Pilot Study of a Kinect-Based Video Game to Improve Physical Therapy Treatment

Jacob Samuel Brown
jsbrown@purdue.edu

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

Part of the Game Design Commons, and the Therapeutics Commons

http://docs.lib.purdue.edu/cgtheses/30

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 Jacob Samuel Brown

Entitled
PILOT STUDY OF A KINECT-BASED VIDEO GAME TO IMPROVE PHYSICAL THERAPY
TREATMENT

For the degree of Master of Science

Is approved by the final examining committee:

David Whittinghill

Bedrich Benes

Raymond Hassan

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): David Whittinghill

Approved by: Craig Miller 04/26/2013

Head of the Graduate Program Date
PILOT STUDY OF A KINECT-BASED VIDEO GAME TO IMPROVE PHYSICAL THERAPY TREATMENT

A Thesis
Submitted to the Faculty
of
Purdue University
by
Jacob Samuel Brown

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

May 2013
Purdue University
West Lafayette, Indiana
This study is dedicated to Dr. La Verne Abe Harris, Ph.D. and Dr. David M Whittinghill, Ph.D, both to whom I owe much thanks and gratitude. Thank you for all your support.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>LIST OF TABLES</th>
<th>v</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF FIGURES</td>
<td>vi</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>vii</td>
</tr>
<tr>
<td>CHAPTER 1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Background</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Significance</td>
<td>2</td>
</tr>
<tr>
<td>1.3 Research Question</td>
<td>2</td>
</tr>
<tr>
<td>1.4 Assumptions</td>
<td>2</td>
</tr>
<tr>
<td>1.5 Limitations</td>
<td>3</td>
</tr>
<tr>
<td>1.6 Delimitations</td>
<td>3</td>
</tr>
<tr>
<td>1.7 Definitions</td>
<td>3</td>
</tr>
<tr>
<td>1.8 Summary</td>
<td>4</td>
</tr>
<tr>
<td>CHAPTER 2. LITERATURE REVIEW</td>
<td>5</td>
</tr>
<tr>
<td>2.1 Exergaming</td>
<td>5</td>
</tr>
<tr>
<td>2.2 Cerebral Palsy</td>
<td>6</td>
</tr>
<tr>
<td>2.3 Kinect</td>
<td>7</td>
</tr>
<tr>
<td>2.4 OpenNI</td>
<td>8</td>
</tr>
<tr>
<td>2.5 Gestures</td>
<td>9</td>
</tr>
<tr>
<td>2.6 Previous Games</td>
<td>10</td>
</tr>
<tr>
<td>2.7 Physical Therapy</td>
<td>12</td>
</tr>
<tr>
<td>2.8 Summary</td>
<td>14</td>
</tr>
<tr>
<td>CHAPTER 3. METHODOLOGY</td>
<td>14</td>
</tr>
<tr>
<td>3.1 Introduction</td>
<td>15</td>
</tr>
<tr>
<td>3.2 The Game</td>
<td>15</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 4.2.1 Gesture Data Group A</td>
<td>26</td>
</tr>
<tr>
<td>Table 4.2.2 Gesture Data Group B</td>
<td>27</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure .............................................................. Page
Figure 3.1: A picture of a mountain pass in Burnie.........................16
Figure 3.2: A picture of a frozen lake within Burnie........................16
Figure 3.3: Burnie flying through a forest, collecting power-ups........17
Figure 3.4: Dive Position..........................................................18
Figure 3.5: Flap Position.............................................................18
Figure 3.6: Right Position..........................................................19
Figure 3.7: Left Position............................................................19
Figure 3.8: This figure shows the joints recorded for calibration within Burnie. The x, y, and z values for the joints are Euler angles relative to the blue node located in the center of the player. Figure 9 explains this concept in more detail...20
Figure 3.9: In this figure the red axes correspond to the red nodes in Figure 8. The blue axes correspond to the blue node in the same figure. The alpha, beta, and gamma values are stored as the x, y, and z values for the local Euler angles of the joints.................................................................21
Figure 3.10: Group A, Gesture Intensity of 2....................................22
Figure 3.11: Group B, Gesture Intensity of 1.................................23
ABSTRACT

Brown, Jacob S. M.S., Purdue University, May 2013. Pilot Study of a Kinect-based Video Game to Improve Physical Therapy. Major Professor: David Whittinghill.

*Burnie* is an exergame being developed at Purdue University and is used in this study. *Burnie* was developed using the Unity3D engine and OpenNI to interface with the Xbox Kinect. This study looked at how gesture intensity affected perceived enjoyment and perceived fatigue of the game.

The results of the study could not reject the null hypothesis. Gesture intensity does not have a significant relationship to perceived enjoyment and perceived fatigue. This result means that future studies can alter the gesture intensity of the game *Burnie* without adversely affecting the player's enjoyment and fatigue levels.
CHAPTER 1. INTRODUCTION

1.1 Background

An exergame is a video game that also functions as exercise using technology to track body movement and actions. Physical inactivity in children is becoming a serious health issue in the public. Trials that study the effects of exergaming have shown that they can increase positive results related to health outcomes (Sinclair et al., 2007, p. 289). However, more research on the effectiveness of exergaming needs to be done.

