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A Physiological Feedback Controlled Exercise Video Game

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A Physiological Feedback Controlled Exercise Video Game

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "**A Physiological Feedback Controlled Exercise Video Game**" submitted by Graham Baradoy in partial fulfilment of the requirements of the degree of Masters of Science.

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0 Abstract

Purpose: This thesis presents a proof-of-concept for the use of physiological feedback in active video games to control the heart rate of players.

Rationale: Physiological feedback controls can be used to increase or decrease the physical demands of an active video game presented to the user. We introduce DanceBeat, a physiological feedback controlled active video game, designed with the intent to control players' heart rates.

Methods: A repeated measures crossover study was performed (n=23). Participants were exposed to two bouts of DanceBeat with target HRR zones corresponding to light and moderate intensity exercise.

Results: The Light level kept participants within target zone 87(18)% of the time whereas the Moderate level kept participants in the zone 76(21)% of the time. The 95% confidence interval for mean HRR for both levels fell within the respective target zones.

Significance: DanceBeat has the potential to be an entertaining and effective form of exercise.

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Contents

1 Introduction

1.1 Why?

While it is clear that a certain degree of exercise is essential to a long and healthy life, not everyone has a job that keeps them in shape, and there are many people who do not enjoy taking time from their day to get a decent workout. Indeed, some loathe the idea of using an exercise bike or going for a run. Some people listen to music while running, bringing an MP3 player along; some will arrange their exercise room so that their elliptical faces the television, and they can watch their favorite shows while burning a few hundred calories. Any of these can make exercise more palatable and thus increase the likelihood that the exercise program will be continued. However, it does not make exercise more enjoyable for those who don't enjoy it, but simply distracts them from what they see as a tedious necessity. Many dentists now have televisions over their chairs so that patients can watch Star Trek or the news while undergoing treatment – it amounts to the same thing.

It's a shame that exercise is seen as dull, because many of us do not get enough exercise. There has been an increase in physically inactive lifestyles in recent years (Booth, Gordon, Carlson, & Hamilton, 2004) which is a likely contributor to the observed increase in obesity and chronic disease. At the same time, media consumption has risen (Rideout, Foehr, & Roberts, 2010); individuals are increasingly playing more video games and watching more television. There is a steady trend away from physical activity and towards multimedia. This may be in part due to the fact that many jobs no longer have a physical component and involve fewer hours per day. This leaves us with more time to do things that we find interesting, and television's appeal is based on our desire to be entertained while sitting.

Without a doubt, the more individuals enjoy an activity, the more they will be willing to partake in it. If we can increase an individual's enjoyment of exercise, we can increase the willingness and thus, the frequency with which they exercise. The existence of some sports can be partially explained by this. A game of soccer can be more enjoyable than running on the spot. For those who aim to increase the amount that people exercise, they should consider attempting to make more enjoyable activities physically active. This is the motivation behind many exergames; combine the entertainment value of video games with physical activity to increase the amount the player exercises.

Setting up a video game in front of an exercise bike can increase the motivation to exercise (Warburton et al. 2007). This is the same concept as listening to music while jogging. Pair an activity with something enjoyable and there is a greater willingness to partake. But there are problems with just attaching a standard video game to an exercise bike. For starters, the player can enjoy that same video game or music without the physical activity. Further, the attention of the player is always split between the video game and the exercise. The ideal is to create a game that merges the physical activity and the gameplay so that focusing purely on playing the game will result in the desired amount of physical activity.

An exergame fails if it is not entertaining, or if it is not exercise. Although often referred to as exergames, most games in Wii Sports do not actually meet the criteria for them to be effective exercise (Graves, Ridgers, & Stratton, 2008). There are many supposed exergames out there that are not exercise or do not have a lasting entertainment value (Radon et al. 2011).

This thesis is about creating a game that is both exercise and entertainment. It is about creating a game that will cause the player to reach a target physiological response just by playing the game.

This thesis takes the approach of modifying a rhythm dance game, which already has high level of physical exertion (Graf, Pratt, Hester, & Short, 2009) and enjoyment, and adds a mechanic that controls the physiological responses of the player while playing the game.

1.2 Statement of Purpose

This thesis is to present the novel active video game DanceBeat and provides a proof of concept for a physiological feedback heart rate control mechanic for an active video game. DanceBeat is a rhythm dance game designed with the intent of controlling players' heart rates. A proof of concept study was performed using DanceBeat. Players were presented with two DanceBeat levels with different heart rate goals. The heart rates of participants were measured during gameplay. The effectiveness of DanceBeat's heart rate control mechanic is examined. Recommendations are presented for future versions of DanceBeat.

1.3 Chapter Roadmap

This chapter gives an introduction to DanceBeat and the motivations for its creation. The form of this thesis is laid out here.

The relevant literature is reviewed in chapter 2. Most of the literature reviewed is directly related to active video games. The chapter begins with a brief examination of the term "exergame" and discusses why the term active video game is preferred in this thesis. Player's preference for active video games is examined followed by a discussion of opinions that oppose active video games. Methods of measuring the physiological effects of playing active videos games and measurements of playing active video games are discussed. Other games that have a physiological control element are discussed as well as related heart rate control exergames. This leads to an examination to some novel and noteworthy exergame designs. The chapter is concluded with a discussion on what motivates players and what makes a balanced game.

The design of DanceBeat is examined in chapter 3. The relationship of DanceBeat's design to the concepts looked at in the literature review is discussed. The elements that make up a game are presented with their corresponding elements in DanceBeat. This is followed by a description of the specifics of DanceBeat's design and implementation. The tools used in creating DanceBeat and the terminology needed in a discussion of DanceBeat are given. The specific mechanics used in DanceBeat for balance and heart rate control are presented.

Chapter 4 is the methodology section. A study was performed to determine the effectiveness of DanceBeat and the specifics of the methodology for that study are outlined in this chapter. The limitations of the study are discussed followed by a summary of what statistical methods are used to analyze the results of the study.

The results of the study are presented in chapter 5. This chapter begins with an outline of what tools were used in analyzing the data and what variables were involved. Summary data is presented which describes how close players were to their target heart rate during play and how long they stayed in the target zone. Outliers are discussed and reasons for the removal of a participant from the results are given. The results of the analysis discussed in chapter 4 are presented.

In chapter 6, the results are broken down into three different profiles. The specific conditions for these profiles are discussed and graphs that are representative of each of the profiles are presented.

In chapter 7, the results are discussed. Various claims are made about DanceBeat's heart rate control mechanic. Factors that change the effectiveness of DanceBeat's heart rate mechanic are discussed. The results of this study are compared to the results of a different exergame that has a similar mechanic.

In chapter 8, the discussion on the strengths and shortcomings of DanceBeat takes place from the perspective of recommendations for a future edition of DanceBeat. The discussion and information from the results, profile analysis, and discussion chapter are combined to alter the design of DanceBeat and present a concrete new mechanic.

In chapter 9, the thesis is concluded with a review of the evidence and arguments presented.

1.4 Significance

The purpose of this research is to demonstrate that active video games can use physiological feedback to control players' exercise intensity.

DanceBeat uses StepMania's code as its base. As StepMania is released under the open source MIT license, DanceBeat will also be released under the MIT license. As such, DanceBeat will be freely available, modifiable, and extendable under the MIT license. If DanceBeat is successful in keeping participants' heart rates within desired ranges, then DanceBeat can be a fun and effective form of exercise that is freely available to the public.

1.5 Research Question

Can an enjoyable active video game use physiological feedback (heart rate) to keep youth and young adults within desired heart rate ranges?

2 Literature Review

2.1 Active Video Games

2.1.1 The Term Active Video Game

Oh and Yang (2010) provide a literature review examining the terminology of active video games. An active video game is a video game which contains an exertion component. Many terms are used to describe what is referred to here as active video games. Active video games are also referred to variously as exertainment, interactive video game, physical game and activity promoting video game. The term exergaming is the most commonly used in the literature. However, health related researchers use the term exergame less frequently.

The term exergame is a combination of exercise and video game. In this case, the term of exercise is used somewhat imprecisely. Exercise is a subset of physical activity, but specific conditions distinguish it. Exercise is doing physical activity “intentionally to improve or maintain physical fitness with a planned, repetitive, and structured format” (Oh & Yang, 2010). Active video games can be used for exercise, but that does not mean that playing an active video game is necessarily exercise. In some instances, we should be cautious which active video games we call exercise (Anders 2008).

Exergaming implies intent, repetition, and structure. Therefore, this thesis uses the term *active video game* in preference to *exergame*, but considers the terms equivalent when referencing other work.

Exergames are a subset of serious games. Serious games are those that are not intended primarily for amusement but have some additional external goal such as education. There is vast literature on serious games (Becker, 2008), but much of this literature focuses on the educational aspects of serious games. The literature reviewed here that covers the topic of serious games will focus on the narrower topic of exergames.

2.1.2 Video Games Audience

According to Williams, Yee, and Caplan (2008), 40% of American adults and 83% of teenagers are regular players of video games. The average age of players is 35 and has been increasing. Video games surpass television in terms of the time spent among some populations (Williams, Yee, and Caplan, 2008).

Rideout et al. (2010) report a rise in the average amount of time American youth spent with video games. The average time spent with video games rose from 26 minutes per day in 1999 to 73 minutes per day in 2009.

Video games have become a mainstream activity and a regular part of life. The video game industry reached $7.4 billion dollars in sales in 2006 and has only shown signs that the size of the industry and number of players will increase (Williams et al. 2008; Rideout et al. 2010). The Entertainment Software Association states that the number has increased to $24.75 billion for 2011[1].

2.1.3 Obesity

Obesity is on the rise in youth (Boot et al. 2004). The current rate of obesity in Canada is 26% for children aged 2-17 and 59% for adults[2]. Many factors contribute to obesity, but it is generally caused by unhealthy diet and lack of physical activity (Stubbs & Lee, 2004).

Marshall, Biddle, Gorely, Cameron, and Murdey (2004) caution that although there is a statistically significant relationship between television viewing and obesity, it is too small to be of much relevance. Time spent with television or video games may be cutting into time that would otherwise be used to be active or may go along with other unhealthy habits like snacking.

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[1] The Entertainment Software Association reports consumer spending of $24.75 billion on video games in 2011. http://www.theesa.com/facts/index.asp last accessed August 9, 2012.

[2] The Childhood Obesity Foundation reports obesity statistics. http://www.childhoodobesityfoundation.ca/statistics last accessed August 9, 2012.

2.2 Preference of Active Video Games

Player Preference

The large number of sales of the Nintendo *Wii* (Nintendo 2011) and *Dance Dance Revolution* (DDR) are evidence of the positive reception that active video games are receiving but are not proof of actual use.

Preference and relative reinforcing value (RRV) are a measure of a player's motivation to continue an activity. Preference and RRV is examined between active and sedentary video games (Penko & Barkley 2010). Twenty-four children, ages 8-12, presented with sedentary video games *Nintendo Punchout* and active video game *Wii Sports Boxing* reported on a visual analog scale liking the active video game (8.5±1.8) over the sedentary alternative (6.9±2.6) ($t(23) = 3.42$, $p < 0.002$). The RRV between the active video game and the sedentary video game was measured. Lean children demonstrated better RRV of the Wii boxing game over that of the sedentary video game ($t(10) = 5.02$, $p < 0.001$) whereas overweight children did not demonstrate a significant difference ($t(10) = 0.60$, $p > 0.50$). Unfortunately, the difference between *Punchout!* and *Boxing* is significant in that the two games have different mechanics. This introduces preferences for mechanics as a confounding factor.

It is suggested that DDR using a dance pad has a higher RRV than DDR without a dance pad for children ages 8-12 both overweight and otherwise (Epstein, Beecher, Graf, & Roemmich, 2007). Epstein et al. (2007) limits game preference as confounding factor by presenting subjects with an active video game identical to the sedentary video game in all but active controls. The physical activity of the participants was measured using an accelerometer. Although the study did not find that there was a change in preference for the active video game over the non-active video game from normal to overweight children, there was a difference in physical activity. The activity counts for the non-overweight children were 2.4 times that of the overweight children. Although overweight and non-overweight children both have a preference for active video games, this study does not tell us if this preference would be maintained for an active video game that had higher physiological demands.

Barkley and Penko (2009) also suggest that *Wii Sports Boxing* is preferred to treadmill walking and sedentary video games using a 10 cm visual analog scale ($p \leq 0.001$) (Barkley & Penko, 2009). However, the selected sample (31.5 ± 12.4 years old) is not generalizable to youth and young adults.

As participants for the above studies were recruited through flyers, newspaper advertisements, and previous contacts, these studies likely suffer from a strong self-referral selection bias towards preference for active video games. This is likely to have caused an overestimation in preference and puts the validity of the above studies into question. Despite strong suspicions that youth and young adults may be motivated to play active video games at least as much as the sedentary alternatives; the literature is not yet conclusive.

2.2.1 Opposition to Active Video Games

There is still a distinction considered between active video games and "real" exercise. Part of that may be due to some active video games not demanding large amounts of exertion. Ridgers, McKinney, Stratton, and Graves (2011) suggests that due to the difference in HR and energy expenditure, step-powered video gaming can be used as a supplement to physical activity, but should not be used as a replacement of activities such as jogging.

Criticism for active video games in part comes from the lack of energy required to play some of them. Wii Sports was marketed as a form of exercise[3] but the physiological requirements of playing Wii Sports may not have lived up to the hype. Graves et al. (2008) performed a study (n=11) comparing playing Wii Sports with playing sedentary video games for youth. Wii Sports, although better than sitting, results in

[3] When the Nintendo Wii and Wii Sports where launched, the author was employed by a company hired by Nintendo to promote the Wii and other products. The author was witness to the Nintendo and Wii Sports being marketed as an exercise tool, but will not disclose the official policy of Nintendo or his employer due to concerns over non-disclosure agreements.

physiological responses much less than their non-virtual counterparts (e.g., Wii Sports Tennis compared to a game of tennis, Wii Sports Boxing compared to boxing). Graves concludes that Wii Sports games are not of high enough intensity to contribute to the recommended amount of exercise in children. Although many active video games may come with the illusion of being appropriate for exercise not all of them may be suitable for the task.

Radon et al. (2011) suggests that initial interest in active video games will waver over time. In a study (n=77) of obese adolescents in a voluntary rehabilitation study, the median usage of active video games declined from 27 minutes in the first week to 0 minutes in the fourth week onwards. This may be indicative of an overall loss of interest in active video games over time, or it may be a result of a lack of diversity in games as some participants suggested, or a lack of interest in those particular games.

2.3 Physiology

This thesis does not focus on the mechanics of heart rate. It is sufficient for the purpose of this thesis to establish that there is a connection between the amount of work performed by an individual and that individual's heart rate. This section examines how other papers in the area have discussed heart rate and the measurements they have done and other attempts at using heart rate in active video games.

2.3.1 Measurements of Exercise

2.3.1.1 Metabolic Equivalent of Task

A metabolic equivalent of task (MET) is the ratio of work to a standard metabolic resting rate (Ainsworth et al. 2000). For example, 1 MET would be the metabolic rate of quiet sitting, 0.9 MET would be the metabolic rate of sleeping, and 18 MET would be the metabolic rate of running at 17.5 km/h.

Miyachi, Yamamoto, Ohkawara, and Tanaka (2010) performed a study with adults while playing active video games in a metabolic chamber. The METs of various games and activities were measured including

Wii Sports. Ainsworth et al. (2000) provide a compendium of physical activities and corresponding MET values. The American College of Sport Medicine (ACSM) also provides a list of METs associated with common physical activities (Thompson et al. 2010). A short list of relevant activities and associated METs compiled from Ainsworth et al. (2000), (Thompson et al. 2010), and Miyachi et al. (2010) are shown on *Table 1 – Physiological Measures for Various Activities*.

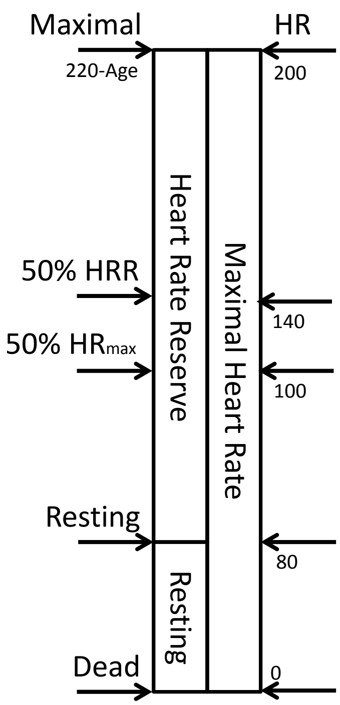
Table 1 – Physiological Measures for Various Activities

Activity	Measure
Riding a Bus[1]	1.0 MET
Walking Slowly[2]	2.0 MET
Wii Sports Golf[3]	2.0 MET
Mild Stretching[1]	2.5 MET
Wii Sports Bowling[3]	2.7 MET
Wii Sports Baseball[3]	3.0 MET
Wii Sports Tennis[3]	3.0 MET
Walking the Dog[1]	3.0 MET
Wii Sports Boxing[3]	4.2 MET
Dance Dance Revolution(step difficulty of 4)[4]	7.0 MET
Bicycling[1]	8.0 MET

1. Ainsworth et al. (2000) , 2. Thompson et al. (2010), 3. Miyachi et al. (2010), and 4. Tan et al. (2002).

Using a MET to prescribe a workout for exercise intensity can be difficult. Thompson et al. (2010) contains suggestions for using different MET levels to define exercise intensity based on a person's physical fitness. In order to prescribe specific physical activities as defined by the ACSM we would need to measure the fitness level beforehand. On the other hand, METs give us a good way to compare different physical activities.

Figure 1 – Heart Rate Reserve.



The left side shows the relationship of heart rate and heart rate reserve and the right side shows an example subject with a maximal heart rate of 200 and a resting heart rate of 80.

2.3.1.2 Heart Rate Reserve

Heart Rate reserve (HRR) is a term used to describe the range between a person's predicted maximum heart rate and resting heart rate (Swain & Leutholtz, 1997). Heart rate reserve is usually discussed in terms of a percentage. Fifty percent HRR would correspond to half way between a person's resting heart rate and maximal heart rate.

Percentage of maximal oxygen uptake ($VO_2max(\%)$) or percentage of oxygen uptake reserve ($VO_2R(\%)$) are often used to determine the intensity of exercise (Thompson et al. 2010). Measuring either

VO_2max(%) or VO_2R(%) requires a metabolic cart or other sophisticated tools, equipment that is cumbersome, relatively expensive and not easily accessible. On the other hand, a heart rate monitor can be purchased for less than $100, is less cumbersome, and a more accessible instrument than a metabolic cart. It has been shown that HRR is closely related to VO_2R(%) (Swain & Leutholtz, 1997; Dalleck & Kravitz, 2006) allowing us to effectively estimate VO_2R(%) with HRR(%). The ACSM also has recommendations for exercise intensity in the form of HHR(%).

When calculating the desired heart rate, the following is used:

Equation 1 – Target Heart Rate Calculation

Target Heart Rate = (Heart Rate Reserve × Percent Target Heart Rate Reserve) + Resting Heart Rate

2.3.1.3 Recommendations for Exercise

The ACSM provides exercise recommendations for healthy adults (ACMS 8th 2010). The quantity or volume of exercise is a function of the frequency, intensity and duration of the exercise performed. There is a dose-response relationship for the volume of exercise necessary for health/fitness benefits. The ACSM recommends moderate intensity exercise for at least 30 minutes 5 days a week, vigorous intensity exercise for at least 20 minutes 3 days a week, or some combination of moderate and vigorous intensity exercise 3 to 5 days a week.

The ACSM categorizes exercise intensity in terms of VO_2R(%), HRR(%), HR_{max} and METs. With their recommendations, the ACSM includes definitions for light intensity as 20-39 VO_2R(%) or 50-63 HR_{max}(%), for medium intensity as 40-59 VO_2R(%) or 64-76 HR_{max}(%), and for hard intensity as 60-84 VO_2R(%) or 77-93 HR_{max}(%) (Thompson et al. 2010). For exercise prescription purposes, the ACSM assumes that HRR(%) provides the same intensity as VO_2R(%).

As has been mentioned previously, at this stage, DanceBeat does not aspire to be exercise. Rather DanceBeat sets the groundwork for future iterations of the game to be an exercise tool. If the design of

DanceBeat can cause participants' heart rates to stay within zones prescribed by the ACSM through play, the next iteration of DanceBeat has less of a distance to go in becoming an exercise tool.

2.3.2 Prediction of Heart Rate Response

In general, a subject's heart rate will increase as exercise intensity increases. Heart rate response to an imposed exercise power closely follows a monotonic increasing, negative exponential function. The increase of heart rate is asymptotic to some maximum value and the rate of heart rate increase diminishes as it approaches this maximum value. However, heart rate increases nearly linearly with submaximal work (Bowyer, Thomas, & Bowyer, 1993). As DanceBeat is not concerned with anything but submaximal work, heart rate increase can be considered to be near linear.

In terms of DanceBeat, it would be ideal to have a simple equation that would define the exact DanceBeat difficulty level needed for a player to meet a target heart rate. Unfortunately, there are a few factors that prevent this. Pasch, Berthouze, Dijk, and Nijholt (2008) report that different styles of playing Wii Sports Boxing can lead to different energy expenditure while playing. It would follow that different styles of play for DanceBeat would lead to different heart rates. Physiological responses to an amount of work are different amongst individuals, but can also change within an individual as a response to training (Krzemiński, Nazar, Cybulski, & Niewiadomski, 1991). Further, for longer play sessions, given the same work rate, heart rate will begin to slowly drift upwards (Sinclair 2011). Thus the work rate needs constant adjustment and a static difficulty level should not be relied upon.

2.3.3 Methods of Physiological Measurements in Active Video Games

There are a few methods of measuring physiological effects of playing active video games. This section examines some of those methods found in the literature and discusses their relevance to DanceBeat and this thesis.

Miyachi et al. (2010) performed a study where 12 adult participants played Wii Sport and Wii Fit Plus in a metabolic chamber. The metabolic chamber consisted of an airtight room (20,000 or 15,000 L) with controlled temperature and humidity. The oxygen and carbon dioxide concentrations of the air supply and exhaust were measured by mass spectrometry. Oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were measured through the exhaust from the chamber. Energy expenditure is estimated from VO_2 and VCO_2 using Weir's equation. The accuracy of these measurements was determined to be 99.2% ± 3.0 over 30 minutes. Heart rate data was not recorded in this study.
The main advantage of a metabolic chamber is that it allows accurate readings of energy expenditure while allowing free movement of the individual (as opposed to a metabolic cart which requires a facemask which can restrict movement). However, this form of measurement is not practical for use with DanceBeat for a few reasons. Firstly, DanceBeat, using physiological measures as an input, requires more immediate measures than can be gathered from a metabolic chamber. Secondly, DanceBeat is designed for home use and it is highly unlikely that an average home user will have a metabolic cart let alone a metabolic chamber available in their home.

Tan et al. (2002) performed a study where forty participants played Dance Dance Revolution and measured their heart rate and VO_2 uptake. VO_2 was measured with the K4 Cosmed portable oxygen and carbon dioxide analyzer. This analyzer is worn on a harness over the subject's attire. The system comprises of the analyzer unit, battery pack and facemask. The combined weight of the unit is about 800g. Heart rate of the participants was measured using the Polar Sports Tester heart rate monitor. Both heart rate and VO_2 were measured once every 15 seconds. Like the metabolic chamber, it is unlikely that an average home user will have access to this equipment. Furthermore, the mask on the analyzer hinders movement to a further extent than that of a simple chest worn heart rate monitor.

Many studies use just a heart rate monitor as their method of physiological measure (Stach & Graham, 2009; Oliver & Kreger-Stickles, 2006; Oliveira & Oliver, 2008; Nenonen et al. 2007). DanceBeat uses just a heart rate monitor for its physiological measurements. A heart rate monitor should provide sufficient information without being limiting in terms of movement or in terms of accessibility.

The Zephyr HxM BT heart rate monitor is the tool that was decided on for use in testing DanceBeat. Much of this decision was made due to the relative low cost of the monitor and the accessibility of the software development kit for the Zephyr HxM. Zephyr's BioHarness uses the same technology as the HxM but includes additionally the capturing of breathing rate, posture, thoracic skin temperature, and activity level. The BioHarness is also more expensive than the HxM. Zephyr performed a validity study of the BioHarness' heart rate against the Cortex BioPhysik MetaMax CPX using four participants. The BioHarness was valid in terms of heart rate when compared against the MetaMax with r=0.99, bias – 1.2 and SE = 0.29 (n=144) (Zephyr, 2008). As the HxM uses the BioHarness technology (excluding the extra features) we can consider this a validation of the HxM as well.

2.3.4 Physiological Measurements in Active Video Games

Several attempts have been made to determine heart rate and energy expenditure associated with playing various active video games (Biddiss & Irwin, 2010). In a pilot study, comparisons of energy expenditure in university students between active and sedentary games have been made (Leatherdale, Woodruff, & Manske, 2010). Unsurprisingly, an active video game (*Wii Sports Tennis*) (97.4 ± 62.8 $kcal_{/30min}$) was found to have higher ($p<0.01$) energy expenditure versus an inactive video game (*Mario Power Tennis*) (64.7(33.4) $kcal_{/30min}$). Further comparisons (Graves et al. 2008) have been made with *Wii Sports* games (*Boxing, Bowling* and *Tennis*) amongst 11-17 year olds. Graves found that playing *Boxing* [267.2(115.8) J $kg^{-1}min^{-1}$, 136.7(24.5)HR] had a higher energy expenditure than playing *Bowling* [182.1(41.3) J $kg^{-1}min^{-1}$, 103.2(16.7)HR] and *Tennis* [200.5(54.0) J $kg^{-1}min^{-1}$, 107.0(15.2)HR].

Unfortunately, these studies do not discuss the difficulty settings selected in the game, which could have a profound impact on the results. Willems and Bond (2009) conclude that of the *Wii Sports* games, brisk treadmill walking has higher physiological and metabolic response than *Tennis* and *Bowling* but the same as *Boxing*. Miyachi et al. (2010) measured METs associated with *Wii Sports* and *Wii Fit Plus* and compared them to the daily exercise guidelines provided by the American College of Sports Medicine (ACSM). Miyachi et al. (2010) concludes that only one third of the activities found in these games can count towards the daily amount of exercise recommended by the ACSM. Willems and Bond (2009) issue caution when comparing studies on active video games stating that game experience, fitness levels, voluntary effort and instructions provided may influence the outcomes.

There are forms of active video games that require greater lower body involvement than *Wii Sports*, specifically dance games. *Dance Dance Revolution* (DDR) and its counterparts *In the Groove* (IG), and *StepMania* are some examples. Graf, Pratt, Hester, and Short (2009) compares treadmill walking at different speeds, *Wii Sports Boxing*, and two difficulty settings of DDR. The second difficulty for DDR was found to have higher energy expenditure adjusted for body mass than that of treadmill walking (5.7 km/hour) despite treadmill walking having a higher step count than DDR. However, the study also found that heart rate was higher for *Boxing* than the other activities. Although this study did compare energy expenditure of two difficulty settings for DDR, they could not measure the higher difficulty settings as these difficulty settings were limited by user experience and skill.

Jordan, Donne, and Fletcher (2010) introduce $PS2_{limb}$, an input method for *Playstation 2* games not unlike that of a dance pad for dance games. In a comparison (n=15) across running, *Wii Sports Boxing*, cycling, and $PS2_{limb,}$ Jordan et al. found that $PS2_{limb}$ requires more energy expenditure than *Wii Boxing*, less than running (9.6 km/h), but the same as cycling (120W). It is suggested that lower limb controlled active video games will have a significantly higher energy expenditure (EE) than active video games without lower limb involvement. Jordan et al. conclude that *PS2*$_{limb}$ meets ACSM's 1998 guidelines for cardiovascular fitness whereas Wii Sports does not.

Player skill and experience can be a confounding factor if not accounted for. In measuring physiological demands of *Wii Sports* games it is important to consider that *Wii Sports* has a balancing mechanic that may require less movement from less skilled players.

In an exploratory study among male college students comparing experienced and inexperienced DDR players, Sell, Lillie, and Taylor (2008) reported that experienced players exhibited significantly higher average exercise than inexperienced players. This held for all cardiovascular variables including heart rate (HR), rate of perceived exertion (RPE), respiratory exchange rate (RER), and VO_2. Experienced DDR players were found to achieve a moderate intensity workout while inexperienced players only achieved a low intensity workout. Inexperienced players are unlikely to be able to keep up with higher difficulty settings in DDR. Sell et al. (2008) concludes that a longitudinal study is warranted to evaluate a training effect on energy expenditure.

Tan, Aziz, Chua, and Teh (2002) performed a study where forty subjects (n=40) (age 17.5 ± 0.7) had their HR and VO_2 measured while playing DDR for ten minutes. The participants were first given two weeks to familiarize themselves with the game before the tests began. The participants were instructed to gradually increase their difficulty (measured in steps on a scale from 1 to 8) on self-selected songs/levels. After the familiarization phase, the participants were asked to report the highest difficulty that they could confidently complete. The mean HR was 137 ± 22 and VO_2 was 24.6 ± 4.7 $ml \times kg^{-1} \times min^{-1}$. Tan et al. conclude that participants met the ACSM 1998 minimum guidelines for exercise intensity in terms of heart rate and METs (7.0 METS) but not in terms of VO_2. Unfortunately, Tan et al. do not report if there was a connection found between the difficulty played by a participant and HR, VO_2, or compliance with ACSM exercise guidelines.

