotional arousal via skin conductance, a form of electrodermal activity that grows higher during states such as excitement, attention, or anxiety and lower during states such as boredom or relaxation. After conducting the study, please fill out our post-study survey. You will answer the questions using a combination of Likert scale and short answer. To save you time, you will have 10 minutes of game time per genre and a total of 10-15 minutes of survey time. The actual study should not take longer than 45 minutes.

Thank you for your help!
PRE-STUDY USER PROFILE QUESTIONNAIRE

Demographics

For the following questions, please check the box:

1. Age: 
2. Gender:  □ Male  □ Female

Gaming Experience

For the following questions, please check the box:

3. How many hours each day do you spend playing video games? 

4. What kind of video games do you play?
   □ First-Person Shooting  □ Simulation
   □ MMORPGS  □ Music
   □ Real-Time Strategy  □ Party
   □ Action Adventures  □ Other
   □ Racing  □ Fighting
   □ Sports

For the following questions, please circle YES or NO:

5. Do you prefer playing console-based video games over PC-based games?  YES / NO
6. Do you prefer a mouse and keyboard setup for gameplay over a controller?  YES / NO
7. Have you ever played Crysis?  YES / NO
8. If so, do you own Crysis on PC or console?  YES / NO
9. Have you ever played Dead Space?  YES / NO
10. If so, do you own Dead Space on PC or console?  YES / NO
11. Do you have any visual impairment that may detract you from enjoying video games?  YES / NO
12. If so, explain:

13. How would you rate your knowledge of the game Crysis?
   □ Novice  □ Beginner
   □ Intermediate  □ Expert

14. How would you rate your knowledge of the Dead Space?
   □ Novice  □ Beginner
   □ Intermediate  □ Expert
For the following questions, please rate your responses on a scale from 1 (lowest) to 10 (highest):

15. On a scale from 1-10, how often do you play survival horror video games?

   1 2 3 4 5 6 7 8 9 10

16. On a scale from 1-10, how often do you play action-adventure video games?

   1 2 3 4 5 6 7 8 9 10

17. On a scale from 1-10, how often do you play shooter video games (first person or third person perspectives)?

   1 2 3 4 5 6 7 8 9 10

Thank you for completing our pre-study survey.
Appendix F  Post-Study Questionnaire

POST-STUDY PERFORMANCE QUESTIONNAIRE – PART A

DEFINITIONS:

- **Graphical quality**: a game’s graphical settings. High graphical quality is graphical parameters at the highest available settings, providing the best graphical imagery resolution, whereas low graphical quality is graphical parameters at the lowest available settings, providing the worst graphical imagery resolution.

**CRYSTAL**

For the following questions, please circle the corresponding number:

1. How easy was it to pick up the gameplay mechanics? 1, 2, 3, 4, 5
2. Was it easy to play the game using a keyboard and a mouse? 1, 2, 3, 4, 5
3. How would you rate the difficulty level of this game level? 1, 2, 3, 4, 5

For the following questions, please circle the corresponding number regarding **CRYSTAL**:

4. How important would emotional response be in this game? 1, 2, 3, 4, 5
5. How well was action demonstrated by graphics in the game? 1, 2, 3, 4, 5
6. Is graphical quality important in this game? 1, 2, 3, 4, 5

For the following question, please circle the corresponding number:

7. If you were to rate this game based on how well graphical fidelity was used in the game, how would you rate it? 1, 2, 3, 4, 5
8. Would you recommend this game to other people? 1, 2, 3, 4, 5

For the following questions, please answer to your best abilities and in short sentences:

9. Did you experience any emotions playing **CRYSTAL**?
   If so, please explain what emotions you experienced and what caused them.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
10. Did you feel any tension/fear/stress during this game’s playthrough? YES / NO
   If so, explain:
   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________

11. Do you think higher or lower graphical quality could cause a change of impact on your emotions while playing this game? YES / NO
   Please explain:
   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________

COMMENTS

Part A of Post-Study Complete.
Please wait after second game playthrough to complete second portion of the study.