Exergaming can be used in clinical setting to aid in rehabilitation. It can aid in the encouragement and completion of rehabilitation activities. However, more research could be done using games that are made specifically for rehabilitation (Sinclair et al., 2007, p. 294).

*Burnie* is an exergame being developed at Purdue University and is used in this study. *Burnie* was developed using the Unity3D engine and OpenNI to interface with the Xbox Kinect. I was the lead programmer and lead designer for the *Burnie* project. My responsibilities included the design and implementation of the game mechanics and control mechanisms.
1.2 **Significance**

This research directly aids the development of an exergame that has the potential to augment physical therapy for children with cerebral palsy. The results of this study can help forward the understanding of how the controls of this kinect-based exergame affect the perceived enjoyment and perceived fatigue of the user.

1.3 **Research Question**

Does the addition of gesture intensity within an exergame affect the perceived enjoyment and perceived fatigue of the exergame?

1.4 **Assumptions**

- All participants will be able to stand unassisted.
- All participants will be able to perform the requested gestures.
- All participants will be able to finish the game.
- All participants will answer the questionnaires truthfully.
- The software and hardware being used will function properly.
1.5 Limitations

Exergaming is used in many different environments, such as physical education and recreation. As a result, this research can only be analyzed in the context of exergaming as an additional piece of physical therapy sessions for children with cerebral palsy. The speeds of the gestures also pose a limitation. The speed at which a user performs a gesture has no effect on the movement of the game character.

1.6 Delimitations

All participants in this study will not possess motor impairments or other physical impairments. Gestures will be calibrated for each individual participant. The only tracking device being used in this study is an Xbox Kinect.

1.7 Definitions

- Exergame - A video game that also functions as exercise using technology to track body movement and actions (Sinclair, 2007).
- Gesture intensity – The number of gestures required to perform in order for the player to move from origin to the maximum bounds of the level.
- Perceived fatigue - The subject’s perceived fatigue after playing the game as indicated by the likert scale on the questionnaire.
• Perceived enjoyment - The subject’s perceived enjoyment after playing the game as indicated by the likert scale on the questionnaire.

• OpenNI – “Established in November 2010, the not-for-profit OpenNI consortium was formed to promote and standardize the compatibility and interoperability of Natural Interaction (NI), devices, applications and middleware. Today, OpenNI is the largest 3D sensing development framework and community. Its open source SDK is the recognized standard for developing computer vision middleware and 3D solutions….OpenNI provides developers with an open source platform enabling them to develop Natural Interaction middleware and applications for markets such as robotics, TV and gaming, computers, mobile devices, healthcare, industry, interactive displays, retail and many others via the OpenNI SDK…” (OpenNI, n.d.)

1.8 Summary

In this chapter, an introduction to the study was presented. The significance of the study and the research questions were presented. The assumptions, limitations, and delimitations were addressed, as well as the definitions of key terms.
CHAPTER 2. LITERATURE REVIEW

2.1 Exergaming

Exergaming describes videos games that also function as exercise activities. Exergaming originated in the 1980’s but did not gain prominence until the mid 2000’s (Sinclair et al., 2007, p. 289). The idea behind using exergaming is two fold. One, it helps encourage the user to perform physical activity while playing the game. Two, it helps to encourage the user to seek out physical activity outside of the game. With an increase in childhood obesity rising in technologically advanced countries, exergaming is being looked at more as a possible solution (Sinclair et al., 2007, p. 294). Exergaming benefits to follow the 9 step “flow” model created by Mihaly Csikszentmihalyi in 1975:

1. A balance between skills and challenge,
2. Combining action and awareness,
3. Clear goals,
4. Unambiguous feedback,
5. Concentration and focusing,
6. A sense of control over the situation or activity,
7. A loss of feeling of self-consciousness,
8. A transformation of the user’s experience of time (immersion), and
The “flow” characteristics help maintain the attention of the game player, and the model has successfully been applied to activities other than video games, such as sports and education. The level of intensity needed to engage the player in an exergame depends on the player’s physical abilities (Sinclair et al., 2007, p. 289).

2.2 Cerebral Palsy

Cerebral Palsy is a set of non-progressive disorders than can affect many parts of the human body, including movement, senses, and brain functions. In order to classify motor functions, cerebral palsy researchers have developed the Gross Motor Function Classification System (GMFCS). This system divides the amount of activity they perform into incremental amounts:

- Low Activity – Fewer than 15 steps per minute
- Moderate Activity – Between 15 and 42 steps per minute
- High Activity – Greater than 42 steps per minute

In addition, they classify persons with cerebral palsy (CP) into three categories (I, II, III), where I represents someone with mild CP and III represents someone with severe CP. Persons with Category III CP engage in high levels of activity for approximately 37 minutes per day (Belza et al., 2007).

It has been shown that short monitoring periods are necessary to accurately gauge the number of steps taken by children with cerebral palsy. In one study, Ishikawa (2013, p. 136) states:
“Though caution may be warranted, because potential confounders of PA (physical therapy) are yet to be fully identified, a shorter monitoring period is necessary to reliably estimate the ambulatory activity level of participants with more functional limitations compared with less functionally challenged youth with CP ages 2 to 14 years.”

Physical exercise is beneficial for people with cerebral palsy. It can help alleviate pain, prevent the progression of impairment, and helps to maintain overall fitness (Damiano et al., 2006). Exergames have been shown to help with cerebral palsy rehabilitation. However, more research needs to be done using exergames that are made specifically for therapy relevant to cerebral palsy (Borbely et al., 2008).