2.3.5 Physiologically Controlled Exercise Games

Some work has been done with games that are physiologically controlled. It is a much simpler matter to measure heart rate than other physiological measures, so the games that use physiological controls use heart rate as their physiological input.

Stach and Graham (2009) created Heart Burn, a multiplayer bicycle racing active video game that uses real-time heart rate data. The game is designed to reduce the performance gap that can be found between players of high and low physical fitness in multiplayer active video games. The game allows players at different levels of physical fitness to compete based on effort relative to their fitness level. The players' in game performance is based on cycling speed and scaled by their heart rate. A less fit player that cycles at a slower speed but has a high heart rate can compete against a fit player that can cycle faster. A user study (n=24) showed that the heart rate scaling provided closer races between players while not negatively affecting player engagement. This opens the door to further competitive multiplayer active video games that can cross fitness levels.

Neonen et al. (2007) created an active video game prototype: *Pulse Masters Biathlon*. This biathlon active video game uses real-time heart rate data to control the player's avatar. Unlike most active video games, *Pulse Masters* does not have a physical input device such as a stationary bicycle, balance board, or a dance mat. Instead, the game uses the player's real time heart rate to control the ski speed of their avatar and a combination of gestures, computer vision and heart rate to control the player's shooting and shooting accuracy. This allows the player to choose the form of exertion they prefer to get their heart rate going so long as it leaves their hands free to gesture. In user tests (n=8), players were provided with the choice of a stationary bike and a mini stepper, but preferred the stationary bike for ease of use. The higher a player's heart rate was in the skiing section, the faster their avatar would travel. However, the game also reduced the player's shooting accuracy for higher heart rates. This provided a self-balancing mechanic encouraging players to keep their heart rate high to go fast while skiing, but not so high that they could not make accurate shots. The purpose of *Pulse Masters Biathlon* was not to control the player's heart rates or even to place the player's heart rate within a specific zone. However, by adjusting the speed and aim functions and with explicit feedback, *Pulse Masters Biathlon* could potentially be used to promote the user to self-balance their heart rate within a desired zone.

A boxing game with heart rate feedback is introduced by Masuko and Hoshino (2006). The content of the game is adjusted based on real-time heart rate data to attempt to give the player sufficient exercise and to maximize the player's sense of accomplishment. The input for the game is a camera that follows the motions of the player's boxing gloves and a heart-rate monitor. The game recognizes eight different motions that the player can make which are categorized as high, medium, or low intensity actions. By adjusting the likelihood of each type of action that is required by the player, the game can affect the player's heart rate. Increasing the ratio of high intensity actions increases the player's heart rate, whereas increasing the ratio of low intensity actions decreases the player's heart rate. During a small user study, users' heart rates were maintained and sense of accomplishment for different modes were reported. Unfortunately, the sample size for the evaluation was far too small (N=3) to make any conclusions.

TripleBeat, described by Oliveira and Oliver (2008) and Oliver and Kreger-Stickles (2006), is a mobile phone music player that uses heart rate and pedometer feedback to assist runners in their workout. A runner selects a workout schedule that includes his target heart rate. TripleBeat then selects a song for the runner based on the song's tempo and the runner's current and target heart rate. As the player runs, TripleBeat continues to select songs to keep the runner close to their target heart rate.
Runners using TripleBeat are scored on their compliance with their desired heart rate zone and how close they keep their heart rate to the target heart rate. In a small user study (n=10) TripleBeat was able to keep participants within a desired heart rate zone 82.8% of the time.

Sinclair, Hingston, Masek, and Nosaka (2010) describe an active video game with a physiological feedback loop. The game uses a stationary bike, heart rate monitor and standard game controller as input. The game consisted of the player controlling a helicopter collecting coins in a narrow passageway. The height of the helicopter was controlled by the RPM of stationary bike. The game adjusted the optimal RPM to play the game to match the RPM required to bring the players heart rate close to the target heart rate. The RPM value is calculated using a proportional-integral-derivative (PID) controller feedback loop. A pilot study with 21 subjects was performed with the desired heart rate set to 60% of the participants HRR. Although little information was provided on the physiological measures taken, the authors did report the mean value of the absolute difference between the heart rate and target heart rate as 4.43. This number is compared to a "static intensity" mean heart rate error of 9.79.

Sinclair (2011) followed up this study with another iteration of this game system. One of the main differences in the new design is the use of a genetic algorithm to control the desired RPM. In this iteration, the mean difference between desired and actual heart rate was 3.654 (0.704) for the dynamically controlled work intensity. This demonstrates that heart rate control in active video games is possible.

The work presented by Sinclair et al. (2010) and Sinclair (2011) has many similarities to DanceBeat and could have been an excellent resource for the initial design of DanceBeat. Specifically, the use of the PID controller as an approach to controlling heart rate would have been a good beginning. Unfortunately, the existence of Sinclair's work did not become known until after DanceBeat was implemented and the testing was concluded. An examination of the differences and similarities of DanceBeat and Sinclair's work can be found in *Chapter 7: Discussion*.

2.4 Game Design

In this section, game and game design is examined from the perspective of active video games. Interesting and noteworthy active video games that have not already been discussed in the *Physiology* section are discussed here. Recommendations for active video games from the literature are reviewed. There is an examination of flow and motivation and how they relate to active video games and DanceBeat.

2.4.1 Noteworthy Designs for Active Video Games

Mueller, Stevens, Thorogood, O'Brien, and Wulf (2007) assert that active video games can promote social interaction and bond forming between participants despite geographic distance. Mueller and Agamanolis (2008) present the multiplayer shadow boxing active video game *Remote Impact.* This simulates full body contact between geographically distant players. The game is played with two players in different locations but identical play areas. Each player stands close to a screen that has their own shadow and the other player's virtual shadow. The game is played by the each player trying to land hits on the other player's shadow. The game is designed to promote socialization and allows the players to freely talk to each other while playing.

Break out for Two is an active video game that uses a camera, projector, and an audio connection to play a breakout like game with players in different locations (Mueller et al, 2007). The players simultaneously kick a ball against the wall to remove blocks from the screen.

Mueller, Vetere, Gibbs, Agamanolis, and Sheridan (2010) present *Jogging over a Distance*. This tool is designed to allow participants to jog together socially despite geographical distance. A headset is used to allow communication between two joggers. The joggers' relative heart rates are used to spatialize the joggers. The closer the joggers are to their desired heart rates, the closer they will sound through their headsets.

Most active video games take an aerobic approach to exercise. Tucker (2006) presents an active video game, *Tetris Weightlifting*, which uses a weightlifting based interface. A Tetris like game is played by lifting weights in buckets through pulleys and handgrips. The game of Tetris involves arranging geometric shapes into patterns. The time element of Tetris was removed to fit the weightlifting nature of the game. Pulling the left handgrip would move a piece left, pulling the right grip would move the piece right, and pulling both grips simultaneously would drop the piece. Players are allowed to set their own weights in the buckets, effectively setting their own intensity.

Buttussi, Chittaro, Ranon, and Verona (2007) present two active video games that focus on two different types of movement. *GeoKaos* is an Arkanoid/Breakout inspired game. The goal of the game is break as many blocks at the top of the screen by bouncing a ball off a panel at the bottom of the screen. The panel is controlled by the user by jumping from side to side. The sizes of the jumps dictate the amount that the panel moves in the game.

Flareqoor is a side scrolling “shoot’em up”. The player tries to destroy enemy spaceships with their own continuously firing spacecraft. The player controls the height of their own spacecraft by standing erect or bending their knees. In effect, the player must perform a series of squats to control their spacecraft.

2.4.2 Design Considerations for Active Video Games

The skill demands of rhythm dance games can limit the intensity of physical exertion achieved while playing them (Thin and Poole, 2010). Thin and Poole (2010) suggests that in order to realize significant health benefits, the design of future active video games must be informed by exercise physiology and psychology principles. It is recommended that active video games should be designed with very low initial skill demands in order to maximize a player’s level of exertion and to realize and reward progress, thereby helping to promote enjoyment and counterbalance any sense of discomfort caused by exertion (Thin & Poole, 2010).

It is important to account for different play styles when designing an active video game. Pasch et al. (2008) found that different play styles of Wii Sports Boxing can result in different energy expenditures. It is also likely that different play styles in a dance game like DanceBeat would also see different physiological responses.

2.4.3 Motivation to Play

DanceBeat is of little use if no one is interested in playing it. Good game design demands that the player's experience and motivation to play be considered.

There is an extrinsic motivation associated with keeping active (Goldfield, Kalakanis, Ernst, and Epstein, 2000). A player may experience extrinsic motivation in keeping active through an active video game. However, children who are more intrinsically motivated are more likely to engage in a task and work to improve their abilities (Wigfield, Guthrie, Tonks, and Perencevich, 2004).

Vansteenkiste, Lens, and Deci (2006) describe intrinsic motivation as the pure enjoyment and unconditional interest in participating in an activity without any external pressure. A willingness to partake in physical activity simply for internal rewards is related to a higher likelihood of long term exercise adherence (Ryan, Frederick, Lepes, Rubio, & Sheldon, 1997).

Warburton et al. (2007) performed a 6-week study (n=14) comparing an exercise program where participants used a stationary cycle at the same time as they played a video game against a traditional exercise program where participants used the stationary cycle without a video game. It was found that the group using video games were significantly more likely to adhere to the exercise program than the group not using video games (78% ± 18% vs. 48% ± 29% respectively). There was also a significantly greater increase in VO_2max and reduction in systolic blood pressure in the video game group over the control group.

Video games can be a motivating factor for exercise (Sinclair, 2001). Saelens and Epstein (1998) performed a study (n=14) demonstrating that obese children would choose to play video games or watch movies over other sedentary activities even if it was contingent on having to exercise on a stationary bicycle to do so.

Video games can be used as a reward or extrinsic motivation for physical activity (Goldfield et al. 2000). Goldfield et al. (2000) performed a study (n=34) where obese children could earn access to video games and television through physical activity. The study consisted of 20 minutes where the children were free to read or do physical activity and 10 minutes of access to television or video games if the children reached a particular step count. In the study, the children that were required to reach 1500 steps to play video games engaged in more physical activity than the group that were only required to reach 750 steps. Both groups engaged in more physical activity than the group that had no step requirements.

Video games can be used as a great motivation for physical activity (Goldfield et al. 2000). Video games can be used to intrinsically motivate physical activity by combining video games and exercise or as extrinsic motivation by using video games as a reward for exercise.

DanceBeat has a greater potential to be used effectively as an exercise tool if we can increase engagement, enjoyment, and motivation to play.

2.4.3.1 Flow

The state of flow occurs when participants are completely engrossed in their activity and discover an internal feeling of accomplishment and enjoyment (Csikszentmihalyi, 1990). Flow is the achievement of an optimal state of intrinsic motivation and the willingness to participate in an activity for its own sake, with little regard for any external reward (Csikszentmihalyi, 1990; Sheehan & Katz, 2012). Flow can be achieved by promoting the following elements (Sheehan & Katz, 2012; Jackson & Eklund, 2002): Challenge-skill balance, clear goals, unambiguous feedback, concentration on task, sense of control, loss of self-consciousness, decreased awareness of time, and autotelic experience. Although flow is defined by the above 8 elements, Csikszentmihalyi has primarily relied on the challenge-skill balance as the key measure and predictor of flow (Jackson & Eklund, 2002). The design of DanceBeat will primarily focus on the challenge-skill balance element of flow.

2.4.3.2 Game-Flow

Sweetser and Wyeth (2005) propose a model of flow specifically for games. *GameFlow* suggests criteria for player enjoyment in games. There are 8 elements in game flow:

1. *Concentration* - The game should require concentration and the player should be able to concentrate on the game.
2. *Challenge* – The game should be sufficiently challenging and match the player's level of skill.
3. *Player Skills* – The game must support player skill development and mastery.
4. *Control* – The player should feel a sense of control over their actions in the game.
5. *Clear Goals* – The game should provide the player with clear goals at appropriate times.
6. *Feedback* – The players must receive appropriate feedback at appropriate times.
7. *Immersion* – The player should experience deep but effortless involvement in the game.
8. *Social Interaction* – The game should support and create opportunities for social interaction.

2.4.3.3 Dual-Flow

Sinclair (2011) proposes a construct for flow specifically for active video games. Dual-Flow is concerned with attractiveness and effectiveness. Sinclair's 2011 thesis on the subject describes the concept:

> The left part of [*Figure 2 – Sinclair et al's (2010) Dual-Flow construct*] illustrates the standard skills versus challenge balance of the flow model, which can be represented by a diagram featuring four quadrants. Boredom is reached when skills surpass the challenge, and if the challenge is too high compared to skill level, anxiety sets in. A state of apathy results when there is both the lack of skill and any meaningful challenge.

The balance between intensity and physical capacity is represented in a similar four-quadrant balance model in the right part of [*Figure 2 – Sinclair et al's (2010) Dual-Flow construct*]. If intensity and physical capacity are matched, the quadrant of physiological flow is reached and the fitness of the subject improves with continued exercise. Where the intensity of exercise far surpasses the physical capacity of the participant, a state of failure occurs - the exercise participant is unable to continue the exercise. If the participant has a low fitness level and there is no perceivable intensity in the exercise (e.g., playing an ordinary computer game with keyboard and mouse) there is no benefit to the participant. If physical capacity exceeds the exercise intensity, there is also potential for the participant to enter a state of deterioration where the fitness level will drop. (p. 52)

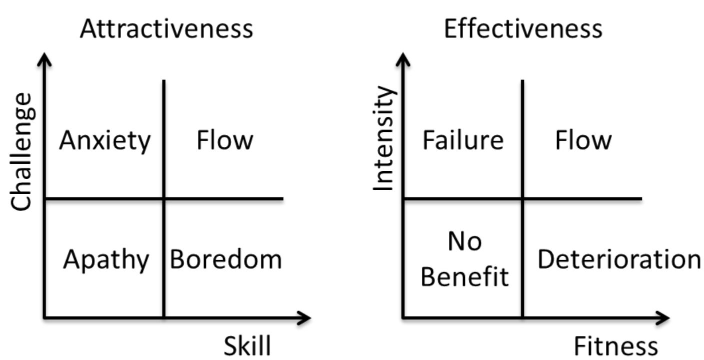


Figure 2 – Sinclair et al's (2010) Dual-Flow construct

2.4.3.4 Incongruity theory

Incongruity theory (Lankveld, Spronck, Herik, & Rauterberg, 2010) states that every context (e.g., a game) has a level of complexity. Incongruity is defined as the difference between the complexity of a context and the complexity of the internal human model of the context. According to incongruity theory, a large incongruity reduces the enjoyment of the game. System complexity is the complexity of a mental model that a person has of the world. Context complexity is the complexity of the world or part of the world. When context complexity is higher than system complexity, it is called a positive incongruity and is believed to lead to frustration. When the context complexity is lower than the system complexity, it is called a negative incongruity and is believed to lead to boredom. A low incongruity is believed to produce pleasure. In the context of a game, Lankveld et al. equates the game difficulty to the context complexity and the player's skill to the system complexity. Lankveld et al. describes a game Glove with three difficulty settings: easy, balanced, and hard. The three difficulty settings correspond to a high negative incongruity, a low incongruity and a high positive incongruity respectively. On a Likert scale, players of the game (n=24) reported that the game had increasing "frustration" from easy, balanced and hard. A significant difference was found for "pleasure" between balanced and hard, but not between easy and balanced.

2.4.4 Balance

The difference between Flow, Game-Flow, Dual-Flow, and Incongruity Theory may be too subtle for the purposes of this thesis. What should be focused on is that balancing the challenge of a game to a player's skill is one of the more important parts of promoting a positive experience for players.

We define game balance as the adaptation of the game difficulty towards the player's skill (Lankveld et al. 2010). A balanced game is one where the player's skill and the game's difficulty are comparable.

Game balance consists in changing parameters of the game in order to avoid the extremes of getting a player frustrated because the game is too hard or becoming bored because the game is too easy (Andrade, Ramalho, Gomes, & Corruble, 2006).

In a well-balanced game, a player is challenged by the complexity of the game, but not to the extent they become frustrated (Lankveld et al. 2010). Balancing a game effectively matches skill to challenge and thus promotes the Flow state in individuals. Game balance is also a key component in the

GameFlow and Dual-Flow constructs. A more balanced game will also have a smaller incongruity. In essence, a balanced game will increase the overall enjoyment of the game and the intrinsic motivation associated with the game.

A traditional approach to game design is to define a few difficulty levels (easy, medium or hard, for example) with set parameters, and let the player choose one of these levels for themselves. The obvious flaw with this strategy is that there is a large diversity amongst players in terms of skill as well as a large diversity amongst players in terms of their capacity to learn and adapt to the game. It is impossible to develop a game with an appropriate level of challenge and difficulty to satisfy players using a static difficulty approach (Bailey & Katchabaw, 2005).

One approach to dealing with this flaw is for the game to contain an adaptation mechanism to provide dynamic game balancing based on the player's skill (Andrade et al. 2006). Changing the challenge level of the game in response to the player's ability is sometimes called dynamic difficulty adjustment (DDA). Andrade suggests three basic requirements for dynamic game balancing: Firstly, the game must identify and adapt itself to the player's initial level quickly. Secondly, the game must track the player's changes for performance. Thirdly, the behavior of the game must be believable.

2.5 Relevance and Rationale

It may be possible to increase interest in physical activity among youth and young adults by presenting physical activity in the form of an active video game. Unfortunately, many active video games do not provide rigorous exercise. However, if the physiological demands of an active video game are increased too significantly it may reduce youth interest in these games. A balance must be struck between keeping youth interested and the physiological demands of active video games. It is hoped that we can find this balance through physiological feedback. If we make heart rate or other physiological feedback part of the controls for an active video game, it is hoped we can customize the physiological demands of an active video game to the user. In the end this may provide an attractive active video game that will keep users engaged and provide sufficient exercise.

Lower body controlled interactive dance video games would be well suited to using physiological feedback. Increases or decreases in the tempo of a song could be used to change the required frequency of player's steps. Changing the frequency of the player’s steps should change the player’s physiological response.

3 Game Design

“Game Design is the art of enjoyable frustration” – Andrew Mayor[4]

3.1 Overview

DanceBeat is a rhythm dance game not unlike Dance Dance Revolution, In the Grove, or StepMania. It requires a computer, dance pad, monitor and heart rate monitor to play. DanceBeat uses StepMania’s source code as its base. The main design goal behind DanceBeat was to produce a rhythm dance game that responds to and controls a player’s heart rate.

DanceBeat should be engaging despite the player’s physical fitness level or proficiency at rhythm dance games. However, the game should not be so challenging, either in terms of proficiency or physical fitness, so as to deter players from playing. DanceBeat should promote the state of flow in the players and should be highly intrinsically motivating. The game should promote, to the extent that it can, a balance in the challenge and skill for the players. In terms of DualFlow (Sinclair et al. 2010), we wish to promote effectiveness and attractiveness of DanceBeat through game design.

3.1.1 Rhythm Dance Games

Rhythm games are a class of games that are music themed and the skill demands focus on a player’s sense of rhythm. Some of the earliest games in the rhythm genre include PaRappa the Rapper and FreQuency. Rhythm dance games are a class of rhythm video games that use a dance pad as input. Rhythm dance games present the player with a song and steps that the player dances to. Direction arrows indicating step positions move up the screen. There is a target zone at the top of the screen. The arrows reach the target zone in time with the music. Players step on the respective direction arrow on

[4] Quoted from http://www.gamespot.com/news/pax-2008-when-player-feedback-backfires-6197068 last accessed July 31, 2011.

the dance pad as the arrow reaches the target zone on the screen. Players are scored based on how well their steps matched the timing of the steps shown on screen.

Figure 3 - DanceBeat in play

3.1.2 DanceBeat

DanceBeat is a rhythm dance game designed with the intent of keeping a participant's heart rate within a specified submaximal range. The game can be played using a standard dance pad and has a similar user interface to other rhythm dance games such as DDR. DanceBeat is designed to use the player's heart rate as part of the input for the game. The game uses the tempo of the music and steps being presented to the user in order to manipulate the physiological requirements of the game. DanceBeat attempts to keep players within a desired heart rate zone by monitoring their heart rate and changing the tempo accordingly.

3.1.3 StepMania

StepMania is an open source rhythm dance game. Its source code is freely available to be distributed and modified. StepMania is released under the MIT license[5]. DanceBeat has been implemented using StepMania as its base code. The advantages of this are twofold. Much of the extra programming in terms of user interface that would otherwise be outside of the scope of this project were already

[5] http://opensource.org/licenses/MIT

completed. The enhancements that have been made for DanceBeat will be sent back to the community and can be included in StepMania. This will allow the features to be made available to the general public.

3.1.4 Heart Rate Feedback

DanceBeat is unique among rhythm dance games in its use of a heart rate feedback model.

The game makes decisions on whether to increase or decrease the tempo, or to leave the tempo as it is. The decision is made based on the player's current heart rate in relation to the desired heart rate zone and the player's score over the last few seconds. The farther the player's heart rate is from the center of the desired heart rate zone the more likely the game is to make the decision to change the tempo. If the player's heart rate is approaching the bottom of the desired heart rate range the game will respond by increasing the tempo. Likewise, if the player's heart rate is approaching the top of the desired heart rate range, the game will respond by decreasing the tempo. If the game is beyond the player's skill, the game will compensate by modifying the steps presented to the player.

3.1.5 Iterative Design

Iteration is a large part of game design (Swain, Fullerton, & Hoffman, 2008; Salen & Zimmerman, 2004). It is almost impossible to know if a game that is being created is good until it is played. Prototyping and play testing is part of the design process. This is especially true with a game like DanceBeat which has much room for tweaking in terms of its heart rate control mechanic.

DanceBeat is another iteration of an existing game called StepMania. DanceBeat as presented in this chapter and the next is not a final version, but just another iteration towards a more final version. The design of the current version of DanceBeat is discussed in this chapter, but much of what is discussed here is in preparation for the "Future Game Design" chapter towards the end of this thesis. In this chapter, the design of DanceBeat is examined in terms of game design concepts and putting together a game based on good principals. In the "Future Game Design" chapter, the design of DanceBeat is re-examined from the perspective of what has been learned from play testing.

3.2 What is a Game?

There are many definitions of the term game.

"A game is the voluntary effort to overcome unnecessary obstacles" – Bernard Suits (Salen & Zimmerman, 2004, p. 76)

"The word [game] is used for so many different activities that it is not worth insisting on any proposed definition. All in all, it is a slippery lexicological customer, with many friends and relations in a wide variety of fields." – Davaid Parlett, The Oxford History of Board Games (Salen and Zimmerman, 2004, p. 71)

When defining games, we generally either make the definition too broad, too narrow, or a combination of the two. Consider the following definition: "A game is an activity among two or more independent decision-makers seeking to achieve their objectives in some limiting context. A more conventional definition would say that a game is a context with rules among advisories trying to win objectives." – Clark C. Abt (Salen & Zimmerman, 2004, p. 74). According to this definition, DanceBeat is not a game as it only has one player.

Instead of defining fun or games, this paper will include descriptions of common elements that are found in most games (Swain et al. 2008) that are relevant to the discussion of DanceBeat. A very brief examination of premise, objectives, boundaries, rules, interactions, conflict, and outcomes is included below.

3.2.1 Premise

The premise of a game is a concept which establishes the action of the game within a setting or metaphor. The premise of the game Risk is that you are the leader of large armies bent on world domination. The premise of the game Rock Band is that you are in a rock band.

The premise of DanceBeat is that the players are dancing. The premise of DanceBeat is reinforced by the music of the game and the players having to make steps that are not completely unlike dance steps in order to interact with the game.

3.2.2 Objectives

The objective of a game is what the player is trying to accomplish. In chess, the objective is to capture the other player's king. In the game Risk, the objective is own all territories on the board.

In DanceBeat the player's objective is to make as many successful steps during the song as they can. It is worth noting that the player's objective in DanceBeat is not for the player to get their heart rate within a desired zone. The heart rate control is a goal of the design of the game. So long as the player is concerned with making as many successful steps as they can, the game will see to the player's heart rate.

Flow theory calls for clear goals. DanceBeat never leaves any ambiguity as to what the player's objectives are. In the short term, the player is trying to hit the next steps presented to them; in the long term, the player is trying to successfully complete as many steps as they can.

3.2.3 Boundaries

The boundaries in a game are the borders of the physical and conceptual space in which a game takes place. Within the boundaries of a game is the Magic Circle (Huizinga (1998) by way of Swain et al. 2008).

The magic circle is a temporary world where the rules of the game apply rather than the rules of the ordinary world.

The dance pad, the music, the steps that need to be made, can all be considered within the boundaries of DanceBeat. Although heart rate is part of the player's interaction with the game, the player's heart rate is never specifically mentioned during game play and should not be part of the player's conceptual space in the current iteration of DanceBeat. Anything outside of these elements ideally slips away from the player's focus while they play.

Two of the elements of Flow are a concentration on the task and loss of self-consciousness. Both of these are promoted through the interaction of the theme of DanceBeat and the boundaries of the game. If the boundaries are not strong (sometimes called a porous magic circle), then the player's concentration can wander.

3.2.4 Rules

Rules in a game define what objects exist, what players can and cannot do, and what happens when various actions or situations arise. For example, the card game *Innovation* from *Asmadi Games* has the rules "On each of your turns, you must perform two actions [from the list of actions provided]." and "You win immediately upon claiming the last achievement you need!" A computer game has both simple rules such as "The player has three lives" to more complicated rules that simulate physics.

DanceBeat has a few key areas governed by rules. There are rules that determine when arrows travel up the screen and how fast. There are rules that determine if a player has made a successful step. There are rules that determine how fast the music is. And of course there are rules that determine how the game responds to the player's heart rate. More specific details are provided later in this chapter.

3.2.5 Interaction

Every game has a way in which players can interact with the game within the rules. Interaction between a player and a game happens through interfaces. For a video game, interfaces would likely include a monitor and a controller. In other games, the interface can be the physical object of the game itself. In the game of chess, the interface is the board and pieces and a common interaction would be moving one of the pieces.

In DanceBeat, the interfaces are the screen that the steps are shown on, the dance pad, and the heart rate monitor. The players interact with the game by making steps on the dance pad and by their heart rate changing.

One of the elements of Flow is unambiguous feedback. This is achieved in DanceBeat through the intersection of interaction and rules. When the player takes a step, the rules determine if it was successful. Immediately on the screen there is feedback ranging from “Miss”, letting the player know they did not succeed in making the step, to “Marvelous”, letting the player know they timed their step perfectly.

3.2.6 Conflict

Conflict arises when the rules and a player’s skill get in the way of the player achieving their objective. In the game of Sorry, the objective of the game is to get all of your pieces from the start to your home. However, the rules state that you have to go around the board to get to your home. Furthermore, the dice dictate how far each of the pieces can travel. On the way around, other players’ pieces can land on your pieces and send your pieces back to the start. Each of these rules introduces part of the conflict in the game as they place obstacles in the way of achieving objectives. In a game like bowling, the conflict arises largely due to limited player skill.

In DanceBeat the conflict arises from the steps on screen only being available to be hit for a short time and the player being required to hit the right notes. Player skill becomes a large factor. The player must have the ability to translate the steps seen on the screen into precisely timed movements.

Conflict in a game relates to the challenge-skill balance in flow. If the rules interfere too much or too little with the player accomplishing their goal, or if the player's skill is too high or low, then the game does not have a good skill-challenge balance.

3.2.7 Outcome

At the end of most games there is a winner, a loser or some measure of success or failure. In chess, unless the game is a stalemate, there is a winner or a loser. In Dance Dance Revolution, the player can lose or is given a letter grade showing how well they did. Outcomes are almost always tied to the objective of the game.

In the current iteration of DanceBeat, there is no winning or losing, or even a high score. It may be important to include some measure of outcome in a future version.

3.3 Development Tools

The development for DanceBeat was done on MacBook Pro running OS X 10.6.8 and on a PC running Windows 7. Xcode 3.2.6 was used with the MacOSX10.4u base SDK for editing the source code and building the executable. All sound editing was performed using Audacity 1.2.6. Step files were generated by Dance Monkey 1.06 and Gorrilla 1.1.3, referred to together as Dance Gorilla. Additional step files were generated using Perl v5.8.8 and Vim 7.2.108.

3.4 Terminology

Arrows – Arrows are the symbols that travel up the screen that prompt the user to press a direction on the game pad. Arrows should only be pressed when they reach a marker at the top of the screen. We will call the moment that the arrow reaches the marker the arrow's hit time.

Tap and Hop – When a single direction button on the game pad is pressed, usually in response to an arrow, we call that a tap. When two direction buttons are pressed simultaneously, we call that a hop. We use the terms tap and hop because the player usually will make a tapping or hopping motion to perform a tap or hop in the game.

Successful Step – We call an arrow, tap or hop successful if the player has pressed the direction button on the game pad associated with an arrow in a time close enough to the arrow's hit time.

Game-Score (SCORE) – A player's game-score is used to describe how well the arrows are being matched by the player's taps and hops. The game-score is the ratio between successful steps and arrows over the last 20 seconds.

Difficulty – It is useful for us to have a distinction between the physiological demands of the game and other aspects of the game that may hinder game play. When discussing difficulty in this context we are referring to the mental demands and the agility required while playing the game. Physiological demands or responses that are not directly related to agility, such as heart rate, are not included in our use of the word "difficulty". This is useful for distinguishing between attractiveness and effectiveness in terms of Flow concepts.