Thank you!
POST-STUDY PERFORMANCE QUESTIONNAIRE – PART B

DEFINITIONS:

• **Graphical quality**: a game’s graphical settings. High graphical quality is graphical parameters at the highest available settings, providing the best graphical imagery resolution, whereas low graphical quality is graphical parameters at the lowest available settings, providing the worst graphical imagery resolution.

DEAD SPACE

For the following questions, please circle the corresponding number:

1 = Extremely Hard  2 = Hard  3 = Not so Difficult  4 = Easy  5 = Extremely Easy

12. How easy was it to pick up the gameplay mechanics?
13. Was it easy to play the game using a keyboard and a mouse?
14. How would you rate the difficulty level of this game level?

For the following questions, please circle the corresponding number regarding **DEAD SPACE**:

1 = Extremely Unimportant  2 = Unimportant  3 = Not so Important  4 = Important  5 = Extremely Important

15. How important would emotional response be in this game?
16. How well was action demonstrated by graphics in the game?
17. Is graphical quality important in this game?

For the following question, please circle the corresponding number:

1 = Not Recommended  2 = Poor  3 = Fair  4 = Good  5 = Excellent

18. If you were to rate this game based on how well graphical fidelity was used in the game, how would you rate it?
19. Would you recommend this game to other people?

For the following questions, please answer to your best abilities and in short sentences:

20. Did you experience any emotions playing **DEAD SPACE**?
If so, please explain what emotions you experienced and what caused them.
21. Did you feel any tension/fear/stress during this game’s playthrough? YES / NO
   If so, explain:
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________

22. Do you think higher or lower graphical quality could cause a change of impact on your emotions while playing this game? YES / NO
   Please explain:
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________

For the following questions, please circle YES or NO:

1. Did you enjoy playing CRISIS? YES / NO
2. Did you enjoy playing DEAD SPACE? YES / NO

COMMENTS

Part B of Post-Study Complete.
Please wait after second game playthrough to complete second portion of the study.

Thank you!
Appendix G  SPSS Output - Levene’s test and GSR ANOVA results for *Crysis*

### Descriptives

<table>
<thead>
<tr>
<th># Peaks (Averaged Data)</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>1.0</td>
<td>18</td>
<td>17.33</td>
<td>17.2081</td>
<td>4.0560</td>
<td>8.776</td>
</tr>
<tr>
<td>2.0</td>
<td>17</td>
<td>20.706</td>
<td>13.7603</td>
<td>3.3374</td>
<td>13.631</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>18.97</td>
<td>15.4948</td>
<td>2.6191</td>
<td>13.649</td>
</tr>
</tbody>
</table>

### Test of Homogeneity of Variances

<table>
<thead>
<tr>
<th># Peaks (Averaged Data)</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>.0</td>
<td>62.0</td>
</tr>
<tr>
<td>2.0</td>
<td>3.0</td>
<td>49.0</td>
</tr>
<tr>
<td>Total</td>
<td>.0</td>
<td>62.0</td>
</tr>
</tbody>
</table>

### ANOVA

<table>
<thead>
<tr>
<th># Peaks (Averaged Data)</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>99.442</td>
<td>1</td>
<td>99.442</td>
<td>.407</td>
<td>.528</td>
</tr>
<tr>
<td>Within Groups</td>
<td>8063.529</td>
<td>33</td>
<td>244.349</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8162.971</td>
<td>34</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Descriptives

**Average Peak Magnitude (Averaged Data)**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>16</td>
<td>0.2499523577</td>
<td>0.3640037251</td>
<td>0.0857965010</td>
<td>0.669375633</td>
<td>0.4309671521</td>
</tr>
<tr>
<td>2.0</td>
<td>17</td>
<td>0.3071169727</td>
<td>0.3304025039</td>
<td>0.0901546902</td>
<td>0.2171960202</td>
<td>0.5570393251</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>0.3165761421</td>
<td>0.3499794448</td>
<td>0.0951573234</td>
<td>0.1983539965</td>
<td>0.4367962877</td>
</tr>
</tbody>
</table>