2.3 Kinect

The Xbox Kinect is a motion-sensing input device. The device allows the user to control software through the use of gestures and voice commands (E3, n.d.). The device has a 43 degree vertical field of view and a 57 degree horizontal field of view. In addition the device has a tilt range of 27 degrees in either direction, allowing the user to easily adjust the device without needing to move it to a new location. The device has a frame rate of 30 frames per second. The device’s microphone can record audio at 16-kHz and 24-bits using mono pulse code modulation (PCM). The device comes with built in echo cancellation and noise suppression using a four-microphone array. Finally, the Kinect has an accelerometer that has an accuracy of one degree.
One limitation the Kinect device does have is a frame rate dependent depth stream. The resolution of the depth stream will become lower with a lower frame rate (Microsoft MSDN, n.d.).

2.4 OpenNI

The OpenNI Programmer’s Guide defines OpenNI as the following (OpenNI, n.d.):

“The OpenNI 2.0 API provides access to OpenNI-Compliant depth sensors. It allows an application to initialize a sensor and receive depth, RGB, and IR video streams from the device. It provides a single unified interface to sensors and .ONI recordings created with depth sensors.

OpenNI also provides a uniform interface that third party middleware developers can use to interact with depth sensors. Applications are then able to make use of the third party middleware, as well as underlying basic depth and video data provided directly by OpenNI. “

The OpenNI framework is released under the Apache License, meaning that the source code is free to obtain and use.
2.5  **Gestures**

Research has been done with gesture recognition using motion-sensing devices. Wang et al. (2008, p. 993-996) discussed a depth analysis tracking system he developed.

“Natural ways of input, especially body gesture-based input, not only simplify the interaction between a computer and a human, but also greatly enhance the entertainment experience for emerging gaming systems…Gesture recognition based on stereo depth video is still an active area of research, despite the substantial body of work addressing the issue of understanding human gestures leveraging computer vision and pattern recognition techniques…The proposed system is validated through gesture data for a boxing game. Experimental results indicate that our system performs very well and yields excellent precision. The potential usage of the proposed method on gaming applications and generic human computer interaction is very promising.”

Even with accurate gesture recognition, detecting gestures from non-gestures can be difficult. Kang et al. (2004, p. 1701-1702) states:

“Since unintentional movements can be mixed with gestures in an input image sequence, continuous gesture recognition is very difficult and gesture spotting is essential. Especially, if gesture spotting is supported in
a vision-based interface for video games, natural and intuitive
gesticulations is enabled so that a user can enjoy the game without any
restrictions (p. 1701)."

“Gesture spotting suffers from various difficulties. One of difficulties in
gesture spotting is gesture confusion…gesture confusion is caused by
overlapped movements or similar movement (p. 1702).”

Designing gestures that are significantly different from each other can help create a less confusing gesture system when designing a game with a motion-based controller.

2.6 Previous Games

Previous games have been developed for therapy and rehabilitation. One such game was developed at the University of Ulster. This augmented reality game was designed to aid people with upper-limb stroke rehabilitation (Burke J.W. et al., 2010). In it, they discuss meaningful play, describing how a game should react to a player's actions. Burke et al. (2010, p. 75-76) states:

“A good game should provide clear, consistent and meaningful feedback in response to the player's actions. Feedback can be communicated aurally (sound effects, speech), visually (ability to see arm/hand in the game, numerical scores, progress bars) and through haptic technology (vibration). Meaningful play is important to rehabilitation as it is crucial that a person
with stroke playing the game is aware of their goals, what actions they need to take to achieve those goals and whether or not they are achieving those goals (both short-term and long-term) in order for them to engage effectively with the rehabilitation game."

Additionally, Burke addresses failure within gameplay. Having positive feedback for failure is important in games designed for therapy. Burke et al. (2010, p. 76) states:

“Handling failure in a positive way by encouraging and rewarding all engagement with the game will make it more likely that players will not feel discouraged should they not perform as well as they had hoped.”

Commercial motion-based games have also been shown to help in therapy. One study looked at the addition of Wii Sports to the physical therapy administered to elderly patients. Bateni et al. (2012, p. 216) states:

“The results suggest that although Wii Fit training alone did improve balance, physical therapy exercise or a combination of physical therapy exercise and Wii Fit training had a greater benefit. Although Wii Fit training only offered limited improvement in balance, it may be useful for older adults who have no access to physical therapy. Larger studies using complete randomization are required to determine if significant changes in balance result from use of the Wii Fit gaming system.”
Some research has also been done on commercial games used specifically for cerebral palsy. In this study, Deutsch et al. (2008, p. 1204) states:

“A low-cost, commercial gaming system was trial tested in an adolescent with CP (cerebral palsy). He participated in 11 training sessions to augment his existing rehabilitation program, 2 of which included other players. The feasibility of using the system in a school-based setting during the summer session was supported. Improvements in postural control, visual-perceptual processing, and functional mobility were measured after training. To our knowledge, this is first published report on using the Wii to augment therapy for a person with CP.”