Step Difficulty (Diff) – A step difficulty is a collection of arrows that are associated with a level. There are 9 step difficulties, from beginner to challenging. Each step difficulty has more steps and slightly more challenging patterns than the last.

Decision Point – A decision point is a point during a level where the game decides to change the game-speed or not. Decision points happen roughly every 7.5 seconds.

3.5 Level Design

DanceBeat was implemented with four levels. One level was used for the sole purpose of determining a player's sitting heart rate. One level was used as a combination of an introduction to rhythm dance games and measure of a player's proficiency in rhythm dance games. The final two levels were designed to achieve target heart rates.

3.5.1 DB-sitting

The DB-sitting level was used to gather a player's sitting heart rate which is used as an approximation of the player's resting heart rate. The level consists of the player sitting in a chair while sounds of the ocean surf are played. The ocean surf recording was part of *Dan Gibson's Solitudes* collection: *Ocean Surf – Timeless and Sublime*. The level lasted five minutes. The player's heart rate just prior to the level's ending is recorded as the player's sitting heart rate.

3.5.2 DB-Score

The DB-score level is an introduction to rhythm dance games. The level is approximately 266 seconds long. It is designed to start with very simple steps and progress to complicated steps by the end. There is no heart rate control used in this level.

The song played during DB-score is *Eating Candies* by *Vospi*[6]. The song was modified in Audacity to be approximately 285 seconds long.

Eight different sets of steps using different step difficulties were created for this level using Dance Gorilla. These eight difficulties ranged from very simple to complex. Portions of the steps were

[6] Available from http://www.stepmania.com/download.php?file=Songs_StepMix1_Vospi_EatingCandies.smzip when last check on July 26, 2012.

combined together to create one set of final steps. The simplest steps were used in the beginning of the song with each subsequent section of the song getting more complex. This produced a level that had a gradual increase in difficulty.

3.5.3 DB-light and DB-moderate

The DB-light and DB-moderate levels are identical in everything except their target heart rates. These levels are seven minutes long. DB light uses the target HRR range of 35-54% and DB-moderate uses the target HRR range of 55-69%. Both levels use ranges recommended by the ACSM (Armstrong, Whaley, Otto, & Brubaker, 2006).

3.5.3.1 Music

These levels use the song *Beethoven Virus* by *Diana Boncheva*. The song was modified in Audacity to lengthen it by looping key parts and to create versions of the song with different tempos.

Seventeen versions of the song were created, each with a different tempo. The tempos ranged from +40% to -40% of the original song with a version created for every 5% tempo increment.

3.5.3.2 Steps

The beats per minute of the song were determined by Dance Gorilla. Nine step difficulties were generated for these levels. The steps were stored in step manias *.sm* file format[7]. The steps for the level are created in three passes. The first pass created a simple repeating 2-measure pattern for the entire song. The second pass changed the column in which the simple pattern is found. The third pass was done during play and turned some single steps into hop steps.

[7] Details available at http://www.stepmania.com/wiki/The_.SM_file_format, Last accessed July 26, 2012.

Table 2 – Measures for each Difficulty

1	2	3	4	5	6	7	8	9
0000	0000	0000	0000	0000	0000	1000	0000	1000
0000	0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	1000	1000	1000	1000	1000	1000	1010
0000	0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	0000	0000	1000	0000	0000	0000	1010
0000	0000	0000	0000	0000	0000	0000	0000	0000
1000	1000	1000	1000	1000	1000	1000	1000	1010
,	,	,	,	,	,	,	,	,
0000	0000	0000	0000	0000	1000	1000	1000	1000
0000	0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	0000	0000	0000	0000	0000	0000	0000
0000	1000	1000	1000	1000	1000	1000	1010	1010
0000	0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	0000	1000	1000	1000	1000	1010	1010
0000	0000	0000	0000	0000	0000	0000	0000	0000
1000	1000	1000	1000	1000	1000	1000	1010	1010
,	,	,	,	,	,	,	,	,

The scripts used to generate the step files can be found in Appendix C

The first pass of step creation uses the simple patterns shown in *Table 2 – Measures for each Difficulty*. At this point, the pattern repeats for the entire song and there is no variation in which column the steps are found in.

The purpose of the second pass is to create variation in which columns the steps are found without significantly increasing the overall complexity of the steps. In the second pass, the song is broken down into 11-measure segments. For each segment, a semi random column is chosen. All regular steps in a segment are moved to the new column. All hop steps in a segment have one of the steps moved into the new column. The column chosen for a segment is determined by the number of segments before it. This has the added effect that all difficulties will use the same column for corresponding sections of the song. In this way, if the step difficulty presented to the user is changed in mid-segment, the user will still be presented with steps in the same column. This method reduces the confusion caused by changing step difficulty during play.

The last pass takes place during game play. Depending on the players' performance, the game may decide to provide a greater number of hop steps. The method for determining the number of hop steps in a level is discussed later. The game keeps track of the column of each segment. When it needs to transform a regular step into a hop step, it adds another step in the same row to the column of the last segment.

3.5.3.2.1 Steps, Balance and Flow

The progression from difficulty 1 to 9 represents a progression of complexity in steps. Adjusting the step difficulty presented to the user changes the balance of the game. In choosing which steps to present to the user, the game must consider the challenge-skill balance of the user to promote flow and intrinsic motivation of the game.

3.6 Inputs

The game used two main forms of inputs. The dance pad and the heart rate monitor. The dance pad can be any standard USB dance pad. A DDR Game dance pad was used for this study.

Potentially, any Bluetooth capable heart rate monitor could be used. However, it was found that the Zephyr HxM BT heart rate monitor was the most accessible and easiest to program for in this project.

Figure 4 – Dance Pad used for testing

Figure 5 – Zephyr HxM BT Heart Rate Monitor and chest straps.

3.7 Mechanics

3.7.1 Steps-Per-Second

To change the physiological requirements it presents to a player, the game must modify the number of steps-per-second that it presents. The game uses two mechanisms to change the number of steps-per-second. The game can change the tempo of the music presented to the user as well as the step difficulty.

The game has several versions of each song that it uses for heart rate control levels. Each of these versions has a different tempo.

The game has several step difficulties that it can choose from. Each progressive step difficulty has more steps than the difficulty before it. The game can define a percentage of hop steps (%HS). This is the number of steps that the game changes to be hop steps on the fly.

The steps, percentage of hop steps, and the song tempo combine to create the game-speed or steps-per-second for a level. Roughly every seven and a half seconds, the game makes a decision on what the new steps-per-second should be. This decision is based off of a few key variables: The recommended ratio (R_{rec}), the enforced ratio (R_{enf}), the maximum difficulty (D_{max}) and the percentage of hop steps (%HS).

3.7.2 Heart Rate Based Mechanics

Each level that has a heart rate control aspect to it will have an associated desired heart rate reserve range. The game is concerned with the center of this range: the heart rate reserve target (HRR_{target}). This number does not change during a level.

The game keeps track of a rolling average of the player's heart rate (HR_{avg}). The average is updated every time the heart rate monitor reports in. The new heart rate average is calculated in the following way:

Equation 2 – Rolling average heart rate

$$HR_{avg}` = \frac{HR + \left(HR_{avg} * 15\right)}{15 + 1}$$

Where HR is the latest heart rate reported by the heart rate monitor.

The game predicts the player's heart rate. To do this, the game estimates how quickly the player's heart rate is changing (HR_{vec}). The player's HR_{vec} is calculated by:

Equation 3 – Calculation for heart rate vector

$$HR_{vec} = HR - HR_{avg}$$

Using the player's HR, HR_{avg}, HR_{vec}, and HR_{target}, the game finds a ratio (R_{rec}) that it recommends to be used to change the game-speed. This ratio is found by:

Equation 4 – Calculation for recommended ratio

$$R_{rec} = \frac{HRR\left(HR_{target}\right) * 1.095 - HRR(HR_{vec})}{HRR(HR)}$$

Where HRR(x) is the percent heart rate reserve associated with a heart rate of x.

3.7.3 Score Mechanics

3.7.3.1 Hop Steps vs Tap Steps

In the design of this game, it is assumed that hop steps have an energy expenditure at least as large as two tap steps. A hop step requires a small jump, removing the player's weight from the game pad entirely. A tap step requires only a shift in the player's weight or a toe tap. It is also presumed that a hop step is, at most, as difficult as two tap steps.

When calculating game-speed, the game counts a hop step as two tap steps. When comparing two sets of steps with identical game-speeds but with different %HS, the one with the higher %HS potentially has a higher associated energy expenditure and a lower difficulty.

Changing the %HS of the game can allow the game to make decisions that make difficulty and physiological requirements less dependent on each other. This is one aspect that allows us to focus on our other design goals of promoting flow through balancing the challenge of the game towards the player's skill level.

3.7.3.2 Game-Scores and Balance

A balancing mechanic must be used to maintain the challenge-skill balance in order to promote flow and intrinsic motivation. Challenge arises in DanceBeat from three variables: The number of hop steps versus tap steps, the difficulty of the steps being presented, and the tempo of the music. Skill level is primarily measure by game-score. The balancing method of DanceBeat must manipulate the three variables as a response to the player's game-score. The game responds to the player's game-score in three ways: It changes the value of R_{enf} which is used to determine game-speed. It changes the highest difficulty that can be presented to the user (D_{max}). The percentage of hop steps (%HS) is changed.

There are some scenarios in which the heart rate mechanic will not work. Suppose the optimal steps-per-second for a particular player to reach the target heart rate is 3 steps-per-second. Now suppose that the player lacks skill in playing rhythm dance games and cannot keep up with more than 2 steps-per-second. In this case, the player will not be able reach the target heart rate. The heart rate mechanic will presume that the player just needs to be presented with more steps-per-second to achieve the target heart rate. As the game gets faster, the player will no longer be able to keep up with the rising demands. The increasing game-speed will only help to increase the player's frustration and reduce the challenge-skill balance.

At points, the game must make balance in difficulty and skill a higher priority than reaching the target heart rate. The assumption must be made that it is preferable to present the user with fewer steps if it is closer to the player's skill level than to present the player with more steps than they can keep up with even if it means the player cannot reach the target heart rate.

Table 3 – Settings Base on Game-Score

Score>=	Effect
1.0	D_{max}=9, R_{enf}=1.4
0.95	Renf=1.3
0.935	D_{max} =8
0.9	R_{enf}=1.2
0.85	%HS=1/4
0.8	R_{enf}=1.1
0.75	D_{max} = 7
0.7	%HS=1/2, R_{enf}=1.0
0.65	D_{max} = 6
0.6	%HS=3/4, R_{enf}=0.9
0.55	D_{max} = 5
0.5	%HS=1
0.4	D_{max} = 4
0.3	D_{max} = 3
0.2	D_{max} = 2
0.1	D_{max} = 1

3.7.4 Choosing Steps and Speed

Suppose the game is currently using the step difficulty j and the song tempo i. The game will make a decision on the new steps-per-second (SPS`), new step difficulty j`, and new tempo i`, using the following equation:

Equation 5 – Choosing step difficulties.

$$\min_{i`\in I, j`\in J}\left(\left|\min(\mathrm{R_{rec}},\mathrm{R_{enf}})-\frac{\mathrm{SPS}(\mathrm{i`},\mathrm{j`},\%\mathrm{HS})}{SPS(i,j,\%HS)}\right|*\frac{|\mathrm{j}-\mathrm{j`}|+20}{20}*\frac{|\mathrm{i}-\mathrm{i`}|^2+10}{10}\right)$$

Where **I** and **J** are the sets of all possible step difficulties and all available song tempos respectively, %HS and %HS` are old and new hop step percentage respectively. SPS(x,y,z) is the steps-per-minute provided by tempo x and step difficulty y and hop step percent z.

This equation provides a combination of step difficulty and song tempo that is close to the desired change in steps-per-second. It uses the smaller of R_{rec} and R_{enf} as a goal for the desired change. That means that the amount of change from one step to another can be capped by the player's current score.

This equation also attempts to minimize the negative effects of extreme tempo change or extreme difficulty change and to make the changes seem more natural. The two segments $\frac{|\mathrm{j}-\mathrm{j`}|+20}{20}$ and $\frac{|\mathrm{i}-\mathrm{i`}|^2+10}{10}$ make large changes in tempo or difficulty less likely. The more natural the change, the less the game strays from Andrade et al's (2006) advice of believable game behavior.

4 Methods

A proof of concept crossover study was performed using DanceBeat.

4.1 Participants

A convenience sample of 23 to 30 participants was to be recruited. The lower bound was determined by a sample size calculation. The standard deviation, σ=14, has been estimated from a previous study (Sell et. al 2008). The delta, Δ=15, has been gathered from the heart rate range prescribed for medium intensity exercise from the ACSM guidelines (Armstrong et al. 2006).

Equation 6 - Sample Size Calculation.

$$n = \frac{2\sigma^2 (Z_{1-\beta} + Z_{1-\alpha/2})^2}{\Delta^2} = \frac{2(14)^2 (1.64 + 1.96)^2}{15^2} = 23$$

All participants were recruited at the University of Calgary. Posters for the study were placed around the University. A professor showed slides to students in a class that provided extra credit for participating in studies. The investigator recruited students from the hallways.

A convenience sample of twenty-nine participants from the University of Calgary took part in the study. Of the original twenty-nine, five where excluded from the study due to technical mishaps and one was removed from the results as an outlier. This left a sample size of twenty-three (n=23). The reason for the exclusions will be discussed in section 4.5, *Exclusions*. The outlier will be discussed in section 5.3.4, *Exclusion of Outlier*. The sample consisted of 11 females and 12 males between the age of 18 and 27 with a mean age of 20.2 (2.4). Of the 23 participants, 19 had reported playing some amount of rhythm dance games before while 5 reported not having played any rhythm dance games before.

The participants were split into two groups: *Light-First* and *Moderate-First*. The order of the participants determined what group they would be assigned to. A random number generator was used to select 15 of the 30 slots to be *Moderate-First* while the remaining slots were *Light-First*.

4.2 Setup

The study took place in the Sport Technology Research Laboratory's Virtual Reality Lab, located at KNA121 in the Faculty of Kinesiology at the University of Calgary. This was the only study taking place in that room at the time so the setup was left in place between trials.

Figure 6 – The testing setup.

DanceBeat was built for and installed on an iMac (2.66 GHz Intel Core 2 Duo, 4 GB, NVidia GeForce 9400, OSX v10.6.8). A Sony (model:PFM-42B1) monitor with a 42in (36.5x20.5in) screen was placed on a stand 4ft high and was connected to the iMac. The Sony monitor was used to display the game, while the iMac's built in monitor was used to display the readouts from the game. A DDRGame dance pad was placed 2ft in front of the monitor. The iMac was placed on a cart to the right of the dance pad and facing away from the dance pad. The placement of the iMac partially obscured the participants' view of the Investigator; this was done to allow the investigator to see what was presented to the participants' and to be able to watch for non-involvement by participants' while not giving the participants' the impression that they were being monitored.

Figure 7 – The view of the investigator hidden behind the monitor from dance pad.

A DDRgame brand dance pad was used. It has dimensions of 32x36in and has a 1in foam base.

Participants wore a Zephyr HxM Bluetooth Heart Rate Monitor that was connected to the iMac through the iMac's built in Bluetooth chip. The heart rate monitor sent a message every 0.995 (0.192) seconds. The heart rate monitor reported current heart rate, a timestamp of the last fifteen heart beats, the number of strides that have been taken, and a checksum to determine if the message contained errors. DanceBeat would reject messages from the heart rate monitor if the checksum did not match the message received.

4.3 Experimental Protocol

Each participant had an individual session to play the game. The participant would fill out an informed consent form (Appendix C), a questionnaire to screen for health risks (Appendix B; Armstrong et al. 2006), and pre-trial questionnaire (Appendix D). The participant was then instructed on how to wear the heart rate monitor, given a diagram of how the monitor was to be worn, and directed to the change room to fit the heart rate monitor onto themselves. Once the participant returned wearing the heart rate monitor, the Investigator would ensure that readings from the heart-rate monitor were reaching the computer correctly.

The participant was then instructed to sit in a chair and relax while their sitting heart rate was gathered. The sound of waves on the beach was played for five minutes while the participant sat and the game recorded their heart rate.

The participant was then given a sheet of stretches (Appendix G) to perform. Upon completion of the stretches, the participant was directed to the dance pad to begin playing the game.

If the participant was unfamiliar with rhythm dance games they were given an explanation of the mechanics. Participants were first given the DB-score level to play. The DB-score level was used both to estimate the participant's proficiency and to give them an introduction to rhythm dance games. The DB-score level starts with simple steps that a novice should be able to make and gradually moves to more difficult steps. After the completion of DB-score, the participant was given five minutes to relax.

Next, the participant was given one of either DB-light or DB-moderate to play. If the participant was in the *Light-First* group, they were given DB-light to play. If the participant was in the *Moderate-First* group, they were given DB-moderate to play. Upon completion of that level, the participant was given five minutes to relax.

The participant was then given the last level to play: DB-moderate if they were in the *Light-First* group and DB-light if they were in the *Moderate-First* group.

Finally, the participants were given a post-trial questionnaire (Appendix D) and asked to return to the changing room so that they could return the heart rate monitor.

4.4 Measurements

During each level, DanceBeat kept a detailed log of the information available to it. DanceBeat would write to a log file every time that the heart rate monitor reported in. The logs contain the following:

Table 4 – DanceBeat Measurements

- Time (T) - The amount of time in seconds since the start of the level.
- Heart Rate (HR) - The current heart rate as reported by the heart rate monitor.
- Heart Rate Average (HR_{avg}) - The rolling heart rate average as calculated by DanceBeat. The heart rate average is calculated every tick using the following:

  Equation 7 – Calculation for Rolling Heart Rate Average.

$$HR_{avg}` = \frac{HR + (HR_{avg} * 15)}{15 + 1}$$

- Heart Rate Vector (HR_{vec}) - The heart rate vector is used to predict the direction and rate that heart rate is changing. HR_{vec} is the distance the current heart rate is from the heart rate average (HR_{vec}=HR-HR_{vec}).

- Target Heart Rate (HR_{target}) - The center of the participant and level specific target heart rate zone.
- Heart Rate Variation - The maximum distance that a participant's heart rate can stray from the target heart rate and still be considered as in the target heart rate zone.
- Strides - The number of strides reported by the Heart Rate Monitor.
- Successful Steps - The number of steps up to this point that the participant has made within the step's hit time.
- Steps Presented - The number of steps up to this point that the game has presented to the player and that the payer could have made.
- Current Game-Score - The number of successful steps over the presented steps for the last 20 seconds.
- StepMania Game-Score - The score that the original StepMania game would assign.
- Total Steps - The number of times up to this point that the participant has pressed a gamepad button.
- Presented Steps-Per-Second (SPS) - The average of the last few seconds of the number of steps-per-second that is presented to the user.
- Tempo Ratio - The ratio of the song's original tempo to the song's current tempo.
- Sound Speed Index - An index that corresponds to the song tempos.
- Step Difficulty Index - An index that corresponds to frequency of steps. Step difficulty index and Sound Speed Index are directly related to the Presented Steps-per-Second.
- Applied Ratio - When the game changes the number of steps-per-second presented to the user, this reports the ratio between the old SPS and the new SPS.

Derived measurements were able to be made from and added to the log files afterwards.

Table 5 - DanceBeat Derived Measurements

- Predicted Heart Rate – Where the game predicts the player's heart rate will be based off of the player's current heart rate and the player's heart rate average.
- Distance From Target Heart Rate – The distance the player's heart rate is from the player's target heart rate.
- Predicted Distance from Target Heart Rate – The distance the player's predicted heart rate is from the player's target heart rate.
- Within Heart Rate Zone – A 0 or 1 indicating if the player's heart rate is within the desired heart rate zone.
- Score Based Maximum Ratio – The maximum change in the steps-per-second that the game will allow due to the player's current score.
- Recommended Ratio – The ratio of the steps-per-second that the game thinks would be ideal based on the player's predicted heart rate and the player's target heart rate.
- Reduction – The difference between applied and recommended ratio.
- HRR – The heart rate reserve calculated using the current heart rate, the participant's age, and the participant's sitting heart rate.

4.5 Exclusions

Of the twenty-nine participants in the study, five where excluded due to technical issues; Four of the participants were excluded due to a bug in the code, and one of the participants was excluded due to an issue with the heart rate monitor.

A bug was discovered in the code after the 4th participant. This bug affected how the game made decisions and reported results. The first 4 participant results are not comparable to the rest of the participants as a result of this bug and were thus excluded from the study. The bug was fixed before the study continued.

For the 10th participant, the heart rate monitor stopped reading correctly part-way through a level. That participant's results would also not be comparable to the remaining participants and was excluded.

As a result of the excluded participants, the size of the randomly assigned groups was disproportionate. To keep equally sized groups, the 27th and the 29th participant were changed from the *Moderate-First* group into the *Light-First* group.

4.6 Limitations

4.6.1 Game Comparison

This study makes few claims about the effectiveness of DanceBeat in controlling heart rate in comparison to other similar games. However, there are few other similar games that are known that have been designed to control heart rate. Sinclair's (2010;2011) game being the most notable exception. The mean tempo and mean steps-per-minute for each DanceBeat level has been recorded. In future studies, this tempo and step rate can be used to choose a level from another rhythm dance game. This chosen level can be compared to DanceBeat in its ability to keep participants in the desired heart rate range during the level.

4.6.2 Carryover Effects

A participant's fatigue from one level may increase the measured heart rate in following levels. By giving a resting period between levels the carryover effects are reduced. By randomizing the order of levels, the carryover effects can be accounted for in the analysis.

4.6.3 Self-Selection Bias

As a convenience sample, the study is susceptible to self-selection bias. It is likely that those who chose to participate have a favorable opinion of video games and do not have an aversion to exercise.

A favorable opinion towards video games may have a higher aptitude for playing video games. This may cause us to see higher game-scores.

Participants who do not have an aversion to exercise would likely be more physically fit than those who do have an aversion to exercise. Those that are more physically fit have a lower heart rate variability (Armstrong et al. 2006) and this might make their heart rates easier to control. This could cause an overestimation in the effectiveness of DanceBeat.

4.7 Analysis

4.7.1 Data Analysis

The main goal of the analysis is to determine how effective DanceBeat is at controlling heart rate and to determine what effects various factors have on DanceBeat's ability to control heart rate. The secondary goal of the analysis is to build a model that will inform future versions of the game.

4.7.1.1 Primary Objectives

Exercise Intensity and Heart Rate Control

The mean, median, 95% mean confidence interval and standard deviation of HRR_{diff} and HRR are reported for each level.

A repeated measures analysis of variance on HRR_{diff} and HRR across gender, game expertise, level order, and game level is used. The ANOVA is used to determine if the game is effective at controlling heart rates, if the game's effectiveness at controlling heart rates changes from one level to the next, if there is a carryover effect, and if a player's game-score affects heart rate control.

A generalized estimating equation is used to determine the amount specific variables affect DanceBeat's ability to control heart rate.

4.7.1.2 Secondary Objectives

<u>Game-Speed</u>

A generalized estimating equation is used to build a model of game-speed. This model is used to inform future versions of the game in *Chapter* 8*: Future Design Considerations*.

4.7.2 Generalizability

As this study uses a convenience sample, statistically speaking, we cannot generalize. However, it is unlikely that DanceBeat's ability to control heart rate is dependent upon players being university students. This study should provide us with a strong indication of the quality and range of DanceBeat's heart rate control mechanic.

5 Results

5.1 Data Collection

The data was collected through DanceBeat by using a Zephyr HxM Bluetooth Heart Rate Monitor and DDR Game Dance Pad. Data was written to the log file every 0.995 (0.192) seconds. A list of the data collected by DanceBeat can be found in section *4.4 Measurements*.

The first sixty seconds of a level are considered warm-up. Although DanceBeat collected data from the entire level, we will not be considering the warm-up sections. Unless otherwise stated, the data examined for each level below is from after the sixty second mark to the end of the level.

5.1.1 Statistical Analysis Tools

The analysis was performed with SPSS 19.0.0 and Microsoft Excel 2010 on a Windows 7 Service Pack 1 running Intel Core i7-2600k (3.4GHz) system.

5.2 Descriptive Statistics

5.2.1 Sample Characteristics

The total number of participants was twenty three (n=23) (excluding one outlier). The sample consisted of 11 females and 12 males between the age of 18 and 27 with a mean age of 20.2 (2.4). Participants had a mean sitting heart rate of 78.26(12.53).

5.2.2 Previous Experience

Of the 23 participants, 19 had reported playing a rhythm dance game before. Of those, 18 reported having played Dance Dance Revolution, 2 reported having played StepMania, and 2 reported having played In the Groove. In the pre-trial questionnaire (Appendix D) participants self-reported the amount of time they had spent with video games and their preference for rhythm dance games (see *Table 6 - Pre-Trial Questionnaire* below).

Table 6 - Pre-Trial Questionnaire

I have played a significant amount of dance rhythm games.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
N	0	5	3	6	9
%	0.00	0.22	0.13	0.26	0.39

I enjoy playing dance rhythm games.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
N	1	12	10	0	0
%	0.04	0.52	0.43	0.00	0.00

I spend a significant amount of time playing video games.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
N	4	4	5	1	9
%	0.17	0.17	0.22	0.04	0.39

5.2.3 Variables

HRR – Interval – The participant's Heart Rate Reserve percentage at the time of the measurement. Range [0%-100%].

HRR_{target} – Interval – The desired heart rate reserve goal set for the current level. Range [0%-100%].

HRR_{dif} - Ratio – The distance from the HRR_{target} that the participant's HRR is at that measurement.

Order – Categorical – A participant's Order is Light-First or Moderate-First depending on whether they played the Light or Moderate level first.

Level – Categorical – The Level refers to the DanceBeat level the participant was playing at the time of the measurement. The possible values are Light and Moderate.

Gender – Categorical – The gender of the participant.

Sitting – Interval – The participant's sitting heart rate recorded during the Sitting level of DanceBeat.

Intro-Score – Interval – The participant's game-score recorded during the Intro level of DanceBeat using DanceBeat's method of score calculation. Range [0-1].

SMScore – Interval – The participant's game-score recorded during the Intro level of DanceBeat using StepMania's method of score calculation. Range [0- ~1200].

Recommended Ratio – Ratio – The change in game-speed that DanceBeat recommends based on just HRR, HRR_{vec}, and HRR_{target} but not based on game-score.

Recommended Ratio Δ - Ratio - The distance the recommended ratio is from 1. Recommended ratio **Δ** = Abs(recommended ratio -1)**.**

Enforced Ratio – Ratio – The maximum allowed change in game-speed determined by the game's score mechanic and the player's game-score.

Reduction – Ratio – The amount that the Recommended Ratio was reduced because it was greater than the Enforced Ratio.

Applied Ratio – Ratio – The ratio between the old game-speed and the new game-speed. Chosen using the minimum of the recommended-ratio and the enforced-ratio.

Applied Ratio Δ - Ratio – The distance the Applied Ratio is from 1. Applied Ratio **Δ** = Abs(Applied Ratio – 1).

Sound Index – Ordinal – The index of the song tempo presented to the player.

Step Index – Ordinal – The index of the step difficulty presented to the player.

Game-Speed – Interval – The number of steps-per-second that the game is presenting to the player.

Game-Score – Interval – The number of successful steps the player made over the number of steps presented to the player. This includes the last 20 seconds of gameplay in the calculation. Range [0-1]

Game-Expertise – Ordinal – The expertise group the participant has been placed in as a result of their intro-score.

5.2.4 Correlations

Tables of variable correlations, which were too large to display here, can be found in the appendices (Appendix A). The correlations were broken down into DB-Light and DB-Moderate levels.

5.3 Summary Data Results

The following section presents the results for summary data. The mean HRR and mean HRR_{dif} have been calculated taken from the longitudinal data for each participant and level pair.

5.3.1 Summary Means

The mean of mean heart rate reserves by level are shown below.

Table 7 – Mean of Mean HRR

Level	Mean	StDev	Median	95% Confidence Interval		Target Zone	
Light	0.439	0.015	0.443	0.433	0.446	0.35	0.54
Moderate	0.577	0.04	0.587	0.56	0.594	0.55	0.69

5.3.2 Mean HRR and HRRdif

Below is a table laying out the means of mean HRR and mean HRR_{dif} broken down by gender, order, and game-expertise for the DB-Light and DB-Moderate levels.