**Average Peak Magnitude (Averaged Data)**

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>0.0000000000</td>
<td>1.290419356</td>
</tr>
<tr>
<td>2.0</td>
<td>0.0155255055</td>
<td>0.9875749633</td>
</tr>
<tr>
<td>Total</td>
<td>0.0000000000</td>
<td>1.290419356</td>
</tr>
</tbody>
</table>

### Test of Homogeneity of Variances

**Average Peak Magnitude (Averaged Data)**

<table>
<thead>
<tr>
<th>Levene Statistic</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.214</td>
<td>1</td>
<td>33</td>
<td>.646</td>
</tr>
</tbody>
</table>

### ANOVA

**Average Peak Magnitude (Averaged Data)**

<table>
<thead>
<tr>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.164</td>
<td>1</td>
<td>.164</td>
<td>1.357</td>
</tr>
<tr>
<td>Within Groups</td>
<td>4.000</td>
<td>33</td>
<td>.121</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4.165</td>
<td>34</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix H  SPSS Output - Levene’s test and GSR ANOVA results for *Dead Space*

### Descriptives

<table>
<thead>
<tr>
<th># Peaks (Averaged Data)</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>1.0</td>
<td>19</td>
<td>22.105</td>
<td>15.2712</td>
<td>3.5035</td>
<td>14.745</td>
</tr>
<tr>
<td>2.0</td>
<td>18</td>
<td>22.000</td>
<td>21.1799</td>
<td>4.9922</td>
<td>11.467</td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td>22.054</td>
<td>18.1230</td>
<td>2.9794</td>
<td>16.012</td>
</tr>
</tbody>
</table>

### Descriptives

<table>
<thead>
<tr>
<th># Peaks (Averaged Data)</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>0</td>
<td>56.0</td>
</tr>
<tr>
<td>2.0</td>
<td>1.0</td>
<td>95.0</td>
</tr>
<tr>
<td>Total</td>
<td>0</td>
<td>95.0</td>
</tr>
</tbody>
</table>

### Test of Homogeneity of Variances

<table>
<thead>
<tr>
<th># Peaks (Averaged Data)</th>
<th>Levene Statistic</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.195</td>
<td>1</td>
<td>35</td>
<td>.661</td>
</tr>
</tbody>
</table>

### ANOVA

<table>
<thead>
<tr>
<th># Peaks (Averaged Data)</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.102</td>
<td>1</td>
<td>.102</td>
<td>.000</td>
<td>.986</td>
</tr>
<tr>
<td>Within Groups</td>
<td>11823.789</td>
<td>35</td>
<td>337.823</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>11823.892</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Descriptives

**Average Peak Magnitude (Averaged Data)**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>19</td>
<td>0.3215422267</td>
<td>0.4038052474</td>
<td>0.0926392772</td>
<td>0.1269143276</td>
<td>0.5161701259</td>
</tr>
<tr>
<td>2.0</td>
<td>18</td>
<td>0.3265497551</td>
<td>0.3370299781</td>
<td>0.0794387276</td>
<td>0.1589486900</td>
<td>0.4941568202</td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td>0.3239733216</td>
<td>0.3676816904</td>
<td>0.004432169</td>
<td>0.2013906082</td>
<td>0.4465620350</td>
</tr>
</tbody>
</table>

**Average Peak Magnitude (Averaged Data)**

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>0.0000000000</td>
<td>1.459468987</td>
</tr>
<tr>
<td>2.0</td>
<td>0.0096249975</td>
<td>1.235046165</td>
</tr>
<tr>
<td>Total</td>
<td>0.0000000000</td>
<td>1.459468987</td>
</tr>
</tbody>
</table>

### Test of Homogeneity of Variances

**Average Peak Magnitude (Averaged Data)**

<table>
<thead>
<tr>
<th>Levene Statistic</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.163</td>
<td>1</td>
<td>35</td>
<td>.689</td>
</tr>
</tbody>
</table>

### ANOVA

**Average Peak Magnitude (Averaged Data)**

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.000</td>
<td>1</td>
<td>.000</td>
<td>.002</td>
<td>.968</td>
</tr>
<tr>
<td>Within Groups</td>
<td>4.868</td>
<td>35</td>
<td>.139</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4.868</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix I  Subjects’ EDA results via Q Sensor software (#1-#36 in order)