2.7 Physical Therapy

The effectiveness of physical therapy is largely dependent on the morbidity of the ailment on the individual. One study conducted on the effectiveness of physical therapy treatment on cerebral palsy stated the following (Anttila H. et al., 2008, p. 141):

“Types of cerebral palsy, physiotherapy interventions and outcome measures all varied so much that comparisons between studies are largely invalid.”
Because cerebral palsy varies so greatly, it is hard to build an exercise pattern that fits the needs of all individuals. Having exercises (and in this study’s instance – gesture recognition and game controls) that adapt to the user is of the utmost importance. J. Larry Durstine discusses this in detail. Durstine et al. (2000, p. 218) state:

“Because there are few specific exercise guide-lines for individuals with many chronic diseases and disabilities, innovative exercise research studies that develop and evaluate programs for accessibility, safety and effectiveness are needed. These types of studies will enable the exercise professional to develop an exercise program that is individually tailored to meet each patient's need.”

Another study has shown that physical activity and motion needs to become part of an individual’s life style if they suffer from cerebral palsy. This discussion began at a conference in 2005. Damiano et al. (2005, p. 1539) states:

“As movement scientists, therapists who treat people with CP need to optimize their limited therapy time by eliminating those approaches or treatment components that have only marginal positive effects and replace them with evidence-based exercise protocols shown to be more effective in improving current, and potentially future, functioning. In addition, we need to identify more ways to help their patients incorporate “activity, activity, activity” into their lifestyles.”
2.8 Summary

This literature review examined the history of exergaming and how it is related to cerebral palsy and physical therapy. Exergaming is a valid way of pursuing innovative means of administering physical therapy to individuals with cerebral palsy. It is also a useful tool when health professionals try to include physical therapy as part of a lifestyle for people with cerebral palsy. Past studies have shown that exergames can effectively aid physical therapy. In addition, the technology behind this game was addressed in this section. OpenNI and the Kinect are great tools that allow researchers to great accurate motion-based games.
CHAPTER 3. METHODOLOGY

3.1 Introduction

This chapter will discuss the design of the game, and the experimental design that is used with said game. Additionally, the statistical analysis and subject pool will be discussed in detail.

3.2 The Game

*Burnie* is a game currently in development at Purdue University. In the game, the player takes control of the player character Burnie – a phoenix. The player navigates the game world and tries to collect as many items and in-game power-ups as possible during gameplay.
Figure 3.1: A picture of a mountain pass in *Burnie*

Figure 3.2: A picture of a frozen lake within *Burnie*
3.2.1 Gestures

Four different gestures are used to control Burnie. Performing one of these gestures signals Burnie to move in a given direction.

- Dive: Moves the player down.
- Flap: Moves the player up.
- Right: Moves the player right.
- Left: Moves the player left.

The following pictures illustrate the controls:
Figure 3.4: Dive Position

Figure 3.5: Flap Position
Figure 3.6: Right Position

Figure 3.7: Left Position
3.2.2 Gesture Calibration

The gestures in *Burnie* are calibrated to each individual that plays the game. Calibration is done before the game begins. The user poses for each position and a "snap shot" of their current position is taken. The position of their shoulders and elbows are used for calibration. These positions are saved as Euler angles (in degrees) relative to a parent object within the game. The following figure demonstrates what is recorded:

![Figure 3.8](image)

Figure 3.8: This figure shows the joints recorded for calibration within *Burnie*. The x, y, and z values for the joints are Euler angles relative to the blue node located in the center of the player. Figure 9 explains this concept in more detail.
3.3 Experimental Design

The independent variable in this study was gesture intensity. Test subjects were divided into Group A and Group B. Group A played through the game with a gesture intensity of 2. Group B played through the game with a gesture intensity of 1. For more information on gesture intensity, please see its definition in Chapter 1 and section 3.3.1 of this chapter.
A pre-game and post-game questionnaire was developed for this study. Each participant would fill out the pre-game questionnaire before gameplay, and would fill out the post-game questionnaire immediately following the end of gameplay.

3.3.1 Gesture Intensity

Gesture intensity is defined as the number of gestures required to perform in order for the player to move from origin to the maximum bounds of the level. The following figures visually demonstrate gesture intensity for each group:

Figure 3.10: Group A, Gesture Intensity of 2
3.4 Procedure

The procedure for each test subject was administered as follows:

- The subject was given presented with a verbal consent or parental assent form.
- Following consent/assent, the subject filled out a pre-game questionnaire.
- The game calibration game next. The participant posed for each gesture while the game recorded their poses.
- The game was played with a given gesture intensity, depending on their corresponding group assignment.
• Immediately following the end of gameplay, the participant filled out a post-game questionnaire.

• The participant was thanked for their participation and informed that they had successfully completed the study.

3.5 Hypothesis

Ho(1) = The addition of gesture intensity does not affect the perceived enjoyment of the exergame.

Ho(2) = The addition of gesture intensity does not affect the perceived fatigue of the exergame.

Ha(1) = The addition of gesture intensity does affect the perceived enjoyment of the exergame.

Ha(2) = The addition of gesture intensity does affect the perceived fatigue of the exergame.

Independent Variable: Gesture Intensity

Dependent Variables: Perceived enjoyment/fatigue
3.6 Participants

Participants were recruited randomly through departmental e-mails and flyers. Participants could be adults or minors with parental assent. Candidates would be healthy individuals who do not suffer from motor impairments. Candidates would also be required to perform the required gestures without impairment.