Table 8 – Mean of Mean HRR and mean HRR_{dif} by Gender, Order, Game-Expertise and Level

				Light				Moderate			
Gender	Order	Expertise	N	Mean HRR	Std. Dev	Mean HRRdif	Std. Dev	Mean HRR	Std. Dev	Mean HRRdif	Std. Dev
Female	Light First	Novice	2	0.459	0.005	0.040	0.011	0.595	0.021	0.055	0.000
		Intermediate	1	0.426	.	0.087	.	0.574	.	0.081	.
		Expert	3	0.427	0.020	0.046	0.025	0.566	0.044	0.086	0.017
		Total	6	0.438	0.021	0.051	0.025	0.577	0.032	0.075	0.019
	Moderate First	Novice	3	0.432	0.004	0.041	0.009	0.505	0.028	0.116	0.027
		Intermediate	2	0.434	0.004	0.077	0.041	0.597	0.027	0.043	0.019
		Expert	1	0.461	.	0.052	.	0.612	.	0.040	.
		Total	6	0.438	0.012	0.055	0.026	0.553	0.057	0.079	0.045
	Total	Novice	5	0.443	0.015	0.041	0.008	0.541	0.054	0.091	0.038
		Intermediate	3	0.432	0.005	0.081	0.030	0.589	0.023	0.056	0.026
		Expert	4	0.436	0.023	0.048	0.021	0.578	0.042	0.075	0.027
		Total	12	0.438	0.016	0.053	0.024	0.565	0.046	0.077	0.033
Male	Light First	Novice	1	0.455	.	0.024	.	0.629	.	0.036	.
		Intermediate	3	0.445	0.004	0.035	0.018	0.596	0.001	0.034	0.011
		Expert	2	0.443	0.000	0.046	0.015	0.564	0.066	0.096	0.022
		Total	6	0.446	0.005	0.037	0.016	0.591	0.038	0.055	0.034
	Moderate First	Novice	1	0.445	.	0.040	.	0.606	.	0.025	.
		Intermediate	3	0.430	0.024	0.063	0.037	0.584	0.009	0.050	0.012
		Expert	1	0.444	.	0.053	.	0.580	.	0.081	.
		Total	5	0.436	0.019	0.057	0.028	0.588	0.012	0.051	0.022
	Total	Novice	2	0.450	0.007	0.032	0.011	0.617	0.016	0.031	0.008
		Intermediate	6	0.437	0.017	0.049	0.031	0.590	0.009	0.042	0.014
		Expert	3	0.443	0.001	0.049	0.011	0.569	0.048	0.091	0.018
		Total	11	0.441	0.013	0.046	0.023	0.589	0.028	0.053	0.028
Total	Light First	Novice	3	0.458	0.004	0.035	0.012	0.606	0.025	0.049	0.011
		Intermediate	4	0.440	0.010	0.048	0.030	0.591	0.011	0.046	0.025
		Expert	5	0.433	0.016	0.046	0.019	0.565	0.045	0.090	0.017
		Total	12	0.442	0.015	0.044	0.021	0.584	0.035	0.065	0.028
	Moderate First	Novice	4	0.436	0.007	0.041	0.007	0.530	0.055	0.093	0.050
		Intermediate	5	0.432	0.017	0.069	0.034	0.589	0.016	0.047	0.013
		Expert	2	0.453	0.012	0.053	0.001	0.596	0.023	0.061	0.029
		Total	11	0.437	0.015	0.056	0.026	0.569	0.045	0.066	0.037
	Total	Novice	7	0.445	0.013	0.038	0.009	0.563	0.058	0.074	0.043
		Intermediate	9	0.435	0.014	0.060	0.032	0.590	0.013	0.047	0.018
		Expert	7	0.439	0.017	0.048	0.016	0.574	0.041	0.082	0.023
		Total	23	0.439	0.015	0.050	0.024	0.577	0.040	0.066	0.032

5.3.3 Percentage of Time in the Target Zone

The mean percentage of time participants spent in the desired heart rate range is shown below. M-Revised represents the percentage of time participants stayed in an expanded zone.

Table 9 – Percentage of Time in Zone

Level	Mean	StDev	Median	95% Confidence	
Light	87%	0.179	0.94	0.793	0.947
Moderate	67%	0.214	0.72	0.578	0.763
M-Revised	76%	0.191	0.79	0.681	0.846

5.3.4 Exclusion of Outlier

One of the participant's results was considered extremely abnormal and is considered an outlier. The participant in question had a mean HRR of 0.387 and mean HRR_{dif} of 0.232 for DB-Moderate. This places the participant's HRR 4.8 standard deviations away from the sample mean and the participant's HRR_{dif} 5.2 standard deviations away from the sample mean. Based on these extreme measures, the participant was considered an outlier. A discussion of this participant's results can be found in the profile analysis section. This participant is not included in the results presented in this section.

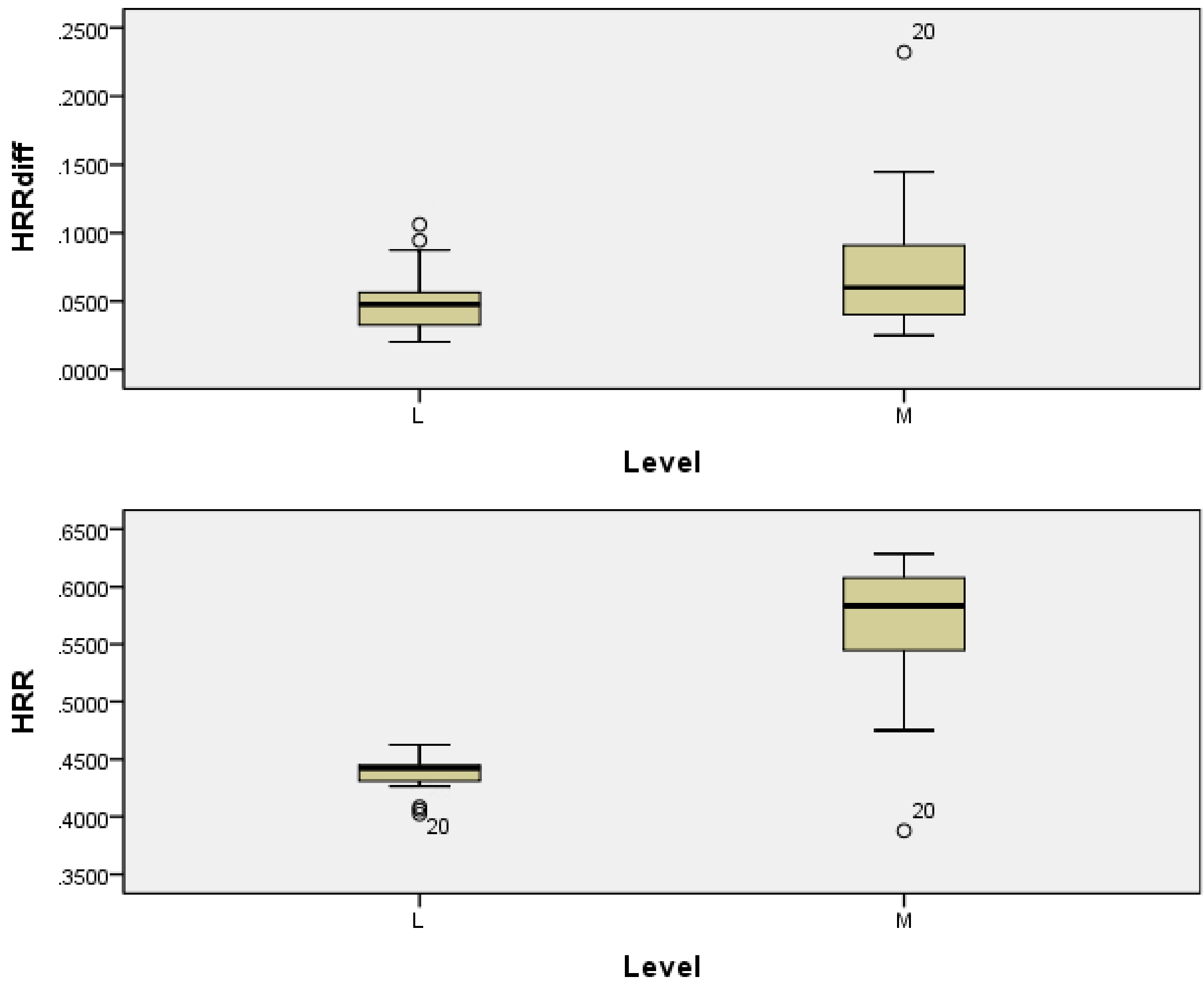


Figure 8 – HRR and HRR_{dif} by Level Boxplot

5.4 Repeated Measures ANOVA

A repeated measures ANOVA was performed on mean *HRR* and mean HRR_{dif} across *level*, *order*, *gender* and *game-expertise*.

Table 10 – Repeated Measures ANOVA results

	HRR		HRR_{dif}	
Source	F	Sig.	F	Sig.
Level	378.96	0	2.329	0.155
Order	0.202	0.662	0.027	0.873
Gender	1.592	0.233	4.964	0.048
Game-Expertise	0.111	0.896	1.803	0.21
Order * Gender	0.131	0.724	0.712	0.417

Order * Game-Expertise	3.943	0.051	1.383	0.291
Gender * Game-Expertise	2.12	0.166	4.085	0.047
Order * Gender * Game-Expertise	1.832	0.206	2.678	0.113
Level * Order	0.126	0.73	0.787	0.394
Level * Gender	1.031	0.332	0.03	0.866
Level * Game-Expertise	0.716	0.51	3.104	0.085
Level * Order * Gender	0.214	0.652	0.197	0.666
Level * Order * Game-Expertise	1.213	0.334	1.015	0.394
Level * Gender * Game-Expertise	2.681	0.113	1.987	0.183
Level * Order * Gender * Game-Expertise	0.411	0.673	1.45	0.276

5.4.1 Significant Results

A significant difference was found in means for HRR between levels (F=378.960, P<0.001).

Table 11 – HRR and HRR_{dif} by Level

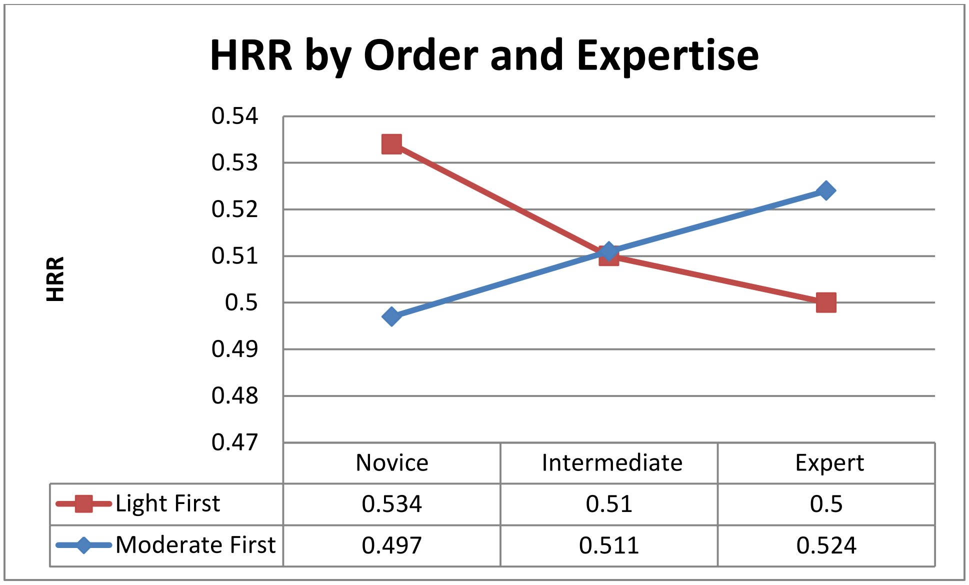
Measure	Level	Mean	StdDev	95% Confidence Interval	
HRR	Light	0.439	0.015	0.433	0.446
	Moderate	0.577	0.040	0.56	0.594
HRR_{dif}	Light	0.050	0.024	0.039	0.060
	Moderate	0.066	0.032	0.052	0.079

A significant difference was found in means for HRR_{dif} between genders (F=4.964 , P=.048).

Table 12 – HRR and HRR_{dif} by Gender

Measure	Gender	Mean	95% Confidence Interval	
HRR	Female	0.507	0.494	0.52
	Male	0.518	0.504	0.532
HRRdif	Female	0.064	0.054	0.074
	Male	0.049	0.038	0.06

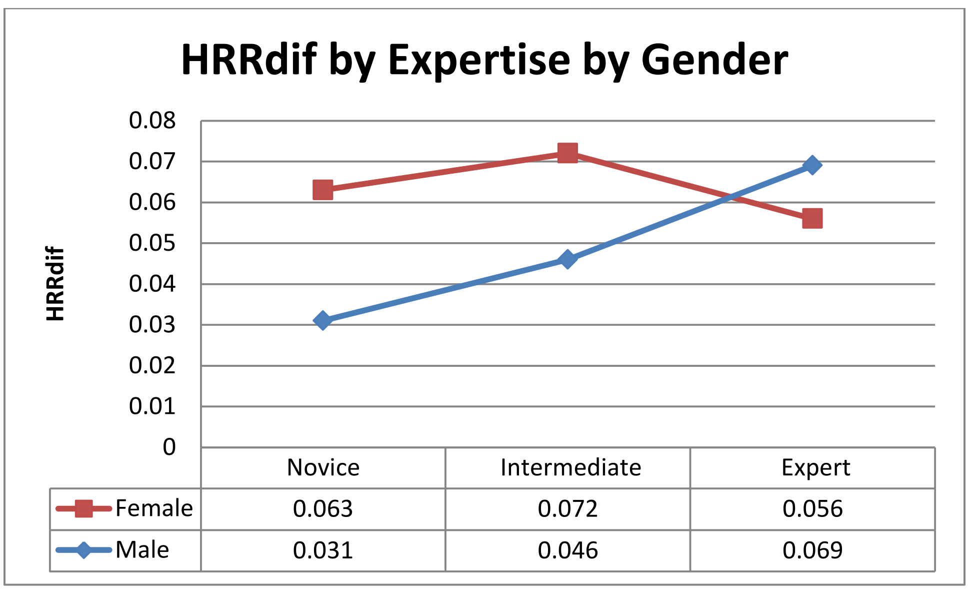
The interaction of HRR between Order and Game-Expertise is close enough to significance that it warrants mention (F=3.943 , P=.051).



	Novice	Intermediate	Expert
Light First	0.534	0.51	0.5
Moderate First	0.497	0.511	0.524

Figure 9 – HRR by Order and Expertise

A significant interaction was found between Gender and Game-Expertise for HRR_{dif} (F=4.085, P=0.047).



	Novice	Intermediate	Expert
Female	0.063	0.072	0.056
Male	0.031	0.046	0.069

Figure 10 – HRR_{dif} by Expertise by Gender

5.5 Model for Distance from Goal

A regression model for HRR_{dif} can help us understand the effects of covariates on predicting HRR_{dif} and hence the effectiveness of DanceBeat.

The above results use summary data. Much information can be lost by using summary data instead of longitudinal data. In order to take advantage of the longitudinal data, we will build a generalized estimating equation. Using a generalized estimating equation takes into consideration correlations among observations.

A generalized estimating equation was calculated for effects of covariates on HRR_{dif}. The generalized estimating equation was calculated using SPSS's genlin command.

Table 13 – Generalized Estimating Equation predicting HRR_{dif}

Parameter	B	Std. Error	Sig.
Intercept	.034	.032	.287
Order	.023	.009	.008
Level	.062	.020	.002
Gender	-.029	.008	.000
Sitting	.000	.000	.747
SMScore	.000	.000	.869
Intro-Score	.083	.067	.219
Enforced Ratio	-.025	.007	.000
Reduction	.092	.036	.010
Applied Ratio	.007	.006	.191
Applied Ratio Δ	.017	.005	.001
Sound Speed Index	.000	.000	.135
Step Difficulty Index	.000	.000	.345
Game-Speed	.004	.002	.037
Game-Score	.042	.010	.000

The Order regression coefficient represents a predicted increase in HRR_{dif} from Light-First to Moderate-First. The Level regression coefficient represents a predicted increase in HRR_{dif} from the Light level to the Moderate level. The Gender regression coefficient represents a predicted decrease in HRR_{dif} from Female to Male.

5.6 Model for Gamespeed

It is useful to build a regression model to predict desirable game-speeds for future game versions. A generalized estimating equation weighted for HR_{vec} and HRR_{dif} gives us a regression model that predicts a desired game-speed when HR_{vec} and HRR_{dif} are low. We will only use covariates in this model that we have at the beginning of the level. The generalized estimating equation was calculated using SPSS's genlin command with $|HRR_{dif}*HR_{vec}|$ as the weight.

Table 14 – Generalized Estimating Equation for Game-Speed

Parameter	B	Std. Error	Sig.
Intercept	-2.144	1.211	0.077
HRRtarget	4.552	0.542	0.000
Gender	0.176	0.279	0.528
Sitting	0.005	0.010	0.599
SMScore	-0.002	0.002	0.291
Intro-Score	3.485	2.074	0.093

The less significant the regression coefficient the less useful it is in predicting the desired game-speed. The model was rebuilt by removing the least significant regression coefficients. This leaves only HRR_{target} and intro-score remaining in the model.

Table 15 – Refined Generalizing Estimating Equation for Game-Speed

Parameter	B	Std. Error	Sig.
Intercept	-0.874	0.604	0.148
HRRtarget	4.449	0.565	0.000
Intro-Score	0.949	0.629	0.131

The estimated marginal mean corresponding to the above generalized estimating equation is shown below.

Table 16 – Estimated Marginal Means for the Refined Generalized Estimating Equation for Game-Speed

Mean	Std. Error	95% Wald Confidence Interval	
2.247158	0.086878	2.07688	2.417436

Covariates fixed at:HRRtarget=0.532,Intro-Score=0.793

5.7 Preference for DanceBeat

In the post-trial questionnaire, participants were asked to report their enjoyment of DanceBeat and their enjoyment of DanceBeat in comparison to other rhythm dance games. Highlighted sections of the responses are shown in Table 17 – *Preference for DanceBeat* below. All of the responses to the post-trial questionnaire can be found in Appendix D. It is important to remember that the study used a convenience sample when considering these results. A discussion of these results can be found in section 7.2, *Enjoyment of DanceBeat.*

Table 17 – Preference for DanceBeat

I enjoyed playing DanceBeat.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
N	6	16	0	1	0
%	26.1	70.0	0.0	4.3	0.0

I enjoyed playing DanceBeat as much as other rhythm dance games.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
N	8	10	4	1	0
%	34.8	43.5	17.4	4.3	0.0

I enjoyed playing DanceBeat more than other rhythm dance games.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
N	4	5	12	2	0
%	17.4	21.7	52.2	8.7	0.0

6 Profile Analysis

The following are some cherry-picked results to illustrate ways in which the game can work. Unless otherwise stated, the numbers discussed below are from the 60 second mark onward.

6.1 Case Study 1

We will call this participant Participant 1, although this does not reflect their ordering in the study. Participant 1 is an example of the game performing well. For the moderate level, they stayed within the desired heart rate zone 83.33 percent of the entire level. They stayed within the zone 97.26 percent of the time after the initial 60-second warm up. Their average heart rate reserve was 59.77(2.47) for a heart rate reserve goal of 62.

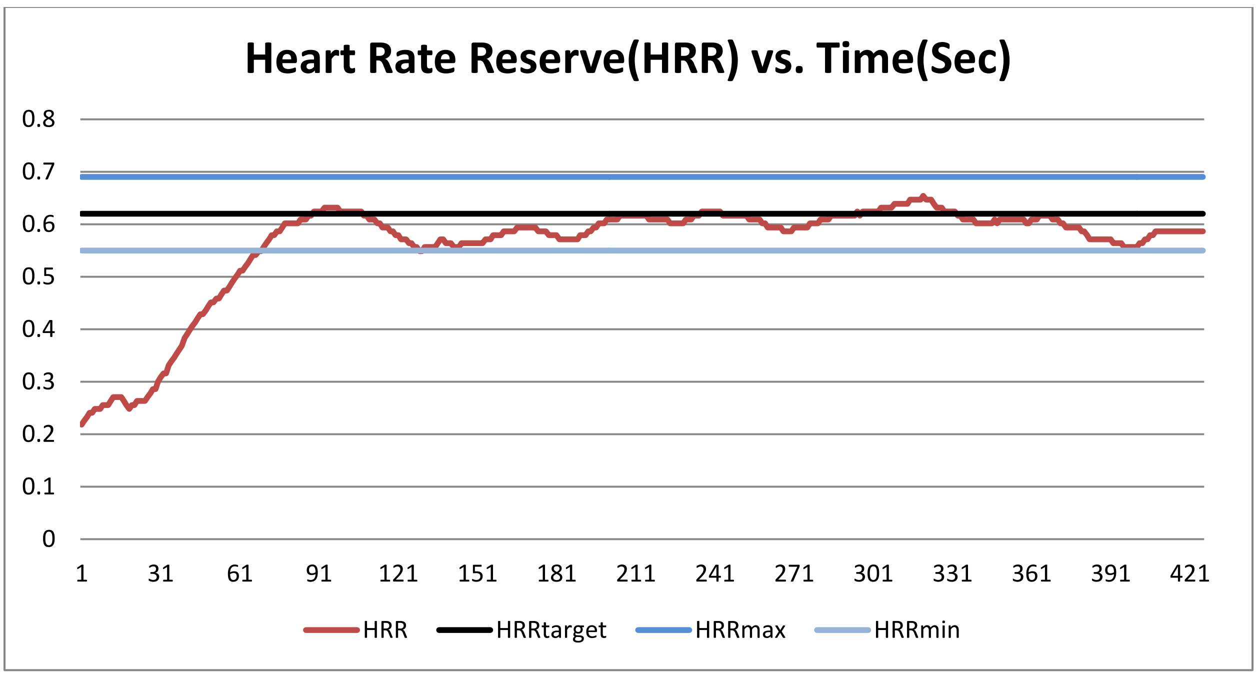


Figure 11 – Participant 1 – Heart Rate Reserve vs Time

Participant 1's HRR entered the target heart rate reserve zone at the 68 second mark. The participant had an average HRR deviation from the target HRR of 2.60(2.07). The mean applied ratio was 1.00 (0.06).

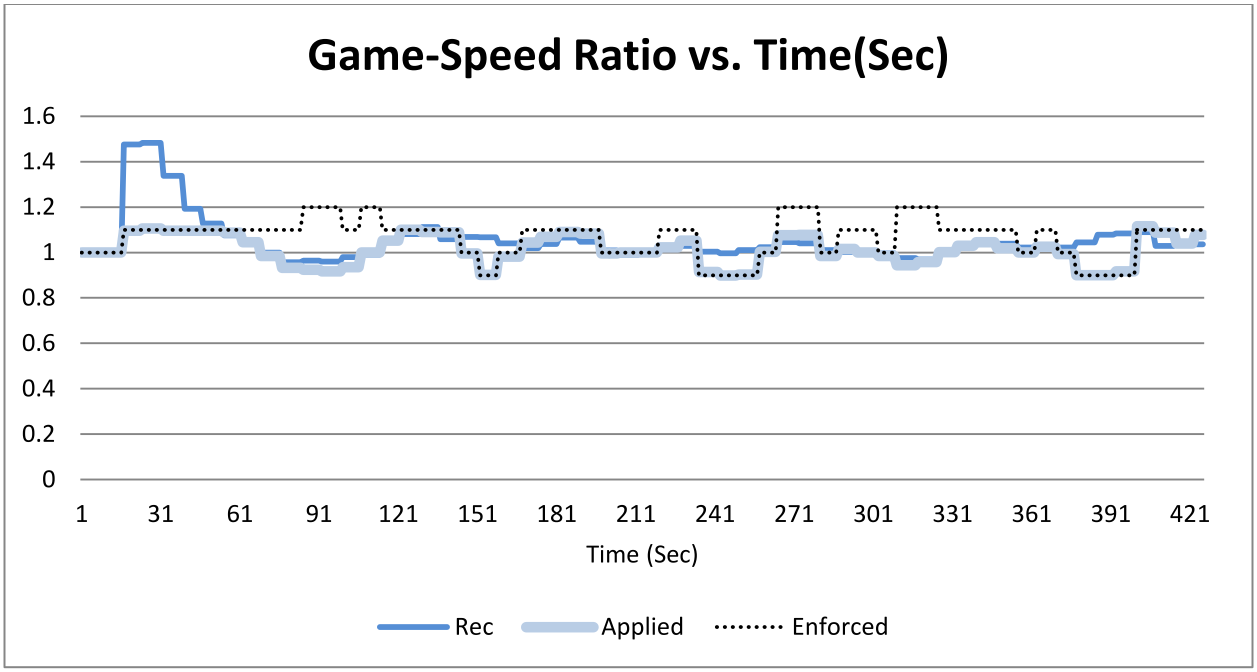


Figure 12 – Participant 1 – Game-Speed Ratio vs Time

Figure 12 – Participant 1 – Game-Speed Ratio vs Time shows Participant 1's game-speed ratio over time. "Rec" represents the game's recommended ratio based on the player's heart rate and target heart rate. "Enforced" represents the maximum ratio that can be applied based on the player's game-score. "Applied" represents the change to game-speed that the game made based off of the recommended and applied ratios. Times when the recommended ratio is above the enforced ratio indicate a time when the player's game-score is limiting the rate at which the game-speed can change.

The participant had an average game-score of 0.72 (0.08). The game-speed was reduced 30.41% of the time with a mean reduction of 0.025 (0.05).

6.2 Case Study 2

We will call this participant Participant 2, although this does not reflect their ordering in the study. This is a case where the participant's skill level limited the game's ability to control their heart rate. For the moderate level, shown in the graphs below, they did not manage to reach the heart rate zone. This participant is the outlier that was removed from the rest of the results. They are included here as an extreme example. The participant had an average HRR of 38.78 (4.53) for a target of 62.

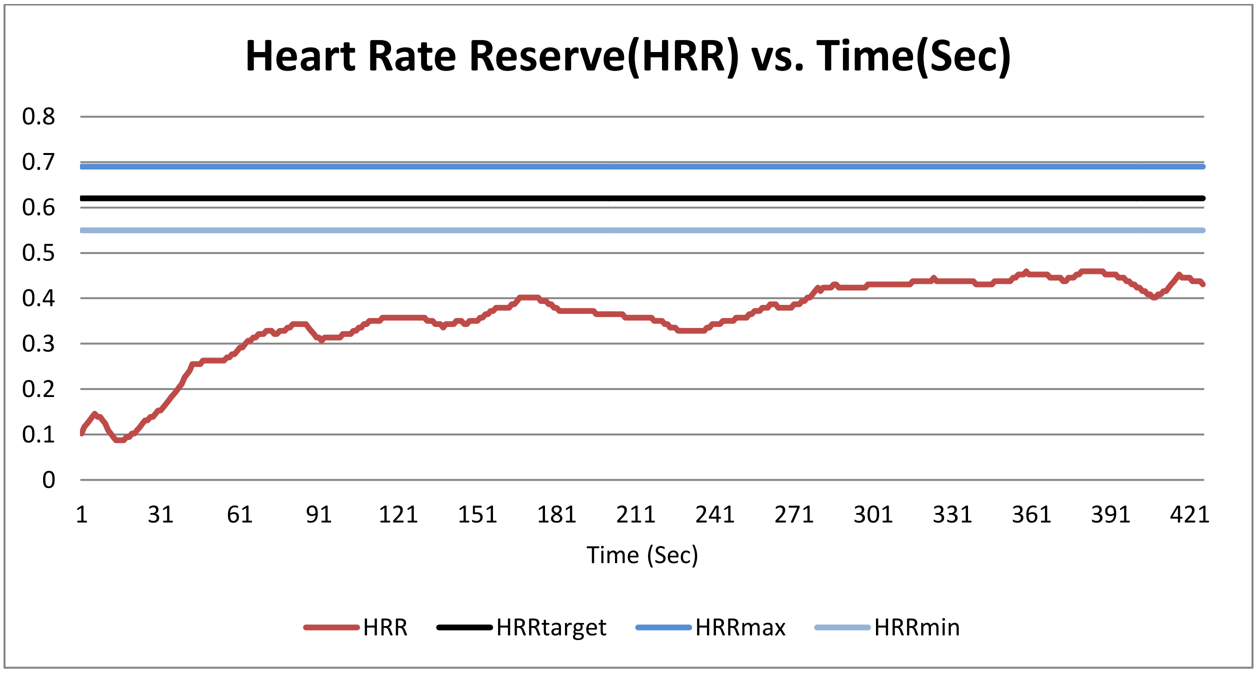


Figure 13 – Participant 2 – Heart Rate Reserve vs Time

Participant 2's HRR did not reach the target heart rate reserve zone. The participant had an average HRR deviation from the target HRR of 23.22(4.53).

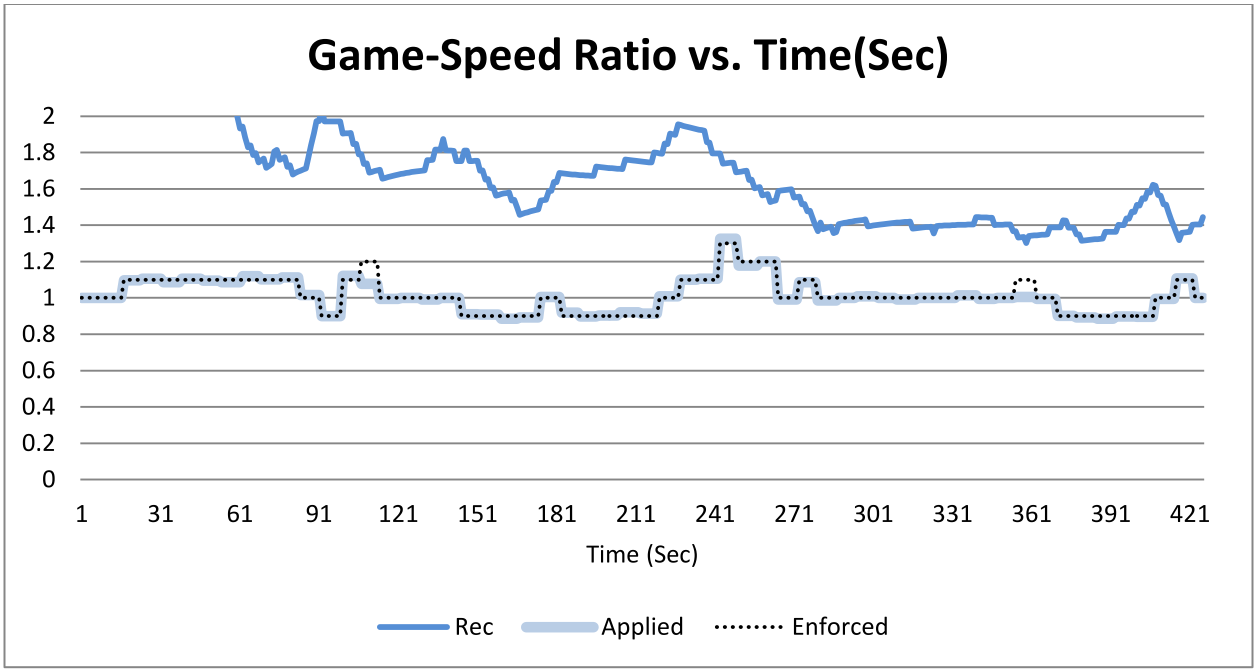


Figure 14 – Participant 2 – Game-Speed Ratio vs Time

The participant had an average game-score of 0.64 (0.11). The game-speed was reduced 100% of the time due to the player's game-score. The mean applied ratio was 1.00 (0.09) with a mean reduction of 0.26 (0.10).

6.3 Case Study 3

We will call this participant Participant 3, although this does not reflect their ordering in the study. This participant is an example of the game performing less than optimally in the area of heart rate control. For the moderate level, depicted in the graphs below, they stayed within the desired heart rate zone 34.74 percent of the level. They stayed within the zone 35.89 percent of the time after the initial 60 second warm up. Their average heart rate reserve was 61.26(10.33) for a heart rate reserve goal of 62.

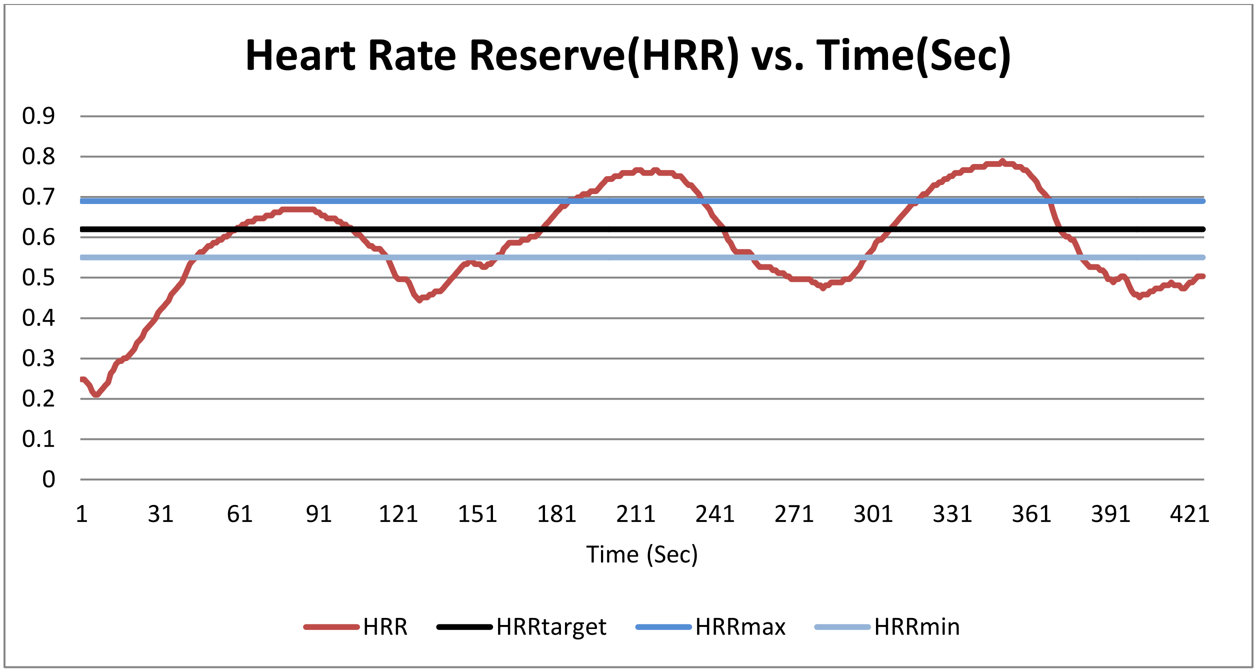


Figure 15 – Participant 3 – Heart Rate Reserve vs Time

Participant 1's HRR entered the target heart rate reserve zone at the 43 second mark. The participant had an average HRR deviation from the target HRR of 9.11(4.91).

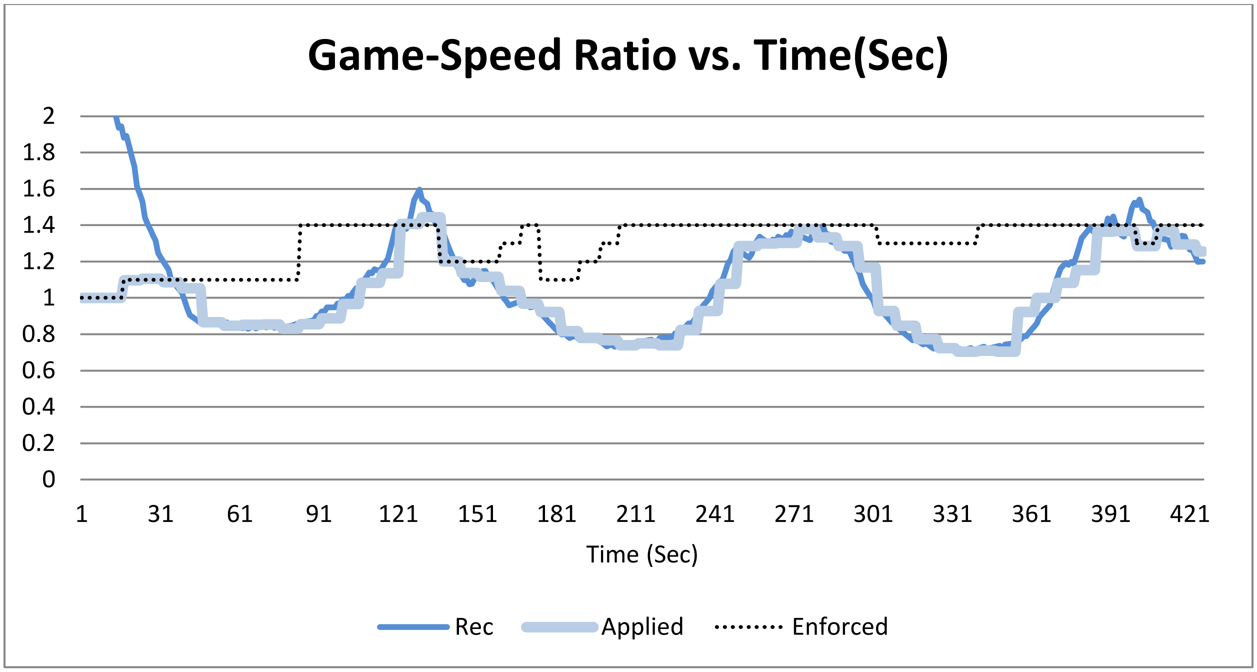


Figure 16 – Participant 3 – Game-Speed Ratio vs Time

The participant had an average game-score of 0.95(0.07). The game-speed was reduced 0% due to the participant's game-score. The mean applied ratio was 1.03 (0.23) with a mean reduction of 0(0).

6.4 Discussion

Particpant 1 represents a case where the game worked very well. This case will mostly be used as a comparison for the other two cases that did not work out as well.

Participant 2 could not reach the desired heart rate range due to their game-score being so low. This means that their proficiency at DanceBeat was less than what would be required for him to reach the desired heart rate range. Participant 2 was excluded from the previous results section due to being an outlier.

Participant 3 represents a case where DanceBeat did not restrict the game-speed based on the participant's game-score. In this case the game keeps overestimating the changes in game-speed required to achieve the desired heart rate.

6.5 Categorizing Results into Profiles

Each result from participant-level pair can be placed into one of three profiles groups. The first is the Curved profile. Participant 3 is an example of a Curved profile. The second is the Reduced profile. Participant 2 is an example of the Reduced profile. The third is the Normal profile. Participant 1 is an example of the Normal profile.

6.5.1 Curved Profile

A result is in the Curved profile group if there are at least three HRR local minima or local maxima that are outside of the target HRR zone. The HRR must cross the target HRR line between two extrema to be counted.

6.5.2 Reduced Profile

A result is in the Reduced profile group if it does not meet the requirements of the Curved profile group and it has a mean reduction greater than 0.025.

6.5.3 Normal Profile

A result is in the Normal profile group if it does not meet the requirements of the Curved or Reduced profile groups.

6.6 Profile Results

A participant may have a different profile for each level. Below is a breakdown of the participants' profile distribution and the HR_{dif} (the distance the players heart rate was from the target heart rate) of participants by profile. HR_{dif} is used instead of HRR_{dif} in this case so that it can be used as a comparison to Sinclair's game in the section *7.3 DanceBeat vs. Sinclair.*

Table 18 – The Mean Distance of Participants' HR from target HR

Level	Profile	Number	Mean HR_{dif}	StdDev
DB-Light	Normal	16	4.67	1.62
	Curved	7	9.22	3.36
	Total:	23	6.06	3.07
DB-Moderate	Normal	11	4.80	1.64
	Curved	5	8.77	2.11
	Reduced	7	11.91	3.59
	Total:	23	7.83	3.95

Table 19 – Breakdown of Participants into Profiles by Level

			Moderate					
			Normal		Curved		Reduced	
Light			11	48%	5	22%	7	30%
Normal	16	70%	7	30%	3	13%	6	26%
Curved	7	30%	4	17%	2	9%	1	4%
Reduced	0	0%	0	0%	0	0%	0	0%

6.6.1 Profile ANOVA

For each level, an analysis of variance has been performed across *Order*, *Gender* and *Profile Group* for HRR and HRR_{dif}. Significance was found for HRR_{dif} in both DB-Light ($F=23.218, P<0.001$) and DB-Moderate ($F=12.350, P=.001$). Significance was also found in DB-Moderate for HRR by Profile ($F=10.950, P=0.\ 002$).

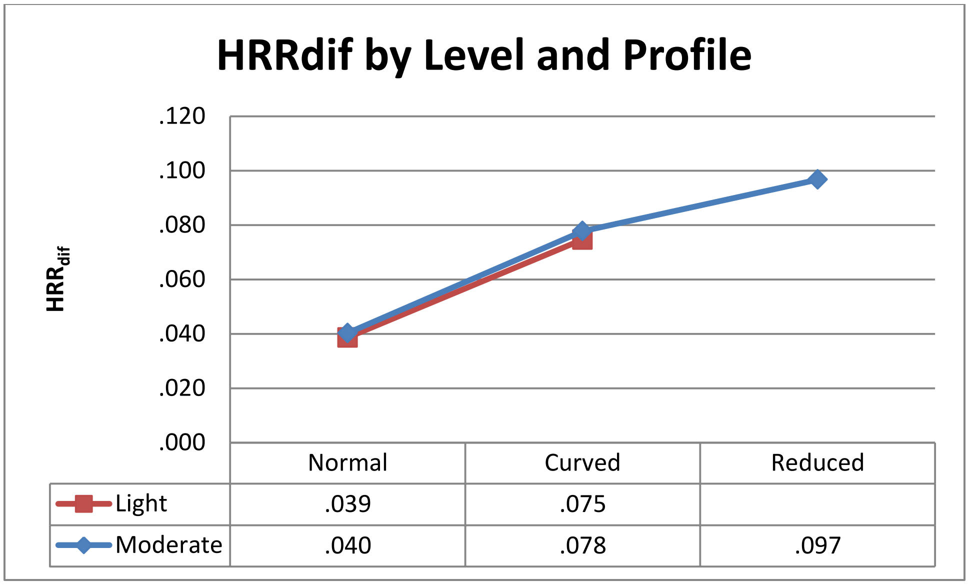


Figure 17 - HRR_{dif} by Level and Profile.

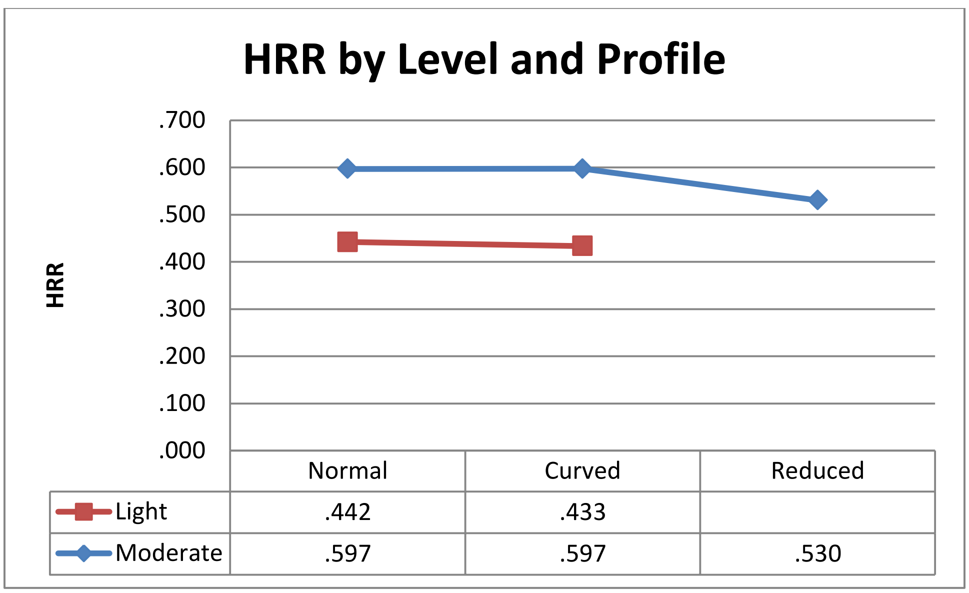


Figure 18 – HRR by Level and Profile

Significance was found for HRR (F=.005,P=.006) and HRR_{dif} (F=8.139, P=0.015) by gender, group and profile in DB-Moderate.

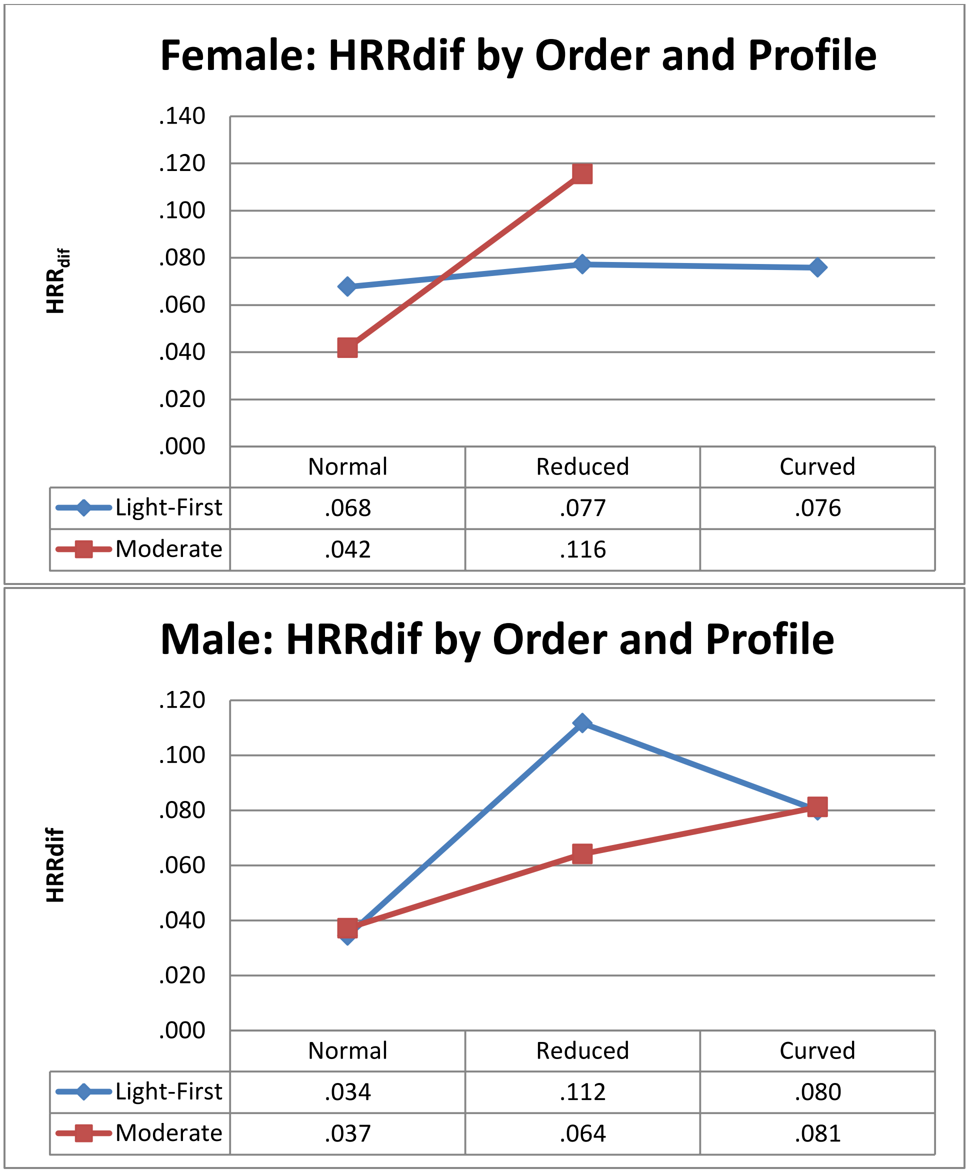
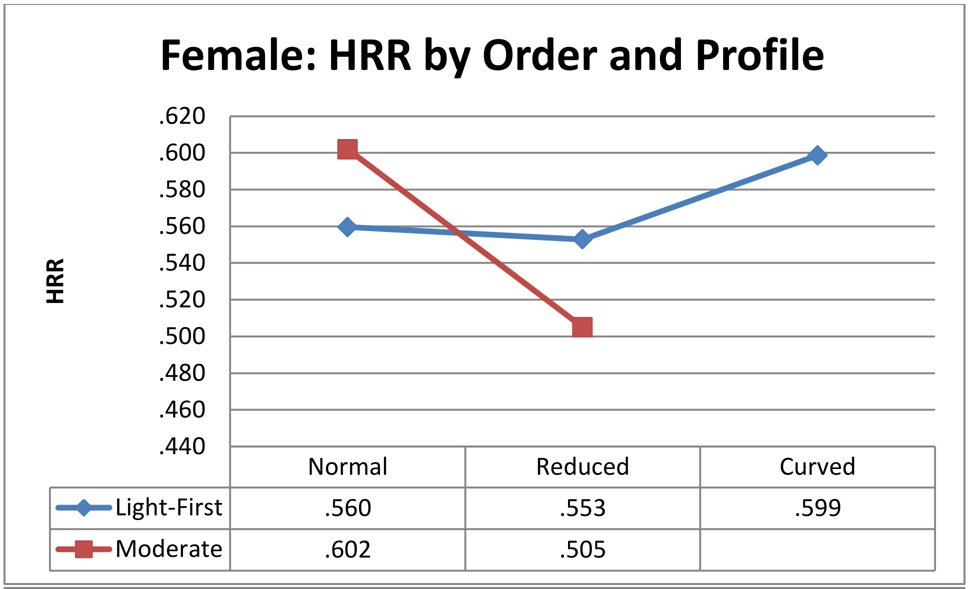


Figure 19 - HRR_{dif} by Order and Profile for Males and Females



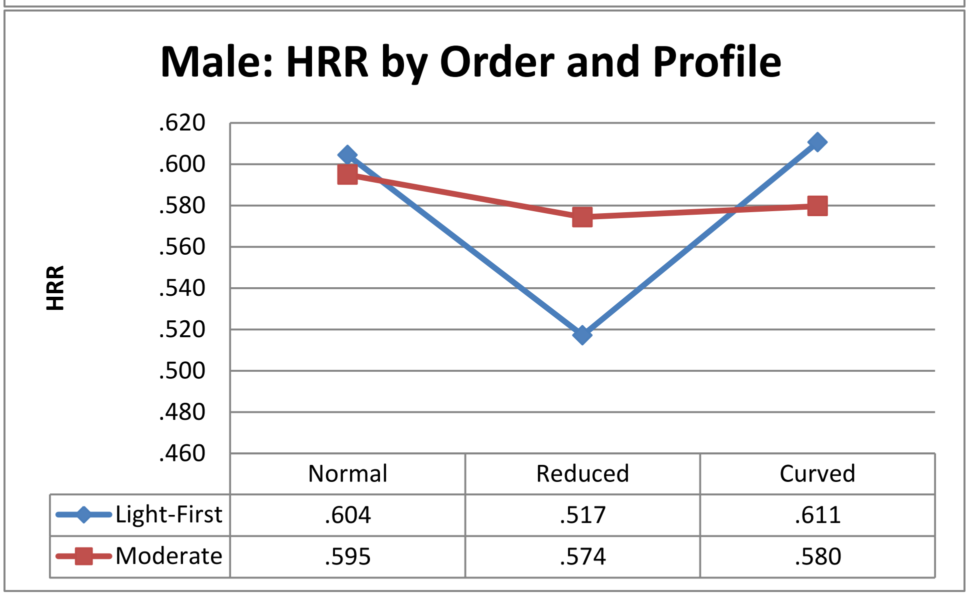


Figure 20 – HRR by Order and Profile for Males and Females

7 Discussion

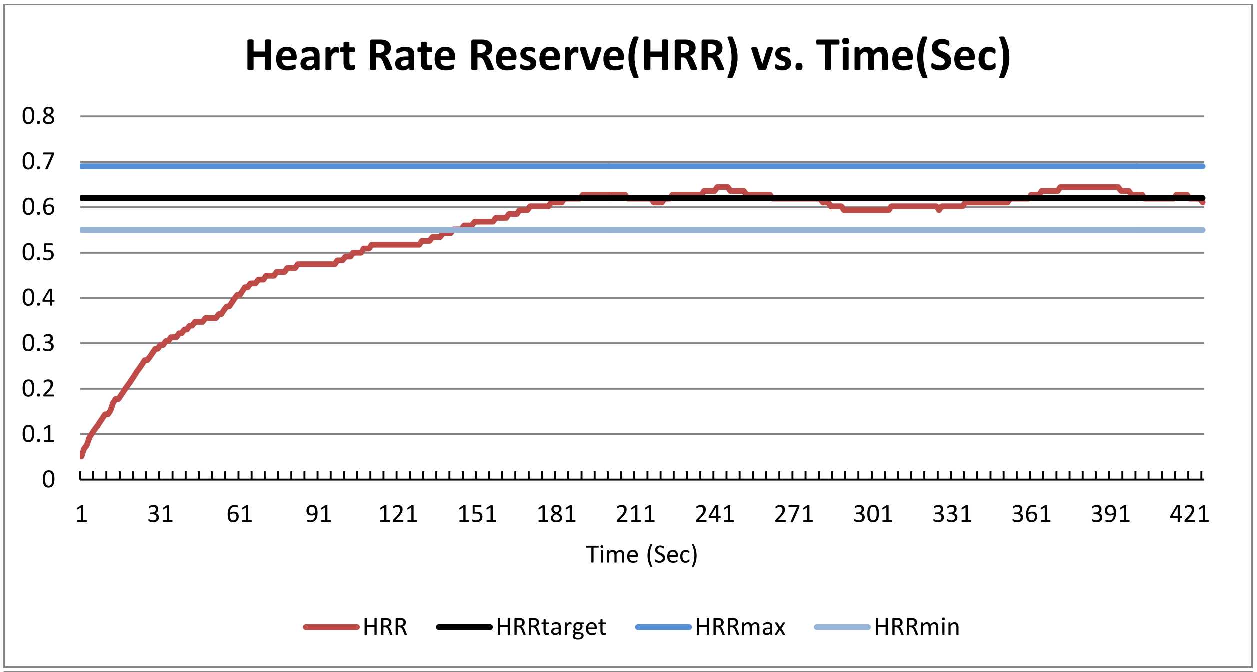
7.1 Heart Rate Control and DanceBeat Effectiveness

How effective is DanceBeat at controlling players' heart rates? What variables change the effectiveness of DanceBeat's heart rate control mechanism? This chapter covers these topics.

7.1.1 Mean HRR

Immediately we can see in *Table 7 – Mean of Mean HRR* that the mean Heart Rate Reserve for the DB-Light level and the DB-Moderate level is different (F=378.96,P<001). Table 7 also demonstrates that the mean HRR for both DB-Light and DB-Moderate fall within their respective target heart rate reserve zone for those levels. Furthermore, the 95% mean confidence interval for the two levels fall within the target heart rate reserve zones for those levels. Thus we can be convinced that DanceBeat is effective in keeping participants' mean HRR within the target zones.

7.1.2 Percentage of Time within the Target Heart Rate Reserve Zone



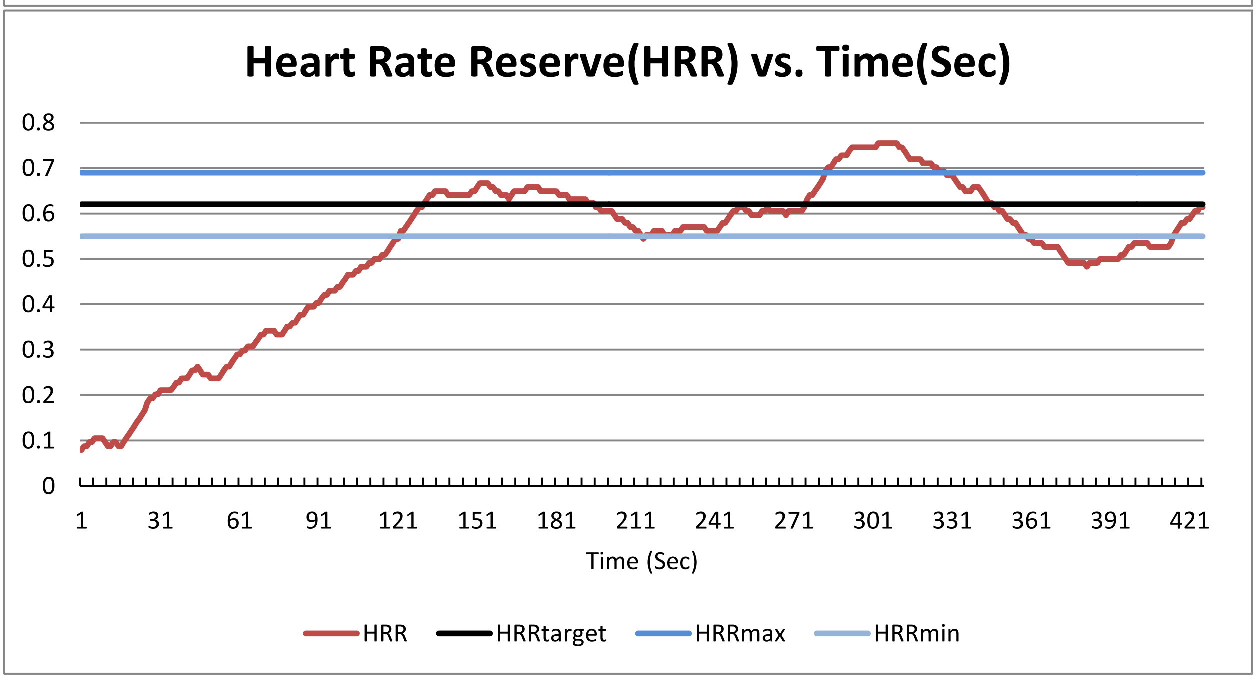


Figure 21 – Heart Rate Reserves with Similar mean HRR but different HRR_{dif} and HRR_{zone} (Participant 25M vs. 16M)

However, as the above two result graphs demonstrate, participants can have similar mean heart rate reserves (0.580(0.101) vs 0.587(0.057)) (t=-1.199,P=0.231) but have different percentages of time spent in the target heart rate zone (0.56 vs 0.78) and significantly different mean HRR_{dif} (0.0816(0.0732) vs 0.0406(0.0516)) ($t=8.66, P<0.001$).

We can use the percentage of time that the participants' HRR was in the target heart rate reserve zone as a better metric of DanceBeat's effectiveness at controlling heart rate. *Table 20 – Mean Percentage Time in Target HRR Zones* summarizes the mean percent of time participants were within the target zone. Unfortunately, the two target heart rate reserve zones are not the same size for the two levels. This makes a comparison between the time spent in the zone for Light and Moderate difficult.

In the table below, the Moderate-Expanded represents the percentage of time the participants would have been within the moderate HRR zone for DB-Moderate if the zone was the same size as the HRR zone for DB-Light.

Table 20 – Mean Percentage Time in Target HRR Zones

Level	Mean	StDev	Median	95%	
Light	87%	0.179	0.94	0.793	0.947
Moderate	67%	0.214	0.72	0.578	0.763
Moderate-Expanded	76%	0.191	0.79	0.681	0.846

7.1.3 Contributors To HRR_{dif}

DanceBeat used the center of the target heart rate zone as the point to push players' heart rate reserves towards. We call the distance from the center of the Target Heart Rate Reserve Zone to the player's actual HRR the HRR_{dif}. When discussing the effectiveness of DanceBeat, we can use HRR_{dif} to describe the distance the player was from the goal. The closer this number was to zero, the more effective DanceBeat was at controlling heart rate.

The initial ANOVA (Table 10) only shows Gender and Gender * Game Expertise as being significant interactions for mean HRR_{dif}. For a better understanding of covariate effects on HRR_{dif}, we can examine the generalized estimating equation in section 5.5. The generalized estimating equation is a generalized linear model for predicting HRR_{dif} that takes into account the correlations among observations.