3.7 Analysis

Primary analysis of the data would be done using Independent Two Sample T-Tests with unequal variance. Unequal variance will be assumed for two reasons:

- There is no guarantee that both subject pools will be equally sized.
- Subject pools are composed of different individuals.

T-Tests will be performed on all questions asked on the post-game questionnaire. When analyzing perceived enjoyment and perceived fatigue, one-way analysis of variance tests will be performed in order to confirm the results of the t-tests. Additional t-tests will be performed on pre-game questionnaire questions and the number of gestures each participant performs.

3.8 Summary

In this chapter, the methodology of the study was covered. The game and the calibration steps were covered in detail. The hypothesis, subject pool, and analysis of data were all presented and explained.
CHAPTER 4. RESULTS

4.1 Participants

A total of 21 individuals participated in this study. Their ages ranged from 6 to 34 years old. There were 15 male and 6 female test subjects. Group A had 11 individuals while Group B had 10 individuals.

4.2 Gestures

Table 4.2.1: Gesture Data, Group A.

<table>
<thead>
<tr>
<th>User ID</th>
<th>Number of Gestures Performed</th>
<th>Gestures Per Minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>17316_747</td>
<td>71</td>
<td>11.83</td>
</tr>
<tr>
<td>174739_356</td>
<td>34</td>
<td>5.67</td>
</tr>
<tr>
<td>18236_521</td>
<td>131</td>
<td>21.83</td>
</tr>
<tr>
<td>161518_315</td>
<td>335</td>
<td>55.83</td>
</tr>
<tr>
<td>174538_687</td>
<td>431</td>
<td>71.83</td>
</tr>
<tr>
<td>145516_262</td>
<td>617</td>
<td>102.83</td>
</tr>
<tr>
<td>151323_562</td>
<td>224</td>
<td>37.33</td>
</tr>
<tr>
<td>153420_334</td>
<td>468</td>
<td>78.00</td>
</tr>
<tr>
<td>171028_048</td>
<td>12</td>
<td>2.00</td>
</tr>
</tbody>
</table>
Table 4.2.2: Gesture Data, Group B.

<table>
<thead>
<tr>
<th>User ID</th>
<th>Number of Gestures Performed</th>
<th>Gestures Per Minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>173831_502</td>
<td>250</td>
<td>41.67</td>
</tr>
<tr>
<td>175516_060</td>
<td>134</td>
<td>22.33</td>
</tr>
</tbody>
</table>
Group A performed an average of 246 gestures during the course of the game, with an average of approximately 41 gestures per minute. Group B performed an average of 405 gestures during gameplay, while performing approximate 67 gestures per minute. When an independent two sample t-test (unequal variance) was performed on the number of performed gestures in each group, a p value of 0.10 was returned. Though not significant when using a critical p value of 0.05, it remains notable and something for future studies with larger subject pools to consider.

4.3 Pre-Test

The following data shows averages for both test groups for the pre-game questionnaire:

- “Do you own an Xbox Kinect?”
  - Only one test subject owned an Xbox Kinect.

- “How familiar are you with the Xbox Kinect? (1: not at all, 10: very)”
  - Group A: 5.8
  - Group B: 4.3

- “How often do you play video games? (1: never, 10: frequently)”
  - Group A: 7.1
  - Group B: 6.1

- “How often do you perform cardiovascular exercise? (1: never, 10: frequently)”
29

- Group A: 6
- Group B: 5.5

- “How often do you perform weight-based exercise? (1: never, 10: frequently)”
  - Group A: 4.8
  - Group B: 4.2

When an independent two sample t-test was performed on the pre-test results compared to the number of performed gestures, two results returns significant values:

- “How familiar are you with the Xbox Kinect?”
  - P value: 2.31 x 10^-5

- “How often do you play video games?”
  - P value: 2.44 x 10^-5

There is a significant relationship between familiarity with the Xbox Kinect and the number of gestures performed. In addition, there is also a significant relationship between how often each subject played video games and the number of gestures they performed. Gesture intensity did not have a significant relationship with any of the pre-game questions.

4.4 Post-Test

The following data shows averages for both test groups for the post-game questionnaire:

- “How would you rank your overall enjoyment while playing the game? (1: low, 10: high)”
• “How aesthetically pleasing did you find the graphics within the game? (1: low, 10: high)”
  o Group A: 8
  o Group B: 7.3

• “By how much did the graphics positively affect your enjoyment of the game (1: not at all, 10: very)”
  o Group A: 7.6
  o Group B: 7.2

• “How pleasing did you find the game controls? (1: not at all, 10: very)”
  o Group A: 4.7
  o Group B: 6.1

• “By how much did the game controls positively affect your enjoyment of the game? (1: not at all, 10: very)”
  o Group A: 5.2
  o Group B: 6.3

• “How fatigued did your arms feel after playing this game? (1: not at all, 10: very)”
  o Group A: 5.6
- Group B: 5.6

- “How fatigued did your legs feel after playing this game? (1: not at all, 10: very)”
  - Group A: 1.5
  - Group B: 1.8

- “Did your fatigue have any effect negative effect on your enjoyment of the game? (1: not at all, 10: very)”
  - Group A: 2.9
  - Group B: 2.4

4.5 Perceived Enjoyment

When an independent two sample t-test was conducted on the perceived enjoyment of the subject pools, it returned a p value of 0.056. This is not significant assuming a p value <= 0.05. To confirm that this value is accurate and that a Type II Error is not being committed, an analysis of variance was performed on these same values. A critical F value of 4.381 or greater was required. The one way analysis of variance test returned an F value of 2.714. Therefore, the relationship between perceived enjoyment and gesture intensity was not statistically significant.
4.6 Perceived Fatigue

When an independent two sample t-test was conducted on the perceived arm fatigue of the subject pools, a p value of 0.48 was returned. This is statistically significant assuming p <= 0.05. A matching two sample t-test was performed with leg fatigue and returned a p value of 0.29. This is also not statistically significant.