7.1.3.1 Order

The regression coefficient for the HRR_{dif} predictor Order (B=0.023, P=0.008) is positive. This means that being in the Light-First order group will result in a smaller predicted HRR_{dif} than the being in the Moderate-First group. Playing the easier level before the harder level yielded better results.

There are two likely explanations for this: Learning and Fatigue.

There could be a learning effect from playing the DB-Light level first. The slower pace of the DB-Light level could allow a user to gain skill faster than the higher paced DB-Moderate level. The DB-Score had the additional purpose, beyond gathering player intro-scores, of providing an introduction or refresher to rhythm dance games. This would have reduced the learning effects seen later, but not necessarily reduced the effects entirely.

There could be a fatigue effect for playing the DB-Moderate level first. DB-Moderate has a higher mean HRR than DB-Light (F=378.96,P<0.001) and would fatigue a player more than DB-Light. There was a 5 minute break between each level; this likely reduced much of the fatigue effect.

7.1.3.2 Level

Level has a positive regression coefficient (B=0.062, P=0.002) for predicting HRR_{dif}. The predicted HRR_{dif} for playing a level is lower for DB-Light than DB-Moderate. The difference in DB-Light and DB-Moderate is the target heart rate reserve zone. Although it is difficult to abstract with only two target zones, we can expect a higher HRR_{dif} with higher target heart rate reserve zones. A study with a wider range of target heart rate reserve zones would yield better results.

7.1.3.3 Enforced Ratio, Reduction and Game-Score

Recommended ratio is capped by the enforced ratio in determining the applied ratio and thus game-speed. The enforced ratio is determined by the player's current game-score. The amount that the recommended ratio is reduced by the enforced ratio is referred to as the reduction. Reduction has a positive regression coefficient (B=0.092,P=0.010) for predicting HRR_{dif}. Restricting the game-speed due to a player's game-score reduces the effectiveness of DanceBeat's heart control mechanic. This is the idea behind the Reduced profile in *Chapter* 6*: Profile Analysis*. The usefulness of the reduction mechanic will be discussed in *Chapter* 8*: Future Design Considerations*.

Enforced ratio has a negative regression coefficient (B=-0.025, P<0.001) for predicting HRR_{dif}. The higher the enforced ratio, the smaller the HRR_{dif}. This is consistent with the results for reduction in that if the enforced ratio is high, then the reduction will be low (DB-Light(r=-0.774,P<0.001),DB-Moderate(r=-0.583,P=0.003)).

As would be expected, game-score is negatively correlated with reduction (DB-Light(r=-0.782,P<001),DB-Moderate(r=-0.626,P=0.001)) and positively correlated with applied ratio (DB-Light(r=0.998,P<0.001), DB-Moderate (r=0.991,P<0.001)). As game-score increases, the enforced ratio increases and thus reduction decreases. However, as game-score increases, the predicted HRR_{dif} increases (B=0.042, P<0.001). Keeping up with the steps provided by the game is a predictor of the game not being able to control the player's heart rate.

How do we explain this counterintuitive result? First, any rise in HRR_{dif} accounted for by a low game-score is accounted for in the model by the reduction variable. Second, higher scored individuals enter into the Curved profile. A two tailed t-test comparing game-score between the Normal and Curved profile in DB-Moderate shows that the Curved profile has a higher game-score than the Normal profile (t=2.815,0.014). Third, at some higher levels of game-score (see in Table 3 section 3.7.3 *Score Mechanics*) there are no Hops and only Taps. Hops have more predictable motion than Taps.

There is something in the game's mechanics that does not handle the Curved profile and high game-scores well. This is discussed in detail in *Chapter* 8*: Future Design Considerations*.

7.1.3.4 Applied Ratio Δ

Large changes in game-speed decrease DanceBeat's heart rate control effectiveness. Applied ratio Δ has a positive regression coefficient (B=0.017, P=0.001) for predicting HRR_{dif}. This is unsurprising as the Applied Ratio is strongly dependent on the distance the player's HRR is from their goal (see *Equation 4 – Calculation for recommended ratio* in section 3.7.2 *Heart Rate Based Mechanics*). The distance a player's HRR is from their goal is the very definition of HRR_{dif}.

It would be ideal if we could examine the effects of several small changes in game-speed as opposed to larger changes in game-speed. Unfortunately, the data does not support this type of analysis as the applied ratio is so closely coupled with HRR_{dif}. Instead, we can examine the Curved profile in the profile analysis section. The Curved profile gives us the indication that the game can overreact to the distance between the player's heart rate and the target heart rate.

7.1.3.5 Game-Speed

As the game gets faster, DanceBeat is less able to control players' heart rates. Game-speed is a positive predictor (B=0.004, P=0.037) of HRR_{dif}. The higher the target HRR, the higher the game-speed,

This, along with Level being a positive predictor (B=0.062, P=0.002) of HRR_{dif}, suggest that the game will not work as well for very high target heart rate reserve zones.

7.1.3.6 Gender

There was found a significant difference for mean HRR_{dif} between Genders (F=4.964 , P=.048). There is a negative regression coefficient for gender (female=0,male=1) (B=-0.029,P<001) in predicting HRR_{dif}. DanceBeat's heart rate control mechanic is predicted to work better with males than females.

An interaction was also found between game-expertise and gender for mean HRR_{dif} (F=4.085, P=0.047) (Table 10).

7.1.4 Heart Rate Reserve Ranges

The target heart rate reserve zones used in DanceBeat for the DB-Light and DB-Moderate levels were using outdated guidelines (Armstrong et al., 2006). Updated guidelines (Thompson et al., 2010) differ from the ones used in DanceBeat. The new guidelines recommend a heart rate reserve range of 20-39 for light intensity exercise as opposed to the 35-54 used by DanceBeat. Likewise, a range of 40-59 was recommended for moderate intensity exercise as opposed to the 55-69 used. The new guideline for hard or rigorous intensity exercise is 60-84. As the new recommended zones are lower than the ones used, and the target heart rate reserve zone is a predictor of the game's effectiveness, we can predict that the game will be more effective in controlling heart rate for each level if the levels are defined by the new zones. Furthermore, as the target heart rate for DB-moderate was within the new rigorous intensity zone, it can be assumed that DanceBeat will be at least somewhat effective for providing rigorous exercise.

7.2 Enjoyment of DanceBeat

The amount participants enjoyed playing DanceBeat is closely linked to the goals of this thesis and the successfulness of the design of DanceBeat. Participants self-reported their enjoyment for DanceBeat in the post-trial questionnaire. The results of the questionnaire can be found on Table 17 – *Preference for DanceBeat* and in Appendix D. However, caution must be used when considering these results as the study used a convenience sample. It can be assumed that people who are more interested in and have a higher preference for active video games would be more likely to participate in this study. This means that the study's sample is likely to have a preference for video games that is not representative of the population at large.

As the sample may be biased towards enjoyment of active video games, positive claims about the enjoyment of DanceBeat are difficult to make. Ninety-six percent of participants agreed or strongly agreed to the statement "I enjoyed playing DanceBeat". What we can conclude from this statement is that the players, who are likely biased towards these types of games, did not have a negative attitude towards the DanceBeat.

Two of the questions asked in the post-trial questionnaire where about the enjoyment of DanceBeat in relation to other rhythm dance games. This can give us a slightly clearer picture of preference for DanceBeat as it better accounts for the bias of a convenience. Seventy eight percent of the participants agreed or strongly agreed to the statement "I enjoyed playing DanceBeat as much as other rhythm dance games". Thirty-nine percent of participants reported agreed or strongly agreeing to the statement "I enjoyed playing DanceBeat more than other rhythm dance games" while fifty-two percent of the participants where neutral on the statement.

It should be considered that a similar bias towards active video games would likely be found in those of the general population who would be interested in trying DanceBeat. Although we cannot generalize the results to the entire population, we can predict with some amount of confidence that there is a subset of the population that will find DanceBeat enjoyable.

7.3 DanceBeat vs. Sinclair

It is important to know how DanceBeat compares to Sinclair's heart rate controlling exergame. In *Table 18 – The Mean Distance of Participants' HR from target HR*, the differences between heart rate and target heart rate is shown by profile. DB-moderate is compared to Sinclair et al's (2010) PID controlled active video game due to the similar target heart rates (60% HRR vs. 62% of DanceBeat's DB-moderate level). There is no difference between the Normal profile and Sinclair's game (P=0.517, t=-0.664). There was a significant difference found between combined profiles (Normal, Reduced, and Curved) and Sinclair's game (P=0.001. t=-3.942).

When DanceBeat works as expected, it works as well as Sinclair's game. But there are profiles for which DanceBeat does not work nearly as well. A moment should be taken to examine the likely reasons for this difference.

One of the main differences between DanceBeat and Sinclair's game is the difference of input devices. DanceBeat uses a dance pad as its input whereas Sinclair's game uses an exercise bike. We know that the intensity of the exertion achieved in a rhythm dance game can be limited by the player's skill (Thin & Poole, 2010). On the other hand, we would not expect to see significant differences in energy expenditures on an exercise bike based on skill. This gives us a good explanation of the differences between Sinclair's game's results and the Reduced profile's results.

Sinclair's game uses a PID controller feedback loop. This is a more sophisticated method of controlling the player's heart rate than the one used by DanceBeat. The PID controller would likely not result in as many over or under estimations as the method used by DanceBeat. This is likely the cause of the difference between Sinclair's game and the Curved profile.

Despite Sinclair's game performing better in many places, there is still an important place for DanceBeat. It is important for there to be diversity in active video games (Radon et al. 2011). Further, rhythm dance games may be more motivating than active video games using an exercise bike as an input (Epstein et al. 2007).

7.4 Design Considerations

DanceBeat does not encourage the player to focus on their own heart-rate during play. Instead, DanceBeat presents the player with the steps and tempo necessary to achieve the target heart rate. The player's focus should be on the steps that are on the screen and not the amount of exercise that they are performing.

It should be considered that someone who has an interest in active video games may also be someone who does not enjoy physical activity for its own sake. The design of an active video game should attempt to reduce a player's focus on physical exertion. The player's focus should instead by on the gameplay mechanics and the in-game goals. The mechanics should be designed so that achieving the in-game goals results in the desired amount of physical exertion.

8 Future Design Considerations

This section contains recommendations for future design changes for DanceBeat.

8.1 Predictive Vs. Reactive Game-Speed

DanceBeat makes decisions for a new game-speed based entirely on the player's current information. It uses the player's current HRR, HRR_{dif}, HRR_{vec}, game-speed, and game-score to determine the steps and tempo presented to the player. The initial game-speed was arbitrarily chosen. A better method would be to calculate an appropriate game-speed based on the desired heart rate range. We can use the refined generalized estimating equation for game-speed as a model to predict the best game-speed option with which to begin a level.

The equation takes the form of:

Equation 8 – Calculation for Initial Game-Speed.

$$GameSpeed = \hat{y} = B_0 + B_1 x_1 + B_2 x_2 = -0.874 + 4.449 * HRR_{Target} + 0.0.949 * IntroScore$$

When a level begins, the above equation will be used to select the starting game-speed. It is unlikely that this will produce the optimal game-speed for every player. This equation is not a replacement for the heart rate control mechanic, but rather a point from which to begin.

8.2 Profile Analysis

This section examines the profiles discussed in the profile analysis chapter in the light of future game design considerations. The Normal profile is obviously the most desirable profile as it has the lowest mean HRR_{dif} for both levels (DB-Light ($F=23.218, P<0.001$), DB-Moderate ($F=12.350, P=0.001$)). If DanceBeat could consistently cause players to be in the Normal profile, then there would be little use for this section. Ways in which DanceBeat's Normal profile can be promoted need to be explored.

8.2.1 Reduced Profile and Balance Mechanics

It is likely that there will always be players that will fall into the Reduced profile. The participant in case study 2 is an example of a player that may lack the dexterity to reach the desired heart rate reserve zone despite any changes made to the game's design. Despite that, we wish to bring as many participants as possible into the Normal profile. Players in the Reduced profile are there as a result of the score mechanic (see section 3.7.3 *Score Mechanics*). Optimizing the score mechanic based on the analysis in *Chapter* 5 *Results* and *Chapter* 6*: Profile Analysis* should give us a better way of handling low game-scores. Having a predictor for the starting game-speed and knowing the mean game-score will allow for design considerations that were not possible without them.

We cannot ignore one of the reasons for the score mechanic. It is more preferable for users to remain engaged with the game but maintain a high HRR_{dif} and low HRR than have the player give up on the game in frustration. Without a score mechanic, players who have less skill at rhythm dance games may not be able to keep up with the pace required to achieve the target heart rate reserve. The heart rate mechanic would continually increase the game-speed to try to bring the player up to the target. The already poorly performing player would become increasingly frustrated with a game that presents a difficulty that moves farther and farther out of their reach.

The current version of the game's score mechanic was partially an attempt to control for player performance. The player is presented with slower or simpler steps if their game-score is low, and with more complicated steps if their game-score is high. However, when the current score mechanic was designed, there was no hard data on which to base decisions. The mechanic was based on arbitrarily chosen values which were only tested on a small collection of pre-test players. Using the data provided by the study, a better score mechanic can be created.

Firstly, the current balancing mechanic should be examined for where it falls short.

8.2.1.1 Improper Game-Score Calculation

The current score mechanic makes decisions every 7.5 seconds based on the last 20 seconds of the player's score. The score mechanic should be choosing new game settings based on the player's response to the current game settings. However, since the game makes decisions faster than the effects of the decisions are shown, an unfortunate amount of now meaningless data is added to the decision-making mechanic.

Instead, after the score mechanic makes a decision, the player's score from before that decision should not be reflected in the next decision point. A decision based on game-score should only be made after there is enough information on which to base the decision. There should be at least 15 seconds of score data before making a decision. Then there must be at least 15 seconds after a score mechanic decision before making the next one.

8.2.1.2 Lack of Memory

The current mechanic lacks a memory of the player's response to previous settings; it tends to return to old settings that did not work.

Suppose a player's game-score falls below 0.7 and, as *Table 3 – Settings Base on Game-Score in Chapter* 3*: Game Design* describes, the game increases the percentage of hop steps, reduces the maximum difficulty of the steps to 7, and sets the Enforced Ratio to 1.0. If this is a comfortable place for the player to be the player's game-score would rise as a result. By the time the player's game-score went over 0.75 the percentage of jump steps would decrease, the maximum difficulty of steps would increase, and the enforced ratio would increase. This would effectively undo the good done by the initial decision by the balance mechanic to lower these settings.

In the example above, it would be preferable if the game kept presenting the user with the higher percentage of hop steps and with the lower maximum step difficulty. A better mechanic would be to arrange the score mechanic effects into a ladder and only move up or down the ladder when the player crossed certain score thresholds. Appropriate values for thresholds can be defined by examining the mean game-score of the Normal profile (0.771 (0.044)). The thresholds can be two standard deviations above and below the mean. The lower threshold would be 0.683 and the upper threshold would be 0.859.

We call this concept the "difficulty ladder". Some details of the difficulty ladder are dependent on the following sections of this chapter and so the ladder is described in detail in *Section 8.4: The Difficulty Ladder*.

8.2.1.3 Enforced Ratio

The current mechanic for assigning enforced ratio does not work well with the new difficulty ladder mechanic. Instead, the enforced ratio should only last for a short time after the player has crossed a threshold for the difficulty ladder mechanic. Every time that a player goes down a rung on the Difficulty Ladder the enforced ratio should be 1.0 for the next 15 seconds. This also corresponds with the number of seconds before the next score mechanic decision. In effect, if a player is having problems with the current game-speed and difficulty, the game attempts to resolve the difficulty problem before trying to increase the game-speed. The game-speed may still be reduced during this time.

There will still be instances where, even on the lowest difficulty settings, the only way to get a player engaged with the game is to reduce the game-speed. To account for this, every time a player goes beneath the bottom rung of the difficulty ladder, the game-speed should be reduced at that time.

8.2.2 Curved Profile

8.2.2.1 Rethinking Enforced Ratios

The curved profile is a result of the game alternating between overestimating and underestimating the Game-Speeds that will result in the desired HRR. The most straight forward way to address this issue is to place limitations on the rate at which the game can change the game-speed.

Currently, there is an effective limitation of how much the game-speed can increase of x1.4 every 7.5 seconds. This limitation is lower if the player's game-score is lower. Before there was a predicting equation for an appropriate starting game-speed, the game-speed may have needed to rise quickly for higher target heart rates. With the predicting equation for game-speed, the game will start with a game-speed that will result in a heart rate reserve closer to the target. There is less of a need to allow for large changes in game-speed.

The maximum rate that the game-speed can change should be reduced while still allowing the game to refine the game-speed. The mean and standard deviation for game-speed (with a HRR_{target}=0.532 and Intro-Score=0.793) is estimated to be 2.247(0.087) by the refined generalized estimating equation for game-speed in Table 15. We would like the mechanic to be able to reach a reasonable game-speed for 99% of the participants within 3 changes of game-speed. If we choose the range for allowed applied ratios to be [0.9, 1.1] then the range of game-speed reachable within three changes is [1.63, 2.99] (assuming the initial speed is 2.247). This falls within three standard deviations of the mean game-speed and using the empirical rule we can see that this should account for 99% of the players within three changes of game speed.

Without having to be concerned about large changes in the game-speed, the mechanics can focus more on accuracy. At every decision point, the game should only consider changing the game-speed under three circumstances:

1. Overshooting: The player's HRR is over the heart rate reserve target and the predicted HRR ($HRR+HRR_{vec}$) is greater than the player's HRR and the top of the target heart rate reserve zone.
2. Undershooting: The player's HRR is under the heart rate reserve target and the predicted HRR is less than the player's HRR and the bottom of the target heart rate reserve zone.
3. Steady-State: There is little movement in the player's HRR; the player's HRR_{vec} is between -1.0 and 1.0.

If a game-speed change is triggered by overshooting, the result is a reduction in game-speed. Likewise, if a game-speed change is triggered by undershooting, the result is an increase in game-speed. If a game-speed change is triggered by the player's heart rate reaching a steady state, the game will make adjustments to get the participant close to the target.

As the player's heart rate will likely take time to react to the change in game-speed, the enforced ratio for the next decision point should be set to 1.0.

8.2.2.2 Proportional-Integral-Derivative Controller

Another step that could be taken to reduce the likelihood of the Curved profile is to follow Sinclair's (2010) lead and use a proportional-integral-derivative (PID) controller. A full discussion of the implementation of a PID controller including its tuning is too involved for a future work chapter. But based on the findings of Sinclair et al. (2010) it can be seen that it may be a better way to find a new steps-per-second than using DanceBeat's current HR_{vec} method.

8.3 Hops and Taps

In *Chapter* 3*: Game Design*, some of the differences between taps and hops were discussed. In this section, we will examine the difference between taps and hops in controlling heart rate. Unfortunately, the study did not gather enough accurate information to build a model to predict the effectiveness of the game based on the number of steps and hops. However, we can use some observations about the nature of taps and hops to help us improve the game design.

The motion for taps is less consistent than the motion for hops. In order for the game pad to register a hop, the player must remove his weight from both game pad buttons that his feet are currently on. This can only be performed by a jumping motion. The motion for taps can range from a stomping motion to a smaller point of the toe. A tap can involve the player shifting their weight, or remaining in the same position. The type of tap that a player will use is not easily predicted and can change often. The different type of tap motions can have a large variation in physical demand. From this we can guess that taps are less effective in controlling players' heart rates.

Based on score mechanics described in *Chapter* 3*: Game Design*, players with higher scores are less likely to be given hop steps and more likely to be given tap steps. This may go some of the way to explaining the counterintuitive results found for the regression coefficient of game-score in predicting HRR_{dif} ($B=0.042$, $P<0.001$).

The temptation is to change the steps to be given to the player to all hops. In early versions of DanceBeat, a similar method was tried without success. Early players consistently complained of shin or calf pain. Including taps and hops in the steps presented reduced the number of complaints.

A new percentage of hop steps should be obtained for at least higher game-scores. An optimal percentage of hop steps cannot be obtained from the current data. The number of jumps and hops are too tied to the player's game-score to be able to examine them separately. We can safely assume that the percentage should be greater than 0%, and likely less than 75%. Future studies should attempt to determine this percentage.

8.4 The Difficulty Ladder

The above design concepts are combined here into a new solid mechanic. The level will begin on the 3rd rung of the difficulty ladder and will move up or down when the player's game-score crosses the thresholds. At each level, the variables take on the values of that rung of the ladder.

D_{max} – The maximum step difficulty that can be presented to the user.

D_{min} – the minimum step difficulty that can be presented to the user.

%HS – The percentage of steps presented to the user that are hop steps.

Table 21 – Difficulty ladder

1	D_{max}=9 D_{min}=5 %HS=1/4
2	D_{max}=8 D_{min}=4 %HS=1/4
3	D_{max}=7 D_{min}=3 %HS=1/4
4	D_{max}=7 D_{min}=2 %HS=1/4
5	D_{max}=7 D_{min}=2 %HS=2/4
6	D_{max}=6 D_{min}=1 %HS=2/4
7	D_{max}=6 D_{min}=1 %HS=4/6
8	D_{max}=5 D_{min}=1 %HS=4/6
9	D_{max}=5 D_{min}=1 %HS=3/4
10	GameSpeed*0.9

8.5 Music Considerations

A video game cannot hold a player's attention indefinitely. Eventually a player will become bored and will not return to the game. However, we can increase the amount of time that a player will remain interested in a game by providing them with new content. In terms of DanceBeat, more content would mean more music or levels.

Currently, there are only two songs that are included in DanceBeat. *Eating Candies* by *Vospi* was used for the DB-Score level and *Beethoven Virus* by *Diana Boncheva* was used in DB-Light and DB-Moderate. Due to copyright considerations, this music will not be distributed with DanceBeat. Instead, DanceBeat should automate the process of taking a song and transforming it into a complete DanceBeat level. In this way, DanceBeat could use a player's existing library of music as the available levels to play.

This would require creating several step difficulties for the music. This is a task that the Dance Gorilla program would be able to perform. It would also be required to change the tempo of the song in real time. There are open source libraries that are able to perform just such a task. Incorporating Dance Gorilla and the correct audio library into DanceBeat would allow the importing of a player's music library.

We may be able to increase the length of interest in DanceBeat by allowing users to import their own music libraries.

8.6 Future Game Design Summary

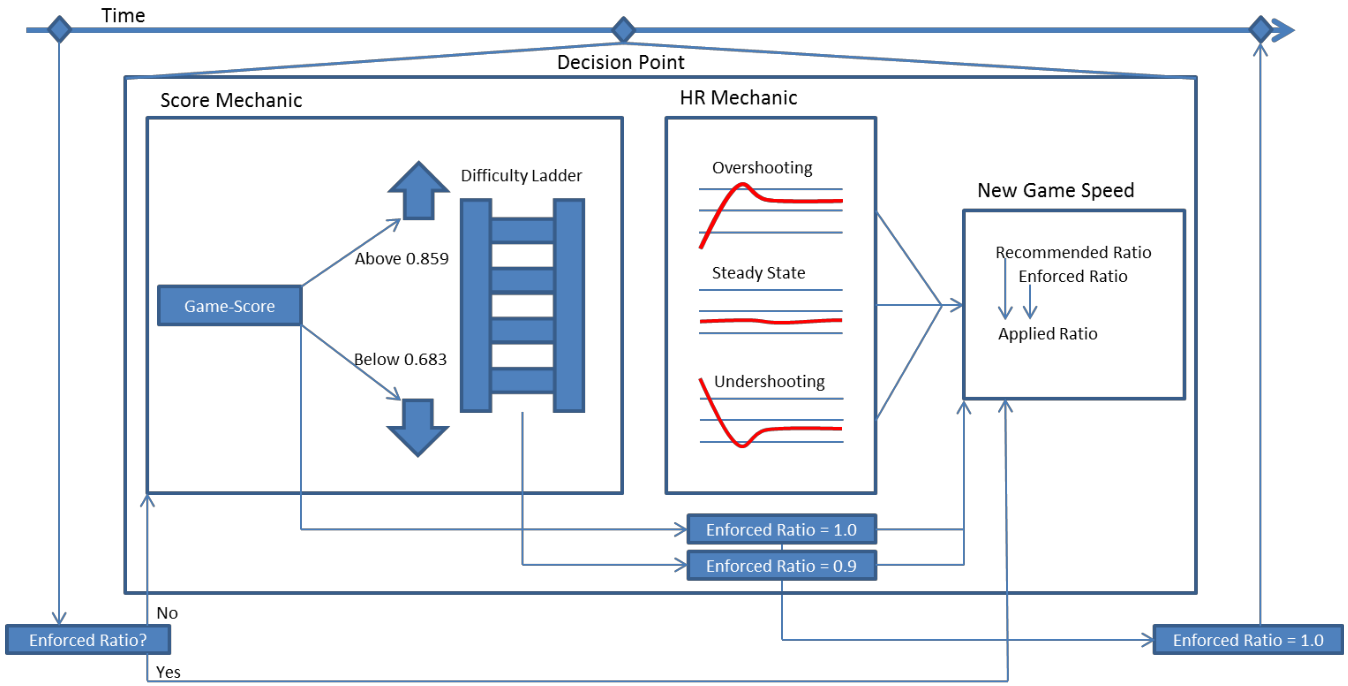


Figure 22 – Game Mechanics including difficulty ladder

Every 7.5 seconds the game reaches a decision point. If the enforced ratio is set, the game skips this decision point and unsets the enforced ratio. The player's game-score determines if the player moves up or down or remains in place on the difficulty ladder. The player's position on the difficulty ladder determines the maximum and minimum difficulty of the steps presented as well as the percentage of hop steps. If the player moves down the difficulty ladder, the enforced ratio is set to 1.0. If the player moves to the last rung of the difficulty ladder and the enforced ratio is set to 0.9, a game-speed change is triggered. If the player is overshooting or undershooting the target heart rate or if the player's heart rate is in a steady state, the game will choose a new game-speed. The new game-speed is chosen using the minimum of the enforced ratio and the recommended ratio. If the game-speed has changed, the enforced ratio will be set to 1.0 for the next decision point.

9 Conclusion

In recent years, there has been an increase in physical inactivity and an increase in consumption of media. This coincides with an increase in obesity rates and an increase in chronic diseases. One approach to encouraging physical activity is to make the activity itself more enjoyable. DanceBeat is an attempt to promote physical activity by taking an enjoyable game and making it conform to desired intensities of physical activity.

The literature suggests that an active video game is more enjoyable than its sedentary counterparts. A boxing game with a physical component is more enjoyable than a sedentary boxing game.

Not all active video games meet the physiological requirements to be used as exercise. Specifically, many of the games in Wii Sports do not meet these requirements. When designing active video games, we must consider the physiological requirements of playing that game and ensure that if this game is meant to be used as exercise it can meet the levels of exertion recommended by the ACSM.

For an active video game to meet specific physiological requirements such as causing the player to fit within a desired heart rate reserve range the game must adapt to the player. The player's fitness, game experience, and play style can all have a large impact on the physiological responses of that player to playing an active video game. In order to control the physiological responses that a player has to an active video game, the game must measure the player's current response and modify its own behavior accordingly.

In the literature, there are active video games that respond to the player's heart rate. The game *Heart Burn* uses heart rate as a balancing mechanic for a multiplayer active video game played using a stationary cycle. The game *Pulse Masters Biathlon* changes parameters in the game to get the player to self-regulate their own heart rate. Triple Bbeat chooses the tempo of songs for running to influence the runner's heart rate. Sinclair's game changes the parameters of itself so that playing the game well puts the player into a target heart rate range.

More than just balancing the physiological demands, a game must balance the challenge level. Balancing the challenge of a game to a player's skill is one of the most important parts of promoting enjoyment in a game. The variation in player skill demands that we change the difficulty of the game dynamically.

DanceBeat is a rhythm dance game. DanceBeat is built off of the open source project StepMania but has the heart rate control and balance mechanic where StepMania does not. DanceBeat is designed with four main levels. The first level gathers the players sitting heart rate. The second level estimates the players' abilities in rhythm dance games. The other two levels are identical in all but the target heart rate parameters. DanceBeat changes the tempo and the steps that are presented to the user on the fly. The game changes in order to promote the player's heart rate being as close to the target heart rate as the game can manage.

9.1 The Study and Results

A study (n=23) was performed to determine the effectiveness of DanceBeat's heart rate control mechanic. The results of the study show that DanceBeat can control the player's heart rate. To support this claim, the mean HRR for the two levels are compared and it is noted that they are significantly different ($F=378.96$, $P<001$). The 95% confidence intervals of the HRR for the two levels fall within the target zones for their respective levels. The only difference between these two levels is the set target HRR and the target HRR zones. The game was able to adapt to both target HRRs and get the player into the target HRR zone.

In the post-trial questionnaire, most participants either agreed or strongly agreed with the statement "I enjoyed playing DanceBeat." There was only a single participant that disagreed with that statement.

We can conclude that DanceBeat can control the participant's heart rates, keep their heart rates within a desired heart rate range, and that it is an enjoyable game to at least some amount of the population. This conclusion reflects the research question in the introduction and the overall goals of DanceBeat. This is reinforced by the fact the participant's mean time spent within the desired zones was 87% for DB-lite and 67% for DB-moderate.

The heart rate data can also be examined from the difference between the player's HRR and the target. This is referred to as the HRR_{dif}. Using a generalized estimating equation, the data can give us some clues to what causes the heart rate control mechanic to work better and what caused the heart rate control mechanic to work less. DB-light resulted in a smaller HRR_{dif} than DB-Moderate ($B=0.062$, $P=0.002$). The higher the target HRR, the less precise was the game's control. This was also true for game-speed, the faster the game had to go to get the player into the zone, the less control the game had on the player's heart rate ($B=0.062$, $P=0.002$).

Despite DanceBeat being able to keep the mean HRR within the desired zone, there where identifiable times where the game did not function as well as intended. Each participant's results for DB-Light and DB-moderate could be categorized into one of three profiles. The Normal profile was the default profile which participants' results for a level fell into if they were not in another profile. The Normal profile is the one in which the game worked the best. A participant's results for a level were in the Curved profile if there were at least three points where a local minima or maxima were outside the target HRR zone. The reduced profile is caused by DanceBeat's heart rate control mechanic repeatedly overcompensating. The final profile was the Reduced profile. A participant's results were considered in the Reduced profile if their game-speed was reduced by the game-score by a significant amount. The Reduced profile is caused by the player's abilities not being sufficient enough to reach the target goal. The Curved profile has a larger HRR_{dif} than the Normal profile and the Reduced profile has a larger HRR_{dif} than the Curved profile.

A comparison of DanceBeat's DB-moderate to Sinclair's game shows us that there is no difference between the game's ability to control heart rate for the normal profile (P=0.517, t=-0.664), but there is a difference with all profiles combined (P=0.001. t=-3.942).

All of this is to say that, although the game worked very well in some conditions, there are conditions under which DanceBeat does not work as well as hoped, and that these conditions should be addressed in a future version of DanceBeat.

9.2 Future Work

Chapter 8, *Future Design Considerations* contains many specific recommendations for a future version of DanceBeat. These recommendations address strategies to avoid the Curved and Reduced profiles. These recommendations also take advantage of the generalized estimating equations to provide an equation for initial game-speed. Chapter 8 describes a new balance mechanic called the Difficulty ladder which should help avoid the reduced profile. These changes should be made to the current version of DanceBeat and repeat tests should be made.

Up until this point, we have avoided attempting to define DanceBeat as exercise according to the precise definition of the word. The ACSM prescribes warm up and cool down times, these should be included in the game. Perhaps the game should include profiles that adjust the workout time based on how many times you have played in a given week.

Additional songs should be added to the game allowing the players to have a variety of music to play over the course of their entire workout. The algorithm for creating levels should be automated so that players can add songs from their own music library and have them as part of their work out.

A longitudinal study should be performed to see if DanceBeat can effectively be used as an exercise, and to measure adherence to an exercise program using DanceBeat. This study should also examine the long-term physiological effects of repeated uses of DanceBeat.

Players can get bored with some games faster than with others. Part of the suggested longitudinal study should be to measure peoples' preference for the game over time. Ideally, a comparison of player preference should be made between providing a library of songs for the players and the players being able to add their own songs.

10 References

1. Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: an update of activity codes and MET intensities. *Medicine and science in sports and exercise*. 2000;32:S498-S516.
2. Anders M. As good as the real thing. *ACE fitnessmatters*. 2008;(August):7-9. Available at: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:As+good+as+the+Real+Thing?#1. Accessed August 16, 2012.
3. Andrade G, Ramalho G, Gomes AS, Corruble V. Dynamic Game Balancing : an Evaluation of User Satisfaction. *AIIDE*. 2006;1:3-8.
4. Armstrong LE, Whaley MH, Otto RM, Brubaker PH, American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription.* Baltimore: Lippincott Williams & Wilkins; 2006.
5. Bailey C, Katchabaw M. An experimental testbed to enable auto-dynamic difficulty in modern video games. In: *Proceedings of the 2005 GameOn North America Conference*.; 2005:18--22. Available at: http://www.cp.eng.chula.ac.th/~vishnu/gameResearch/AI_november_2005/AN EXPERIMENTAL TESTBED TO ENABLE AUTO-DYNAMIC DIFFICULTY IN MODERN VIDEO GAMES.pdf. Accessed August 16, 2012.
6. Barkley JE, Penko A. Physiologic responses, perceived exertion, and hedonics of playing a physical interactive video game relative to a sedentary alternative and treadmill walking in adults. *Journal of Exercise Physiology*. 2009;12(3):12-23.
7. Becker K. *The invention of good games: understanding learning design in commercial video games.* ; 2008.
8. Biddiss E, Irwin J. Active Video Games to Promote Physical Activity in Children and Youth: A Systematic Review. *Archives of Pediatrics & Adolescent Medicine*. 2010;164:664-672.
9. Booth FW, Gordon SE, Carlson CJ, Hamilton MT. Waging war on modern chronic diseases: primary prevention through exercise biology. *Scandinavian Journal of Medicine & Science in Sports*. 2000;10:308-309.
10. Bowyer A, Thomas R, Bowyer S. HEART-RATE RESPONSE TO EXERCISE IN NORMAL WOMEN. *METHODS OF INFORMATION IN MEDICINE*. 1993;32:206-210.
11. Buttussi F, Chittaro L, Ranon R, Verona A. Adaptation of graphics and gameplay in fitness games by exploiting motion and physiological sensors. In: Vol 4569. Berlin, Heidelberg: Springer Berlin Heidelberg; 2007:85-96.
12. Csikszentmihalyi M. *Flow: The Psychology of Optimal Experience.* New York: Harper & Row; 1990.
13. Epstein LH, Beecher MD, Graf JL, Roemmich JN. Choice of interactive dance and bicycle games in overweight and nonoverweight youth. *Annals of Behavioral Medicine*. 2007;33:124-131
14. Goldfield GS, Kalakanis LE, Ernst MM, Epstein LH. Open-loop feedback to increase physical activity in obese children. *International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity*. 2000;24:888-892.
15. Graf DL, Pratt LV, Hester CN, Short KR. Playing active video games increases energy expenditure in children. *Pediatrics*. 2009;124:534.
16. Graves LEF, Ridgers ND, Stratton G. The contribution of upper limb and total body movement to adolescents' energy expenditure whilst playing Nintendo Wii. *European Journal of Applied Physiology*. 2008;104:617-623.
17. Huizinga J. *Homo Ludens: A Study of the Play-Element in Culture.* Vol 3. London: Routledge; 1998.

18. Jackson SA, Eklund RC. Assessing flow in physical activity: The Flow-State Scale-2 and Dispositional Flow Scale-2. *Journal of Sport & Exercise Psychology*. 2002;24:133.
19. Jordan M, Donne B, Fletcher D. Only lower limb controlled interactive computer gaming enables an effective increase in energy expenditure. *European Journal of Applied Physiology*. 2011;111:1465-1472.
20. Krzemiński K, Nazar K, Cybulski G, Niewiadomski W. Endurance training slows down the kinetics of heart rate increase in the transition from moderate to heavier submaximal exercise intensities. *European Journal of Applied Physiology and Occupational Physiology*. 1991;62:297-300.
21. Lance C. Dalleck, Len Kravitz. RELATIONSHIP BETWEEN %HEART RATE RESERVE AND %VO2 RESERVE DURING ELLIPTICAL CROSSTRAINER EXERCISE. *Journal of Sports Science and Medicine*. 2006;5:662-671.
22. Leatherdale ST, Woodruff SJ, Manske SR. Energy expenditure while playing active and inactive video games. *American journal of health behavior*. 2010;34:31.
23. Marshall SJ, Biddle SJH, Gorely T, Cameron N, Murdey I. Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis. *International Journal of Obesity*. 2004;28:1238-1246.
24. Martins N, Consalvo M, Williams D, Ivory JD. The virtual census: representations of gender, race and age in video games. *New Media & Society*. 2009;11:815-834.
25. Masuko S, Hoshino J. A fitness game reflecting heart rate. *Proceedings of the 2006 ACM SIGCHI international conference on Advances in computer entertainment technology - ACE ’06*. 2006:53. Available at: http://portal.acm.org/citation.cfm?doid=1178823.1178886.
26. Miyachi M, Yamamoto K, Ohkawara K, Tanaka S. METs in adults while playing active video games: a metabolic chamber study. *Medicine and science in sports and exercise*. 2010;42:1149.
27. Mueller F, Agamanolis S. Remote impact: shadowboxing over a distance. *CHI’08 extended abstracts ….* 2008:2291-2296. Available at: http://dl.acm.org/citation.cfm?id=1358672. Accessed August 16, 2012.
28. Mueller F, Agamanolis S. Sports over a distance. *Computers in Entertainment*. 2005;3:4.
29. Mueller F, Gibbs MR, Vetere F. Design influence on social play in distributed exertion games. In: *Proceedings of the 27th international conference on Human factors in computing systems - CHI ’09*. New York, New York, USA: ACM Press; 2009:1539. Available at: http://portal.acm.org/citation.cfm?doid=1518701.1518938.
30. Mueller F, Stevens G, Thorogood A, O’Brien S, Wulf V. Sports over a Distance. *Personal and Ubiquitous Computing*. 2007;11:633-645.
31. Mueller F, Vetere F, Gibbs M, Agamanolis S, Sheridan J. Jogging over a distance: the influence of design in parallel exertion games. Association for Computing Machinery. 2010;1(212):63-68. Available at: http://dl.acm.org/citation.cfm?id=1836145. Accessed August 16, 2012.
32. Mueller F. Exertion interfaces: sports over a distance for social bonding and fun. In: *Proceedings of the SIGCHI ….*; 2003:561-568. Available at: http://dl.acm.org/citation.cfm?id=642709. Accessed August 16, 2012.
33. Nenonen V, Lindblad A, Hakkinen V, et al. Using Heart Rate to Control an Interactive Game of Technology. In: *CHI*.; 2007:853-856.
34. Ninentdo. Consolidated Sales Transition by Region. 2011:2000. Available at: http://www.nintendo.co.jp/ir/library/historical_data/pdf/consolidated_sales_e1012.pdf. Retrieved February 24, 2011
35. Oh Y, Yang S. Defining Exergames & Exergaming. In: *Proceedings of Meaningful Play 2010*.; 2010:1-17. Available at: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Defining+Exergames+&+Exer

gaming#0. Accessed August 16, 2012.
36. Oliveira RD, Oliver N. TripleBeat: enhancing exercise performance with persuasion. In: *Proceedings of the 10th international conference on Human computer interaction with mobile devices and services*.; 2008:255-264. Available at: http://dl.acm.org/citation.cfm?id=1409268. Accessed August 16, 2012.
37. Oliver N, Kreger-Stickles L. Enhancing Exercise Performance through Real-time Physiological Monitoring and Music: A User Study. *2006 Pervasive Health Conference and Workshops.* IEEE; 2006:1-10.
38. Pasch M, Berthouze N, Dijk BV, Nijholt A. Motivations, strategies, and movement patterns of video gamers playing Nintendo Wii boxing. In: *Facial and Bodily Expressions for Control and Adaptation of Games*.; 2008:27-33. Available at: http://doc.utwente.nl/64921/1/ecag2008-2.pdf. Accessed August 16, 2012.
39. Penko AL, Barkley JE. Motivation and physiologic responses of playing a physically interactive video game relative to a sedentary alternative in children. *Annals of behavioral medicine : a publication of the Society of Behavioral Medicine*. 2010;39:162-169.
40. Radon K, Fürbeck B, Thomas S, Siegfried W, Nowak D, von Kries R. Feasibility of activity-promoting video games among obese adolescents and young adults in a clinical setting. *Journal of Science and Medicine in Sport*. 2011;14:42-45.
41. Rideout VJ, Foehr UG, Roberts DF. Kaiser Foundation Study: Generation M2. Media in the Lives of 8 to 18 year olds. 2010. Available at: http://myweb.wwu.edu/karlberg/444/readings/GenM2.pdf. Accessed August 16, 2012.
42. Ridgers ND, McKinney J, Stratton G, Graves LEF. Comparing the physiological cost of step-powered video gaming, sedentary video gaming, and self-paced ambulatory activity in university students. Archives of Exercise in Health and Disease. 2011;2:81-88.
43. Ryan RM, Frederick CM, Lepes D, Rubio N, Sheldon KM. Intrinsic motivation and exercise adherence. *International Journal of Sport Psychology*. 1997;28(4):335-354. Available at: http://www.londonmet.ac.uk/fms/LondonMet/Academic Admin/AIU/Cousework/2009/ReAssesments/n-o/NF/2/NF1008N Behavioural Studies - Ryan et al (1997).pdf. Accessed August 16, 2012.
44. Saelens BE, Epstein LH. Behavioral engineering of activity choice in obese children. *International Journal of Obesity*. 1998;22:275-277.
45. Salen K, Zimmerman E. *Rules of Play: Game Design Fundamentals.* Cambridge, Mass: MIT Press; 2004.
46. Sell K, Lillie T, Taylor J. Energy expenditure during physically interactive video game playing in male college students with different playing experience. *Journal of American college health : J of ACH*. 2008;56:505-512.
47. Sheehan D, Katz L. The practical and theoretical implications of flow theory and intrinsic motivation in designing and implementing exergaming in the school environment. *The Journal of the Canadian Game Studies Association*. 2012;6(9):53-68. Available at: http://journals.sfu.ca/loading/index.php/loading/article/viewArticle/103. Accessed August 16, 2012.
48. Sinclair J, Hingston P, Masek M, Nosaka K. Testing an exergame for effectiveness and attractiveness. *2010 2nd International IEEE Consumer Electronics Society's Games Innovations Conference.* IEEE; 2010:1-8.
49. Sinclair J. Feedback control for exergames. 2011. Available at: http://ro.ecu.edu.au/theses/380/. Accessed August 16, 2012.
50. Stach T, Graham T. Heart rate control of exercise video games. *Proceedings of Graphics ….* 2009:125-132. Available at: http://dl.acm.org/citation.cfm?id=1555912. Accessed August 16,

2012.
51. Stubbs CO, Lee AJ. The obesity epidemic: both energy intake and physical activity contribute. *Medical Journal of Australia*. 2004;181(9):489-491.
52. Swain C, Fullerton T, Hoffman S. *Game Design Workshop: A Playcentric Approach to Creating Innovative Games.* Amsterdam: Elsevier Morgan Kaufmann; 2008.
53. Swain DP, Leutholtz BC. Heart rate reserve is equivalent to %VO2 reserve, not to %VO2max. *Medicine and science in sports and exercise*. 1997;29:410.
54. Sweetser P, Wyeth P. GameFlow: a model for evaluating player enjoyment in games. *Computers in Entertainment*. 2005;3:3.
55. Tan B, Aziz AR, Chua K, Teh KC. Aerobic demands of the dance simulation game. *International journal of sports medicine*. 2002;23:125-129.
56. Thin AG, Poole N. Dance-based exergaming: user experience design implications for maximizing health benefits based on exercise intensity and perceived enjoyment. *Transactions on edutainment IV*. 2010:189-199. Available at: http://www.springerlink.com/index/U35G1287H58557J1.pdf. Accessed August 16, 2012.
57. Thompson WR, Gordon NF, Pescatello LS, American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription.* Philadelphia: Lippincott Williams & Wilkins; 2010.
58. Tucker T. Tetris Weightlifting: An Exploration in Entertainment Fitness. 2006:24. Available at: http://www.tetrisweightlifting.com/artifacts/tetris_weightlifting_paper.doc.
59. van Lankveld G, Spronck P, van den Herik H, Rauterberg M. Incongruity-based adaptive game balancing. *Advances in computer games*. 2010:208-220. Available at: http://www.springerlink.com/index/L356L33154838107.pdf. Accessed August 16, 2012.
60. Vansteenkiste M, Lens W, Deci EL. Intrinsic Versus Extrinsic Goal Contents in Self-Determination Theory: Another Look at the Quality of Academic Motivation. *Educational Psychologist*. 2006;41:19-31.
61. Warburton DER, Bredin SSD, Horita LTL, et al. The health benefits of interactive video game exercise. Applied physiology, nutrition, and metabolism = Physiologie appliquée, nutrition et métabolisme. 2007;32:655-663.
62. Wigfield A, Guthrie JT, Tonks S, Perencevich KC. Children's Motivation for Reading: Domain Specificity and Instructional Influences. *The Journal of Educational Research*. 2004;97:299-309.
63. Willems MET, Bond TS. Comparison of Physiological and Metabolic Responses to Playing Nintendo Wii Sports and Brisk Treadmill Walking by. *Journal of Human Kinetics*. 2009;22(November):43-50.
64. Williams D, Yee N, Caplan SE. Who plays, how much, and why? Debunking the stereotypical gamer profile. *Journal of Computer-Mediated Communication*. 2008;13:993-1018.
65. Zephyr. *Validity of BioHarness ™ Heart Rate vs 3-lead ECG*. 2008. Available at: http://www.zephyr-technology.com/store/images/stories/pdf/whitepaper_heartratevalidation.pdf.

11 Appendix A

Output from SPSS

11.1 Repeated Measures ANOVA

Tests of Within-Subjects Contrasts

Source	Measure	Level	Type III Sum of Squares	df	Mean Square	F	Sig.
Level	HRR	Linear	.186	1	.186	378.960	.000
	HRRdif	Linear	.001	1	.001	2.329	.155
Level * Group	HRR	Linear	6.156E-5	1	6.156E-5	.126	.730
	HRRdif	Linear	.000	1	.000	.787	.394
Level * Gender	HRR	Linear	.001	1	.001	1.031	.332
	HRRdif	Linear	1.553E-5	1	1.553E-5	.030	.866
Level * GameExpertise	HRR	Linear	.001	2	.000	.716	.510
	HRRdif	Linear	.003	2	.002	3.104	.085
Level * Group * Gender	HRR	Linear	.000	1	.000	.214	.652
	HRRdif	Linear	.000	1	.000	.197	.666
Level * Group * GameExpertise	HRR	Linear	.001	2	.001	1.213	.334
	HRRdif	Linear	.001	2	.001	1.015	.394
Level * Gender * GameExpertise	HRR	Linear	.003	2	.001	2.681	.113
	HRRdif	Linear	.002	2	.001	1.987	.183
Level * Group * Gender * GameExpertise	HRR	Linear	.000	2	.000	.411	.673
	HRRdif	Linear	.002	2	.001	1.450	.276
Error(Level)	HRR	Linear	.005	11	.000		
	HRRdif	Linear	.006	11	.001		

Tests of Between-Subjects Effects

Transformed Variable:Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	HRR	9.671	1	9.671	13928.391	.000
	HRRdif	.116	1	.116	274.799	.000
Group	HRR	.000	1	.000	.202	.662
	HRRdif	1.123E-5	1	1.123E-5	.027	.873
Gender	HRR	.001	1	.001	1.592	.233
	HRRdif	.002	1	.002	4.964	.048
GameExpertise	HRR	.000	2	7.712E-5	.111	.896
	HRRdif	.002	2	.001	1.803	.210
Group * Gender	HRR	9.081E-5	1	9.081E-5	.131	.724
	HRRdif	.000	1	.000	.712	.417
Group * GameExpertise	HRR	.005	2	.003	3.943	.051
	HRRdif	.001	2	.001	1.383	.291
Gender * GameExpertise	HRR	.003	2	.001	2.120	.166
	HRRdif	.003	2	.002	4.085	.047
Group * Gender * GameExpertise	HRR	.003	2	.001	1.832	.206
	HRRdif	.002	2	.001	2.678	.113
Error	HRR	.008	11	.001		
	HRRdif	.005	11	.000		

11.2 Correlations

```
CORRELATIONS
  /VARIABLES=Sitting SMScore GameScore GameExpertise HRR appliedDist recDist HRRzone HRRdif recomendedRatio
enforcedratio soundSpeedIndex stepDifficultyIndex stepsPerSecond gamescore_A reduction
  /PRINT=TWOTAIL NOSIG
  /MISSING=PAIRWISE.
```

Correlations

		Sitting	SMScore	GameScore	Game-Expertise	HRR	Applied-Dist	recDist	HRRzone	HRRdif	recomendedRatio	enforcedratio	soundSpeedIndex	stepDifficultyIndex	stepsPerSecond	gamescore	reduction
Sitting	Pearson Correlation	1	.064	-.033	.053	.152	.086	-.302	.044	.021	-.304	.136	-.173	-.273	-.289	.125	-.062
	Sig. (2-tailed)		.765	.877	.805	.477	.690	.152	.838	.922	.149	.526	.418	.196	.171	.560	.773
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
SM-Score	Pearson Correlation	.064	1	.961**	.927**	-.054	.269	.048	-.111	.111	-.029	.562**	.510*	.516**	.401	.551**	-.266
	Sig. (2-tailed)	.765		.000	.000	.803	.204	.826	.606	.605	.891	.004	.011	.010	.052	.005	.209
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

Game-Score	Pearson Correlation	-.033	.961**	1	.870**	-.155	.342	.184	-.242	.226	.088	.535**	.599**	.563**	.465*	.529**	-.250
	Sig. (2-tailed)	.877	.000		.000	.468	.102	.391	.255	.288	.684	.007	.002	.004	.022	.008	.239
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Game-Expertise	Pearson Correlation	.053	.927**	.870**	1	-.152	.189	.086	-.158	.168	.060	.437*	.507*	.460*	.373	.430*	-.105
	Sig. (2-tailed)	.805	.000	.000		.479	.377	.691	.461	.432	.781	.033	.011	.024	.073	.036	.627
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
HRR	Pearson Correlation	.152	-.054	-.155	-.152	1	-.118	-.437*	.552**	-.453*	-.895**	.424*	-.498*	-.233	-.354	.422*	-.728**
	Sig. (2-tailed)	.477	.803	.468	.479		.581	.033	.005	.026	.000	.039	.013	.274	.090	.040	.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Applied-Dist	Pearson Correlation	.086	.269	.342	.189	-.118	1	.811**	-.764**	.858**	.305	.317	-.005	.067	-.016	.305	-.257
	Sig. (2-tailed)	.690	.204	.102	.377	.581		.000	.000	.000	.147	.131	.982	.755	.943	.147	.226
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

recDist	Pearson Correlation	-.302	.048	.184	.086	-.437*	.811**	1	-.921**	.924**	.687**	.045	.040	.006	-.003	.048	.075
	Sig. (2-tailed)	.152	.826	.391	.691	.033	.000		.000	.000	.000	.834	.851	.978	.987	.824	.726
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
HRR-zone	Pearson Correlation	.044	-.111	-.242	-.158	.552**	-.764**	-.921**	1	-.945**	-.731**	-.008	-.106	.018	.001	-.008	-.191
	Sig. (2-tailed)	.838	.606	.255	.461	.005	.000	.000		.000	.000	.971	.623	.934	.998	.970	.370
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
HRRdif	Pearson Correlation	.021	.111	.226	.168	-.453*	.858**	.924**	-.945**	1	.626**	.011	.102	.021	.029	.005	.141
	Sig. (2-tailed)	.922	.605	.288	.432	.026	.000	.000	.000		.001	.961	.634	.923	.891	.982	.511
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
recomended Ratio	Pearson Correlation	-.304	-.029	.088	.060	-.895**	.305	.687**	-.731**	.626**	1	-.347	.370	.138	.232	-.334	.622**
	Sig. (2-tailed)	.149	.891	.684	.781	.000	.147	.000	.000	.001		.097	.075	.519	.275	.111	.001
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

enforcedratio	Pearson Correlation	.136	.562**	.535**	.437*	.424*	.317	.045	-.008	.011	-.347	1	-.134	-.114	-.317	.998**	-.774**
	Sig. (2-tailed)	.526	.004	.007	.033	.039	.131	.834	.971	.961	.097		.532	.594	.131	.000	.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
soundSpeedIndex	Pearson Correlation	-.173	.510*	.599**	.507*	-.498*	-.005	.040	-.106	.102	.370	-.134	1	.762**	.798**	-.128	.308
	Sig. (2-tailed)	.418	.011	.002	.011	.013	.982	.851	.623	.634	.075	.532		.000	.000	.550	.144
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
stepDifficultyIndex	Pearson Correlation	-.273	.516**	.563**	.460*	-.233	.067	.006	.018	.021	.138	-.114	.762**	1	.970**	-.110	.067
	Sig. (2-tailed)	.196	.010	.004	.024	.274	.755	.978	.934	.923	.519	.594	.000		.000	.610	.757
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
stepsPerSecond	Pearson Correlation	-.289	.401	.465*	.373	-.354	-.016	-.003	.001	.029	.232	-.317	.798**	.970**	1	-.316	.266
	Sig. (2-tailed)	.171	.052	.022	.073	.090	.943	.987	.998	.891	.275	.131	.000	.000		.133	.209
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

gamescore	Pearson Correlation	.125	.551**	.529**	.430*	.422*	.305	.048	-.008	.005	-.334	.998**	-.128	-.110	-.316	1	-.782**
	Sig. (2-tailed)	.560	.005	.008	.036	.040	.147	.824	.970	.982	.111	.000	.550	.610	.133		.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
reduction	Pearson Correlation	-.062	-.266	-.250	-.105	-.728**	-.257	.075	-.191	.141	.622**	-.774**	.308	.067	.266	-.782**	1
	Sig. (2-tailed)	.773	.209	.239	.627	.000	.226	.726	.370	.511	.001	.000	.144	.757	.209	.000	
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