When one way analysis of variance tests were performed with these values, they returned F values of 0.001 (arm fatigue) and 0.317 (leg fatigue). These do not meet or exceed the critical F value of 4.381. There was not a statistically significant relationship between both arm or leg fatigue and gesture intensity.

4.7 Other Data

An independent two sample t-test was performed using perceived arm fatigue and perceived enjoyment. The result returned a p value of 0.068. Though not statistically significant assuming p <= 0.05, it is a notable find that may be useful in future studies.

Additional data was recorded from within the game. The following equation is what was recorded each time the player performed a gesture successfully:

- \( N = (|x_1 - x_2|, |y_1 - y_2|, |z_1 - z_2|) \) where,
  - \( N \) = The difference between gesture recorded and the model gesture saved during the calibration step (both in Euler angles in degrees). This data was saved as a 3-dimensional vector where \( N = (x,y,z) \).
  - \((x_1,y_1,z_1)\) = Euler angles of the model gesture saved during calibration
(x2,y2,z2) = Euler angles of the gestured recorded during gameplay

Analysis of this data returned interesting results of potential problem gestures (gestures that did not respond well for certain users following the calibration step). For example, subject 194120_654 had much trouble performing the left turn gesture. When analyzing at the calibrated pose for the subject’s left turn, the x value for the right shoulder’s Euler angle was calibrated at 5.4 degrees. Other users who had success performing left turns had values for that same x value somewhere between 300 and 320 degrees. Similarly, subject 143613_412 had trouble performing the flap gesture. This subject’s y values for both the left shoulder and left elbow were 146.3 and 127.8 degrees respectively. An average user had a value for this gesture between 5 and 30 degrees.

4.8 Conclusions

In this study, the null hypotheses could not be rejected:

- Ho(1) = The addition of gesture intensity does not affect the perceived enjoyment of the exergame.
- Ho(2) = The addition of gesture intensity does not affect the perceived fatigue of the exergame.

Gesture intensity did not have a significant relationship with perceived enjoyment and perceived fatigue. This information means the gesture intensity of the game can be altered without affecting the player’s enjoyment and fatigue.
levels. This is important to future studies looking to conduct research with children who suffer from cerebral palsy. The researcher and physical therapy professional can alter the gesture intensity according to each participant’s needs, without a potential of compromising their gameplay experience.

4.9 Challenges

This study pushed the potential of the Xbox Kinect. The device was prone to suffer from heating issues and failure as a result of said heat. The infrared sensor on the Kinect camera is vulnerable to the sun, and does not function at all under direct and ambient indirect sunlight. The color and shape of subject clothes presented obstacles to the Kinect sensor and its calibration technique. Additionally, stationary objects in the study room could sometimes interfere with the calibration of the test subject. The frame rate dependent depth resolution of the Kinect device demanded optimization of the game, as low frame rates could make it unresponsive to the user. While the study had a significant number of test subjects, it could have benefited from even more participants.
4.10 Future Work

Looking to the future, there are a number of studies that could be done related to exergaming as an addition to physical therapy and *Burnie* specifically. *Burnie* and this study currently utilized a discrete gesture system. Using a continuous gesture recognition system could befit this project in the future. While this study utilized OpenNI drivers for the Kinect device, there are a few competing options. Zigfu is a new, but leading creator of gaming drivers for Kinect development. Additionally, Microsoft has an SDK for the Kinect that works well with Xbox 360 deployments of software.

Future studies could also look into the optimal range of Euler angle values during the calibration step. Identifying when a user lies outside of an optimal range may benefit the ongoing development of this discrete gesture recognition system. Additional optimization could be done within the game world. Procedural loading techniques could serve to increase the frame rate of the *Burnie* game, and therefore, the responsiveness of the Kinect device.
BIBLIOGRAPHY


doi:10.1016/j.apmr.2012.07.027

doi:10.1016/j.patrec.2004.06.016


http://www.openni.org/openni-programmers-guide/


APPENDICES
Appendix A  Pre-Game Questionnaire

Pre-Game Questionnaire

ID Number:_________________

Age:_________________

Gender:_________________

Do you own an Xbox Kinect?  Y  |  N

How familiar are you with the Xbox Kinect?  (1: not at all, 10: very)
1  2  3  4  5  6  7  8  9  10

How often do you play video games?  (1: never, 10: frequently)
1  2  3  4  5  6  7  8  9  10

How often do you perform cardiovascular exercise?  (1: never, 10: frequently)
1  2  3  4  5  6  7  8  9  10

How often do you perform weight-based exercise?  (1: never, 10: frequently)
1  2  3  4  5  6  7  8  9  10
Appendix B  Post-Game Questionnaire

Post-Game Questionnaire

ID Number:_________________

How would you rank your overall enjoyment while playing the game? (1: low, 10: high)
1  2  3  4  5  6  7  8  9  10

How aesthetically pleasing did you find the graphics within the game? (1: low, 10: high)
1  2  3  4  5  6  7  8  9  10

By how much did the graphics positively affect your enjoyment of the game (1: not at all, 10: very)
1  2  3  4  5  6  7  8  9  10

How pleasing did you find the game controls? (1: not at all, 10: very)
1  2  3  4  5  6  7  8  9  10
By how much did the game controls positively affect your enjoyment of the game?
(1: not at all, 10: very)
1 2 3 4 5 6 7 8 9 10

How fatigued did your arms feel after playing this game? (1: not at all, 10: very)
1 2 3 4 5 6 7 8 9 10

How fatigued did your legs feel after playing this game? (1: not at all, 10: very)
1 2 3 4 5 6 7 8 9 10

Did your fatigue have any effect negatively on your enjoyment of the game?
(1: not at all, 10: very)
1 2 3 4 5 6 7 8 9 10

What, if any, parts of the game did you find particularly interesting and/or exciting?

What, if any, parts of the game would you like to see improved or change
Appendix C Participant Consent Form

RESEARCH PARTICIPANT CONSENT FORM

Pilot Study of a Kinect-based Video Game to Improve Physical Therapy Treatment at Purdue Spring Fest 2013

David Whittinghill

Purdue University

College of Technology

Purpose of Research - The study is focused on determining if subjects are entertained by the game and identifying what aspects of the game have the greatest impact upon the good or bad parts of the gameplay.

SPECIFIC PROCEDURES

- You will be asked to fill a Pre-Test questionnaire.
- You will stand or sit in front of a monitor hooked up to a computer and a Microsoft Kinect device. The Kinect is a camera that tracks your body’s movement.
- A QSensor device will be attached to your wrist. This wireless device is about the size of a watch and measures physiological response, such as stress and excitement.
- You will then receive verbal or written instruction on how to play the game or play through a tutorial level telling you how to play the game.
- You will then play through the first level of the motion based video game.
- While playing, the video game will determine how accurate your gestures are to the correct gesture.
- After completion of the first level you will be asked to fill out a Post-Game questionnaire.
DURATION OF PARTICIPATION
The experiment will take 10 to 20 minutes to complete.

RISKS
- The risks are minimal, but you may see these types.
  - Falls. There is a risk of the volunteer falling while playing the game.
  - Fatigue. This risk will be limited by restricting the time volunteers play the game.
  - Failure. This risk is reduced by the game design. No participant can ever "lose" the game. They can only receive a greater or lesser number of points.
  - The risks do not exceed the risks individuals face in daily life.
- In event of a research-related injury, please contact Dr. Whittinghill.

BENEFITS
- There are no expected direct benefits for you beyond the expected satisfaction of playing a video game.
- Society may benefit from this research in that it will further our understanding of how effective motion based video games can help children with impaired motor functions.

Initials _______________ Date _______________

Compensation

There will be no monetary compensation for participation in this study.

CONFIDENTIALITY
THE PROJECT’S RESEARCH RECORDS MAY BE REVIEWED BY DEPARTMENTS AT PURDUE UNIVERSITY RESPONSIBLE FOR REGULATORY AND RESEARCH OVERSIGHT. YOUR INFORMATION WILL BE ALTERED AND MADE PRIVATE WHEN USED FOR THE STUDY. THERE IS A RISK OF BREACH OF CONFIDENTIALITY. SAFEGUARDS ARE IN PLACE TO ENSURE THIS DOES NOT HAPPEN. IF YOU ARE REFERRED SPECIFICALLY IN THE RESULTS OF THE STUDY AN ID NUMBER WILL BE USED INSTEAD OF ANY OF YOUR PERSONAL
INFORMATION. THE KEY CODE RELATING TO IDENTIFY YOUR ID NUMBER WILL NOT BE DESTROYED. THE DATA WILL BE STORED IN A LOCKED CONTAINER AND THE VIDEO DATA WILL BE STORED WITH SECURELY IN THE PURDUE UNIVERSITY RESEARCH REPOSITORY SERVERS. ONLY THE INDIVIDUALS INVOLVED WITH THE RESEARCH AND THEIR SPONSORS WILL SEE THE ANY OF THE DATA. ANY VIDEO DATA CONTAINING IDENTIFIABLE FEATURES SUCH AS YOUR FACE WILL NOT BE USED IN THE PUBLICATION. DATA RELATED TO THIS PROJECT WILL BE STORED INDEFINITELY. ST. VINCENT’S FOUNDATION MAY ALSO REVIEW THIS PROJECT’S RESEARCH RECORDS.

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 David Whittinghill, Ph.d, Assistant Professor, Computer Graphics Technology, KNOY 333, Phone: 765-494-1353, Email: dmwhittinghill@purdue.edu. 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

__________________________________________     ________________________
Researcher’s Signature                                                        Date
Appendix D Parental Consent Form

RESEARCH PARENTAL CONSENT FORM

Pilot Study of a Kinect-based Video Game to Improve Physical Therapy Treatment at Purdue Spring Fest 2013

David Whittinghill
Purdue University
College of Technology

Purpose of Research - The study is focused on determining if subjects are entertained by the game and identifying what aspects of the game have the greatest impact upon the good or bad parts of the gameplay.

SPECIFIC PROCEDURES

- Your child will be asked to fill a Pre-Test questionnaire.
- Your child will stand or sit in front of a monitor hooked up to a computer and a Microsoft Kinect device. The Kinect is a camera that tracks your child's body's movement.
- A QSensor device will be attached to your child's wrist. This wireless device is about the size of a watch and measures physiological response, such as stress and excitement.
- Your child will then receive verbal or written instruction on how to play the game or play through a tutorial level telling your child how to play the game.
• Your child will then play through the first level of the motion based video game.
• While playing, the video game will determine how accurate your child's gestures are to the correct gesture.
• After completion of the first level your child will be asked to fill out a Post-Game questionnaire.

DURATION OF PARTICIPATION
The experiment will take 10 to 20 minutes to complete.

RISKS
• The risks are minimal, but your child may see these types.
  o Falls. There is a risk of the volunteer falling while playing the game.
  o Fatigue. This risk will be limited by restricting the time volunteers play the game.
  o Failure. This risk is reduced by the game design. No participant can ever “lose” the game. They can only receive a greater or lesser number of points.
  o The risks do not exceed the risks individuals face in daily life.
• In event of a research-related injury, please contact Dr. Whittinghill.

BENEFITS
• There are no expected direct benefits for your child beyond the expected satisfaction of playing a video game.
• Society may benefit from this research in that it will further our understanding of how effective motion based video games can help children with impaired motor functions.

Initials _______________ Date _______________

Compensation
There will be no monetary compensation for participation in this study.
CONFIDENTIALITY
THE PROJECT’S RESEARCH RECORDS MAY BE REVIEWED BY DEPARTMENTS AT PURDUE UNIVERSITY RESPONSIBLE FOR REGULATORY AND RESEARCH OVERSIGHT. YOUR CHILD’S INFORMATION WILL BE ALTERED AND MADE PRIVATE WHEN USED FOR THE STUDY. THERE IS A RISK OF BREACH OF CONFIDENTIALITY. SAFEGUARDS ARE IN PLACE TO ENSURE THIS DOES NOT HAPPEN. IF YOUR CHILD IS REFERRED TO SPECIFICALLY IN THE RESULTS OF THE STUDY AN ID NUMBER WILL BE USED INSTEAD OF ANY OF YOUR CHILD’S PERSONAL INFORMATION. THE KEY CODE RELATING TO IDENTIFY YOUR CHILD’S ID NUMBER WILL NOT BE DESTROYED. THE DATA WILL BE STORED IN A LOCKED CONTAINER AND THE VIDEO DATA WILL BE STORED WITH SECURELY IN THE PURDUE UNIVERSITY RESEARCH REPOSITORY SERVERS. ONLY THE INDIVIDUALS INVOLVED WITH THE RESEARCH AND THEIR SPONSORS WILL SEE ANY OF THE DATA. ANY VIDEO DATA CONTAINING IDENTIFIABLE FEATURES SUCH AS YOUR CHILD’S FACE WILL NOT BE USED IN THE PUBLICATION. DATA RELATED TO THIS PROJECT WILL BE STORED INDEFINITELY. ST. VINCENT’S FOUNDATION MAY ALSO REVIEW THIS PROJECT’S RESEARCH RECORDS.

VOLUNTARY NATURE OF PARTICIPATION
Your child do not have to participate in this research project. If your child agrees to participate your child can withdraw from participation at any time without penalty.

Contact Information:
If you or your child have any questions about this research project, you can contact David Whittinghill, Ph.d, Assistant Professor, Computer Graphics Technology, KNOY 333, Phone: 765-494-1353, Email: dmwhittinghill@purdue.edu. If you have concerns about the treatment of research participants, you can contact the Institutional Review Board at Purdue University, Ernest C. Your childing 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 allow my child to participate in the research project described above. I will receive a copy of this consent form after I sign it.

________________________________________
Participant’s Signature

________________________________________
Participant’s Name

________________________________________
Researcher’s Signature

________________________________________
Date
Appendix E Assent Form

Assent Form

Project Title: Pilot Study of a Kinect-based Video Game to Improve Physical Therapy Treatment  
Investigator(s): Dr. David Whittinghill, Jacob Brown

We are doing a research study. A research study is a special way to find out about something. We want to find out if you have fun playing the game. We also want to find out what are the good and bad parts of the game.

You can be in this study if you want to. If you want to be in this study, you will be asked to play a video game for about 5 minutes using the Microsoft Kinect. You will also be given a short test before and after playing the game. You can fill them out if you want to.

We want to tell you about some things that might happen to you if you are in this study. The Microsoft Kinect may cause you to get tired. There is a chance you may stumble while playing the game. You can stop playing whenever you want.

If you decide to be in this study, some good things might happen. You will be helping kids that have trouble moving their arms and legs. But we don’t know for sure that these things will happen. We might also find out things that will help other children some day.

When we are done with the study, we will write a report about what we found out. We won’t use your name in the report.

You don’t have to be in this study. You can say “no” and nothing bad will happen. If you say “yes” now, but you want to stop later, that’s okay too. No one will hurt you, or punish you if you want to stop. All you have to do is tell us you want to stop.