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CORRELATIONS
  /VARIABLES=Sitting_A SMScore_A GameScore_B GameExpertise_A HRR_A appliedDist_A recDist_A HRRzone_A
HRRdif_A recomendedRatio_A enforcedratio_A soundSpeedIndex_A stepDifficultyIndex_A stepsPerSecond_A
gamescore_C reduction_B
  /PRINT=TWOTAIL NOSIG
  /MISSING=PAIRWISE.
```

Correlations

		Sitting	SMScore	GameScore	GameExpertise	HRR	appliedDist	recDist	HRRzone	HRRdif	recomendedRatio	enforcedratio	soundSpeedIndex	stepDifficultyIndex	stepsPerSecond	gamescore	reduction
Sitting	Pearson Correlation	1	.064	-.033	.053	.137	.264	-.247	-.121	-.029	-.276	.268	-.062	-.142	-.262	.221	-.240
	Sig. (2-tailed)		.765	.877	.805	.525	.212	.245	.574	.892	.192	.205	.775	.508	.216	.299	.259
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
SMScore	Pearson Correlation	.064	1	.961**	.927**	.159	.375	.101	-.004	.023	-.083	.741**	.354	.575**	.317	.755**	-.259
	Sig. (2-tailed)	.765		.000	.000	.457	.071	.639	.985	.914	.699	.000	.089	.003	.131	.000	.222
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
GameScore	Pearson Correlation	-.033	.961**	1	.870**	.132	.305	.118	.031	.026	-.052	.683**	.408*	.608**	.371	.700**	-.228
	Sig. (2-tailed)	.877	.000		.000	.539	.148	.584	.886	.905	.810	.000	.048	.002	.074	.000	.284
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

GameExpertise	Pearson Correlation	.053	.927**	.870**	1	.081	.251	.141	-.021	.065	-.009	.631**	.387	.574**	.354	.654**	-.191
	Sig. (2-tailed)	.805	.000	.000		.707	.236	.512	.923	.761	.966	.001	.062	.003	.089	.001	.372
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
HRR	Pearson Correlation	.137	.159	.132	.081	1	.175	-.858**	.772**	-.915**	-.969**	.514*	-.253	-.051	-.288	.556**	-.945**
	Sig. (2-tailed)	.525	.457	.539	.707		.414	.000	.000	.000	.000	.010	.233	.811	.172	.005	.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
appliedDist	Pearson Correlation	.264	.375	.305	.251	.175	1	.197	-.435*	.188	-.178	.654**	-.602**	-.405*	-.613**	.571**	-.163
	Sig. (2-tailed)	.212	.071	.148	.236	.414		.356	.034	.378	.406	.001	.002	.050	.001	.004	.447
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
recDist	Pearson Correlation	-.247	.101	.118	.141	-.858**	.197	1	-.836**	.960**	.913**	-.156	-.005	-.057	.065	-.209	.875**

	Sig. (2-tailed)	.245	.639	.584	.512	.000	.356		.000	.000	.000	.468	.982	.792	.762	.326	.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
HRRzone	Pearson Correlation	-.121	-.004	.031	-.021	.772**	-.435*	-.836**	1	-.916**	-.719**	.067	.174	.230	.148	.159	-.712**
	Sig. (2-tailed)	.574	.985	.886	.923	.000	.034	.000		.000	.000	.755	.416	.280	.490	.457	.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
HRRdif	Pearson Correlation	-.029	.023	.026	.065	-.915**	.188	.960**	-.916**	1	.911**	-.210	.020	-.087	.049	-.277	.887**
	Sig. (2-tailed)	.892	.914	.905	.761	.000	.378	.000	.000		.000	.326	.924	.686	.821	.189	.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
recomendedRatio	Pearson Correlation	-.276	-.083	-.052	-.009	-.969**	-.178	.913**	-.719**	.911**	1	-.461*	.235	.070	.291	-.492*	.965**
	Sig. (2-tailed)	.192	.699	.810	.966	.000	.406	.000	.000	.000		.023	.269	.744	.168	.015	.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

enforcedratio	Pearson Correlation	.268	.741**	.683**	.631**	.514*	.654**	-.156	.067	-.210	-.461*	1	-.142	.196	-.167	.991**	-.583**
	Sig. (2-tailed)	.205	.000	.000	.001	.010	.001	.468	.755	.326	.023		.509	.358	.436	.000	.003
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
soundSpeedIndex	Pearson Correlation	-.062	.354	.408*	.387	-.253	-.602**	-.005	.174	.020	.235	-.142	1	.884**	.935**	-.081	.082
	Sig. (2-tailed)	.775	.089	.048	.062	.233	.002	.982	.416	.924	.269	.509		.000	.000	.708	.702
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
stepDifficultyIndex	Pearson Correlation	-.142	.575**	.608**	.574**	-.051	-.405*	-.057	.230	-.087	.070	.196	.884**	1	.928**	.267	-.133
	Sig. (2-tailed)	.508	.003	.002	.003	.811	.050	.792	.280	.686	.744	.358	.000		.000	.208	.536
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
stepsPerSecond	Pearson Correlation	-.262	.317	.371	.354	-.288	-.613**	.065	.148	.049	.291	-.167	.935**	.928**	1	-.100	.131

	Sig. (2-tailed)	.216	.131	.074	.089	.172	.001	.762	.490	.821	.168	.436	.000	.000		.641	.542
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
gamescore	Pearson Correlation	.221	.755**	.700**	.654**	.556**	.571**	-.209	.159	-.277	-.492*	.991**	-.081	.267	-.100	1	-.626**
	Sig. (2-tailed)	.299	.000	.000	.001	.005	.004	.326	.457	.189	.015	.000	.708	.208	.641		.001
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
reduction	Pearson Correlation	-.240	-.259	-.228	-.191	-.945**	-.163	.875**	-.712**	.887**	.965**	-.583**	.082	-.133	.131	-.626**	1
	Sig. (2-tailed)	.259	.222	.284	.372	.000	.447	.000	.000	.000	.000	.003	.702	.536	.542	.001	
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

11.2.1 Light

		Sitting	SMScore	GameScore	GameExpertise	HRR	appliedDist	recDist	HRRzone	HRRdif	recomendedRatio	enforcedratio	soundSpeedIndex	stepDifficultyIndex	stepsPerSecond	gamescore	reduction
Sitting	Pearson Correlation	1	.064	-.033	.053	.152	.086	-.302	.044	.021	-.304	.136	-.173	-.273	-.289	.125	-.062
	Sig. (2-tailed)		.765	.877	.805	.477	.690	.152	.838	.922	.149	.526	.418	.196	.171	.560	.773
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
SMScore	Pearson Correlation	.064	1	.961	.927	-.054	.269	.048	-.111	.111	-.029	.562	.510	.516	.401	.551	-.266
	Sig. (2-tailed)	.765		.000	.000	.803	.204	.826	.606	.605	.891	.004	.011	.010	.052	.005	.209
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
GameScore	Pearson Correlation	-.033	.961	1	.870	-.155	.342	.184	-.242	.226	.088	.535	.599	.563	.465	.529	-.250
	Sig. (2-tailed)	.877	.000		.000	.468	.102	.391	.255	.288	.684	.007	.002	.004	.022	.008	.239
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
GameExpertise	Pearson Correlation	.053	.927	.870	1	-.152	.189	.086	-.158	.168	.060	.437	.507	.460	.373	.430	-.105
	Sig. (2-tailed	.805	.000	.000		.479	.377	.691	.461	.432	.781	.033	.011	.024	.073	.036	.627

	)																
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
HRR	Pearson Correlation	.152	-.054	-.155	-.152	1	-.118	-.437	.552	-.453	-.895	.424	-.498	-.233	-.354	.422	-.728
	Sig. (2-tailed)	.477	.803	.468	.479		.581	.033	.005	.026	.000	.039	.013	.274	.090	.040	.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
appliedDist	Pearson Correlation	.086	.269	.342	.189	-.118	1	.811	-.764	.858	.305	.317	-.005	.067	-.016	.305	-.257
	Sig. (2-tailed)	.690	.204	.102	.377	.581		.000	.000	.000	.147	.131	.982	.755	.943	.147	.226
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
recDist	Pearson Correlation	-.302	.048	.184	.086	-.437	.811	1	-.921	.924	.687	.045	.040	.006	-.003	.048	.075
	Sig. (2-tailed)	.152	.826	.391	.691	.033	.000		.000	.000	.000	.834	.851	.978	.987	.824	.726
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
HRRzone	Pearson Correlation	.044	-.111	-.242	-.158	.552	-.764	-.921	1	-.945	-.731	-.008	-.106	.018	.001	-.008	-.191
	Sig. (2-tailed)	.838	.606	.255	.461	.005	.000	.000		.000	.000	.971	.623	.934	.998	.970	.370
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

HRRdif	Pearson Correlation	.021	.111	.226	.168	-.453	.858	.924	-.945	1	.626	.011	.102	.021	.029	.005	.141
	Sig. (2-tailed)	.922	.605	.288	.432	.026	.000	.000	.000		.001	.961	.634	.923	.891	.982	.511
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
recomendedRatio	Pearson Correlation	-.304	-.029	.088	.060	-.895	.305	.687	-.731	.626	1	-.347	.370	.138	.232	-.334	.622
	Sig. (2-tailed)	.149	.891	.684	.781	.000	.147	.000	.000	.001		.097	.075	.519	.275	.111	.001
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
enforcedratio	Pearson Correlation	.136	.562	.535	.437	.424	.317	.045	-.008	.011	-.347	1	-.134	-.114	-.317	.998	-.774
	Sig. (2-tailed)	.526	.004	.007	.033	.039	.131	.834	.971	.961	.097		.532	.594	.131	.000	.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
soundSpeedIndex	Pearson Correlation	-.173	.510	.599	.507	-.498	-.005	.040	-.106	.102	.370	-.134	1	.762	.798	-.128	.308
	Sig. (2-tailed)	.418	.011	.002	.011	.013	.982	.851	.623	.634	.075	.532		.000	.000	.550	.144
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
stepDifficultyIndex	Pearson Correlation	-.273	.516	.563	.460	-.233	.067	.006	.018	.021	.138	-.114	.762	1	.970	-.110	.067
	Sig. (2-	.196	.010	.004	.024	.274	.755	.978	.934	.923	.519	.594	.000		.000	.610	.757

	tailed)																
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
stepsPerSecond	Pearson Correlation	-.289	.401	.465	.373	-.354	-.016	-.003	.001	.029	.232	-.317	.798	.970	1	-.316	.266
	Sig. (2-tailed)	.171	.052	.022	.073	.090	.943	.987	.998	.891	.275	.131	.000	.000		.133	.209
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
gamescore	Pearson Correlation	.125	.551	.529	.430	.422	.305	.048	-.008	.005	-.334	.998	-.128	-.110	-.316	1	-.782
	Sig. (2-tailed)	.560	.005	.008	.036	.040	.147	.824	.970	.982	.111	.000	.550	.610	.133		.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
reduction	Pearson Correlation	-.062	-.266	-.250	-.105	-.728	-.257	.075	-.191	.141	.622	-.774	.308	.067	.266	-.782	1
	Sig. (2-tailed)	.773	.209	.239	.627	.000	.226	.726	.370	.511	.001	.000	.144	.757	.209	.000	
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

11.2.2 Moderate

	Sitting	SMScore	GameScore	GameExpertise	HRR	appliedDist	recDist	HRRzone	HRRdif	recomendedRatio	enforcedratio	soundSpeedIndex	stepDifficultyIndex	stepsPerSecond	gamescore	reduction

Sitting	Pearson Correlation	1	.064	-.033	.053	.137	.264	-.247	-.121	-.029	-.276	.268	-.062	-.142	-.262	.221	-.240
	Sig. (2-tailed)		.765	.877	.805	.525	.212	.245	.574	.892	.192	.205	.775	.508	.216	.299	.259
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
SMScore	Pearson Correlation	.064	1	.961	.927	.159	.375	.101	-.004	.023	-.083	.741	.354	.575	.317	.755	-.259
	Sig. (2-tailed)	.765		.000	.000	.457	.071	.639	.985	.914	.699	.000	.089	.003	.131	.000	.222
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
GameScore	Pearson Correlation	-.033	.961	1	.870	.132	.305	.118	.031	.026	-.052	.683	.408	.608	.371	.700	-.228
	Sig. (2-tailed)	.877	.000		.000	.539	.148	.584	.886	.905	.810	.000	.048	.002	.074	.000	.284
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
GameExpertise	Pearson Correlation	.053	.927	.870	1	.081	.251	.141	-.021	.065	-.009	.631	.387	.574	.354	.654	-.191
	Sig. (2-tailed)	.805	.000	.000		.707	.236	.512	.923	.761	.966	.001	.062	.003	.089	.001	.372
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
HRR	Pearson Correlation	.137	.159	.132	.081	1	.175	-.858	.772	-.915	-.969	.514	-.253	-.051	-.288	.556	-.945
	Sig. (2-	.525	.457	.539	.707		.414	.000	.000	.000	.000	.010	.233	.811	.172	.005	.000

	tailed)																
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
appliedDist	Pearson Correlation	.264	.375	.305	.251	.175	1	.197	-.435	.188	-.178	.654	-.602	-.405	-.613	.571	-.163
	Sig. (2-tailed)	.212	.071	.148	.236	.414		.356	.034	.378	.406	.001	.002	.050	.001	.004	.447
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
recDist	Pearson Correlation	-.247	.101	.118	.141	-.858	.197	1	-.836	.960	.913	-.156	-.005	-.057	.065	-.209	.875
	Sig. (2-tailed)	.245	.639	.584	.512	.000	.356		.000	.000	.000	.468	.982	.792	.762	.326	.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
HRRzone	Pearson Correlation	-.121	-.004	.031	-.021	.772	-.435	-.836	1	-.916	-.719	.067	.174	.230	.148	.159	-.712
	Sig. (2-tailed)	.574	.985	.886	.923	.000	.034	.000		.000	.000	.755	.416	.280	.490	.457	.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
HRRdif	Pearson Correlation	-.029	.023	.026	.065	-.915	.188	.960	-.916	1	.911	-.210	.020	-.087	.049	-.277	.887
	Sig. (2-tailed)	.892	.914	.905	.761	.000	.378	.000	.000		.000	.326	.924	.686	.821	.189	.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

recomendedRatio	Pearson Correlation	-.276	-.083	-.052	-.009	-.969	-.178	.913	-.719	.911	1	-.461	.235	.070	.291	-.492	.965
	Sig. (2-tailed)	.192	.699	.810	.966	.000	.406	.000	.000	.000		.023	.269	.744	.168	.015	.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
enforcedratio	Pearson Correlation	.268	.741	.683	.631	.514	.654	-.156	.067	-.210	-.461	1	-.142	.196	-.167	.991	-.583
	Sig. (2-tailed)	.205	.000	.000	.001	.010	.001	.468	.755	.326	.023		.509	.358	.436	.000	.003
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
soundSpeedIndex	Pearson Correlation	-.062	.354	.408	.387	-.253	-.602	-.005	.174	.020	.235	-.142	1	.884	.935	-.081	.082
	Sig. (2-tailed)	.775	.089	.048	.062	.233	.002	.982	.416	.924	.269	.509		.000	.000	.708	.702
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
stepDifficultyIndex	Pearson Correlation	-.142	.575	.608	.574	-.051	-.405	-.057	.230	-.087	.070	.196	.884	1	.928	.267	-.133
	Sig. (2-tailed)	.508	.003	.002	.003	.811	.050	.792	.280	.686	.744	.358	.000		.000	.208	.536
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
stepsPerSecond	Pearson Correlation	-.262	.317	.371	.354	-.288	-.613	.065	.148	.049	.291	-.167	.935	.928	1	-.100	.131
	Sig. (2-	.216	.131	.074	.089	.172	.001	.762	.490	.821	.168	.436	.000	.000		.641	.542

	tailed)																
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
gamescore	Pearson Correlation	.221	.755	.700	.654	.556	.571	-.209	.159	-.277	-.492	.991	-.081	.267	-.100	1	-.626
	Sig. (2-tailed)	.299	.000	.000	.001	.005	.004	.326	.457	.189	.015	.000	.708	.208	.641		.001
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
reduction	Pearson Correlation	-.240	-.259	-.228	-.191	-.945	-.163	.875	-.712	.887	.965	-.583	.082	-.133	.131	-.626	1
	Sig. (2-tailed)	.259	.222	.284	.372	.000	.447	.000	.000	.000	.000	.003	.702	.536	.542	.001	
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

11.2.3 Combined Marker

		Sitting	SMScore	GameScore	GameExpertise	HRR	appliedDist	recDist	HRRzone	HRRdif	recomendedRatio	enforcedratio	soundSpeedIndex	stepDifficultyIndex	stepsPerSecond	game score	reduction
Sitting	Pearson Correlation Sig. (2-tailed) N	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SMScore	Pearson Correlation Sig. (2-tailed) N	0	2	2	2	0	0	0	0	0	0	2	2	2	0	2	0
GameScore	Pearson Correlation Sig. (2-tailed) N	0	2	2	2	0	0	0	0	0	0	2	2	2	2	2	0
GameExpertise	Pearson Correlation Sig. (2-tailed) N	0	2	2	2	0	0	0	0	0	0	2	2	2	0	2	0

HRR	Pearson Correlation Sig. (2-tailed) N	0	0	0	0	2	0	2	2	2	2	2	2	0	0	2	2
appliedDist	Pearson Correlation Sig. (2-tailed) N	0	0	0	0	0	2	2	2	2	0	1	1	1	1	1	0
recDist	Pearson Correlation Sig. (2-tailed) N	0	0	0	0	2	2	2	2	2	2	0	0	0	0	0	1
HRRzone	Pearson Correlation Sig. (2-tailed) N	0	0	0	0	2	2	2	2	2	2	0	0	0	0	0	1
HRRdif	Pearson Correlation Sig. (2-	0	0	0	0	2	2	2	2	2	2	0	0	0	0	0	1

	tailed) N																
recomendedRatio	Pearson Correlation Sig. (2-tailed) N	0	0	0	0	2	0	2	2	2	2	1	0	0	0	1	2
enforcedratio	Pearson Correlation Sig. (2-tailed) N	0	2	2	2	2	1	0	0	0	1	2	0	0	0	2	2
soundSpeedIndex	Pearson Correlation Sig. (2-tailed) N	0	2	2	2	2	1	0	0	0	0	0	2	2	2	0	0
stepDifficultyIndex	Pearson Correlation Sig. (2-tailed) N	0	2	2	2	0	1	0	0	0	0	0	2	2	2	0	0

stepsPerSecond	Pearson Correlation Sig. (2-tailed) N	0	0	2	0	0	1	0	0	0	0	0	2	2	2	0	0
gamescore	Pearson Correlation Sig. (2-tailed) N	0	2	2	2	2	1	0	0	0	1	2	0	0	0	2	2
reduction	Pearson Correlation Sig. (2-tailed) N	0	0	0	0	2	0	1	1	1	2	2	0	0	0	2	2

11.3 Model for Distance from Goal

```
genlin HRRdif by newgroup newlevel with gender sitting SMScore score
enforcedratio reduction appliedRatio Apllied d1 soundSpeedIndex stepDifficultyIndex stepsPerSecond gamescore
/model newgroup newlevel gender sitting SMScore score
enforcedratio reduction appliedRatio Aplliedd1 soundSpeedIndex stepDifficultyIndex stepsPerSecond gamescore
/repeated subject = id corrtype = ar(1)
/print modelinfo cps solution workingcorr.
```

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	.034	.0316	-.028	.095	1.136	1	.287
[newgroup=1.00]	-.023	.0086	-.039	-.006	7.030	1	.008
[newgroup=2.00]	0[a]	.	.	.	.	.	.
[newlevel=1.00]	-.062	.0204	-.102	-.022	9.178	1	.002
[newlevel=2.00]	0[a]	.	.	.	.	.	.
gender	-.029	.0081	-.045	-.013	12.572	1	.000
sitting	7.383E-5	.0002	.000	.001	.104	1	.747
SMscore	-8.932E-6	5.4135E-5	.000	9.717E-5	.027	1	.869
score	.083	.0675	-.049	.215	1.508	1	.219
enforcedratio	-.025	.0068	-.038	-.011	13.152	1	.000
reduction	.092	.0356	.022	.161	6.633	1	.010
appliedRatio	.007	.0055	-.004	.018	1.710	1	.191
Aplliedd1	.017	.0051	.007	.027	11.791	1	.001

soundSpeedIndex	.000	.0002	.000	.001	2.232	1	.135
stepDifficultyIndex	.000	.0004	-.001	.000	.893	1	.345
stepsPerSecond	.004	.0020	.000	.008	4.363	1	.037
gamescore	.042	.0104	.022	.063	16.618	1	.000
(Scale)	.004						

Dependent Variable: HRRdif

Model: (Intercept), newgroup, newlevel, gender, sitting, SMscore, score, enforcedratio, reduction, appliedRatio, Aplliedd1, soundSpeedIndex, stepDifficultyIndex, stepsPerSecond, gamescore

a. Set to zero because this parameter is redundant.

11.4 Model for Game-Speed Step 1

```
genlin stepsPerSecond with TargetHRR gender sitting SMScore score
/model TargetHRR gender sitting SMScore score
SCALEWEIGHT=Scale
/repeated subject = id corrtype = ar(1)
/emmeans
/print modelinfo cps solution workingcorr.
```

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-2.144	1.2105	-4.516	.229	3.136	1	.077
TargetHRR	4.552	.5423	3.489	5.614	70.453	1	.000
gender	.176	.2786	-.370	.722	.398	1	.528
sitting	.005	.0101	-.014	.025	.276	1	.599
SMscore	-.002	.0020	-.006	.002	1.117	1	.291
score	3.485	2.0735	-.579	7.549	2.826	1	.093
(Scale)	.160						

Dependent Variable: stepsPerSecond

Model: (Intercept), TargetHRR, gender, sitting, SMscore, score

11.5 Model for Game-Speed Step 2

```
genlin stepsPerSecond with TargetHRR score
/model TargetHRR score
SCALEWEIGHT=Scale
/repeated subject = id corrtype = ar(1)
/emmeans
/print modelinfo cps solution workingcorr.
```

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-.874	.6036	-2.057	.309	2.098	1	.148
TargetHRR	4.449	.5649	3.342	5.556	62.021	1	.000
score	.949	.6287	-.283	2.182	2.281	1	.131
(Scale)	.161						

Dependent Variable: stepsPerSecond

Model: (Intercept), TargetHRR, score

Estimates

Mean	Std. Error	95% Wald Confidence Interval	
		Lower	Upper
2.247158	.0868782	2.076880	2.417436

Covariates appearing in the model are fixed at the following values: TargetHRR=.532490; score=.792502

11.6 GameScore Profile Comparison

```
GET DATA /TYPE=XLSX
  /FILE='C:\Users\Graham Baradoy\Dropbox\DanceBeat\Logs\Parsed\Summary.xlsx'
  /SHEET=name 'Sheet2'
  /CELLRANGE=full
  /READNAMES=on
  /ASSUMEDSTRWIDTH=32767.
EXECUTE.
DATASET NAME DataSet2 WINDOW=FRONT.
DATASET ACTIVATE DataSet1.
T-TEST GROUPS=ModerateProfile('Curved' 'Normal')
  /MISSING=ANALYSIS
  /VARIABLES=ScoreModerate
  /CRITERIA=CI(.95).
```

T-Test

Notes

Output Created		07-Jan-2012 14:13:27
Comments		
Input	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	24
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.

	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.
Syntax		T-TEST GROUPS=ModerateProfile('Curved' 'Normal') /MISSING=ANALYSIS /VARIABLES=ScoreModerate /CRITERIA=CI(.95).
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.002

[DataSet1]

Group Statistics

	Moderate-Profile	N	Mean	Std. Deviation	Std. Error Mean
Score-Moderate	Curved	5	.866959	.0945756	.0422955
	Normal	11	.771322	.0444720	.0134088

Independent Samples Test

	Levene's Test for Equality of Variances	t-test for Equality of Means

		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Score-Moderate	Equal variances assumed	4.455	.053	2.815	14	.014	.0956364	.0339765	.0227639	.1685088
	Equal variances not assumed			2.155	4.825	.086	.0956364	.0443701	-.0196764	.2109491

11.7 Sinclair's Game Vs DanceBeat

11.7.1 Sinclair vs DB-Moderate normal profile

Group Statistics

	Case	N	Mean	Std. Deviation	Std. Error Mean
Sinclair	0	21	4.4324	1.14290	.24940
	1	11	4.7999	1.63848	.49402

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Sinclair	Equal variances assumed	2.545	.121	-.743	30	.463	-.36754	.49457	-1.37758	.64250
	Equal variances not assumed			-.664	15.251	.517	-.36754	.55341	-1.54540	.81033

11.7.2 Sinclair vs DB-moderate all profiles

Group Statistics

	Case	N	Mean	Std. Deviation	Std. Error Mean
Sinclair	0	21	4.4324	1.14290	.24940
	1	23	7.8283	3.95411	.82449

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Sinclair	Equal variances assumed	21.173	.000	-3.790	42	.000	-3.39596	.89595	-5.20406	-1.58786
	Equal variances not assumed			-3.942	25.971	.001	-3.39596	.86138	-5.16665	-1.62526

12 Appendix A

Output from SPSS

AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire

Assess your health needs by marking all *true* statements.

History

You have had:

___ A heart attack
___ Heart surgery
___ Cardiac catheterization
___ Coronary angioplasty (PTCA)
___ Pacemaker/implantable cardiac defibrillator/rhythm disturbance
___ Heart valve disease
___ Heart failure
___ Heart transplantation
___ Congenital heart disease

*If you marked any of the statements in this section, consult your physician or other appropriate healthcare provider before engaging in exercise. You may need to use a facility with a **medically qualified staff**.*

Symptoms

___ You experience chest discomfort with exertion.
___ You experience unreasonable breathlessness.
___ You experience dizziness, fainting, blackouts.
___ You take heart medications.

Other health issues

___ You have diabetes
___ You have or asthma other lung disease.
___ You have burning or cramping in your lower legs when walking short distances.
___ You have musculoskeletal problems that limit your physical activity.
___ You have concerns about the safety of exercise.
___ You take prescription medication(s).
___ You are pregnant.

Cardiovascular risk factors

___ You are a man older than 45 years.
___ You are a woman older than 55 years, you have had a hysterectomy, or you are postmenopausal.
___ You smoke, or quite within the previous 6 mo.
___ Your BP is greater than 140/90.
___ You don't know your BP.
___ You take BP medication.
___ Your blood cholesterol level is >200 mg/dL.
___ You don't know your cholesterol level.
___ You have a close blood relative who had a heart attack before age 55 (father or brother) or age 65 (mother or sister).
___ You are physically inactive (i.e., you get less than 30 min. of physical activity on at least 3 days per week).
___ You are more than 20 pounds overweight.

*If you marked two or more of the statements in this section, you should consult your physician or other appropriate healthcare provider before engaging in exercise. You might benefit by using a facility with a **professionally qualified exercise staff** to guide your exercise program.*

___ None of the above is true.

You should be able to exercise safely without consulting your physician or other healthcare provider in a self-guided program or almost any facility that meets your exercise program needs.

Balady et al. (1998). AHA/ACSM Joint Statement: Recommendations for Cardiovascular Screening, Staffing, and Emergency Policies at Health/Fitness Facilities. *Medicine & Science in Sports & Exercise*, *30*(6). (Also in: *ACSM's Guidelines for Exercise Testing and Prescription*, 7th Edition, 2005. Lippincott Williams and Wilkins http://www.lww.com)

www.acsm-msse.org/pt/pt-core/template-journal/msse/media/0698c.htm

13 Appendix C

Consent

UNIVERSITY OF CALGARY
FACULTY OF KINESIOLOGY
Sport Technology Research Laboratory

Telephone: (403) 220-3418
Fax: (403) 284-2098
Email: katz@ucalgary.ca
www.strc.ucalgary.ca

TITLE: A Physiological Feedback Controlled Exercise Video Game

SPONSOR: Sport Technology Research Laboratory

INVESTIGATORS: Dr. Larry Katz, Graham Baradoy – 403-975-5241

This consent form is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Take the time to read this carefully and to understand any accompanying information. You will receive a copy of this form.

BACKGROUND

It is believed that we can increase interest in physical activity among youth and young adults by presenting physical activity in the form of an active video game. The popularity of commercial products such as Wii Fit, Microsoft's Kinect, and the Playstation Move are evidence of this. Unfortunately, many active video games do not provide rigorous exercise. However, if the physiological demands of active video games are increased too significantly it may reduce youth interest in these games. A balance must be struck between keeping youth interested and the physiological demands of active video games. It is hoped that we can find this balance through physiological feedback. If we make heart rate or other physiological feedback part of the controls for an active video game, it is hoped we can customize the physiological demands of an active video game to the user. In the end this should provide an attractive active video game that will keep users engaged and provide sufficient exercise.

Lower body controlled interactive dance video games would be well suited to using physiological feedback. Increases or decreases in the tempo of a song could be used to change the required frequency of player's steps. Changing the frequency of the player's steps should change the player's physiological response.

WHAT IS THE PURPOSE OF THE STUDY?

We present DanceBeat, a rhythm dance game designed to control player's heart rate. The purpose of this study is to determine if DanceBeat is capable of controlling players' heart rates.

WHAT WOULD I HAVE TO DO?

If you choose to participate, you will be playing the DanceBeat video game. We will be recording your heart rate and DanceBeat game score throughout this session.

You will be given a pre-participation questionnaire that will ask you health related questions that will help you decide if you wish to participate. The result of this questionnaire will not be kept; they will only be used to inform you on your decision to participate.

A pre-trial questionnaire will ask basic demographic information and will contain some opinion questions about video games.

You will have to fit a heart rate monitor to yourself. You will be directed towards the change rooms so that you can fit the monitor to yourself in private.

Your sitting heart rate will then be gathered. To do this, you will sit in a chair and attempt to relax for five minutes while relaxing music is played.

You will then be given an introduction to the DanceBeat. This introduction will include a 3-5 minute level of DanceBeat. You will be given five minutes to rest after the level.

You will be given two more DanceBeat levels to play. These levels will be seven minutes each. You will be given five minutes of rest between each level. The three levels will each have a different estimated exercise intensity:

- A level with an estimated light intensity exercise.
- A level with an estimated moderate intensity exercise.

The order of these levels will be randomized.

At this point, you will be directed towards the change room so that you can remove the heart rate monitor.

Finally, you will be given a post-trial questionnaire. This questionnaire will ask you opinion questions about video games and your experience during the study.

If at any time during the study you decide that you no longer wish to participate, you may stop participating immediately.

WHAT ARE THE RISKS?

The risks involved in this study are no more than the risks of a moderate intensity exercise. If you have any reason for which you would not like to participate in moderate intensity exercise, you should not participate in this study.

WILL I BENEFIT IF I TAKE PART?

If you agree to participate in this study there may or may not be a direct benefit to you. The information we get from this study may help us to provide more enjoyable exercise in the form of DanceBeat.

DO I HAVE TO PARTICIPATE?

Participation is voluntary, anonymous and confidential. You are free to discontinue participation at any time during the study.

WILL MY RECORDS BE KEPT PRIVATE?

Participation is voluntary, anonymous and confidential. No one except the researcher and supervisor will be allowed to see any of the raw data. The data is to be summarized. Only group information will used for any presentation or publication of results. The data will be stored encrypted on a secure sport medicine server and no identifying data is kept electronically. The anonymous data will be stored for three years at which time, it will be permanently erased.

IF I SUFFER A RESEARCH-RELATED INJURY, WILL I BE COMPENSATED?

In the event that you suffer injury as a result of participating in this research, no compensation will be provided to you by the Sport Technology Research Laboratory, the University of Calgary, the Calgary Health Region or the Researchers. You still have all your legal rights. Nothing said in this consent form alters your right to seek damages.

SIGNATURES

Your signature on this form indicates that you have understood to your satisfaction the information regarding your participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the investigators or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time without jeopardizing your health care. If you have further questions concerning matters related to this research, please contact:

Dr. Larry Kayz (403) 220-3418
Or
Graham Baradoy (403) 975-5241

If you have any questions concerning your rights as a possible participant in this research, please contact The Chair of the Conjoint Health Research Ethics Board at the Office of Medical Bioethics, 403-220-7990 or the Ethics Resource Officer, Internal Awards, Research Services, University of Calgary, at 403-220-3782.

Participant's Name	Signature and Date
Investigator/Delegate's Name	Signature and Date
Witness' Name	Signature and Date

The University of Calgary Conjoint Health Research Ethics Board has approved this research study.

A signed copy of this consent form has been given to you to keep for your records and reference.

14 Appendix D

Questionare

Appendix E

DanceBeat: Pretrial Questionnaire

ID # __________

Please circle the answer where appropriate.

Age: ____

Gender: Female Male

Occupation: Student Other:___________

Have you played other rhythm dance games (Dance Dance Revolution, StepMania, In the Groove) before: Yes No

If yes, which dance rhythm games have you played?

Dance Dance Revolution StepMania In the Groove Other____________

Respond to the following statements by circling the word(s) that best describe how you feel about the statement.

I have played a significant amount of dance rhythm games.

Strongly Agree Agree Neutral Disagree Strongly Disagree

I enjoy playing dance rhythm games.

Strongly Agree Agree Neutral Disagree Strongly Disagree

I spend a significant amount of time playing video games.

Strongly Agree Agree Neutral Disagree Strongly Disagree

DanceBeat: Post-Trail Questionnaire

ID # ___________

Thank you for participating in the DanceBeat research project. In order to determine if this was a useful experience, we are conducting a survey and would appreciate it if you would complete the following questionnaire. Your participation is optional, but your opinion is important to us and will help us to better understand how the program works.

Respond to the following statements by circling the word(s) that best describe how you feel about the statement.

I enjoyed playing DanceBeat.

Strongly Agree Agree Neutral Disagree Strongly Disagree

I enjoyed playing DanceBeat as much as other rhythm dance games (Dance Dance Revolution, StepMania, In the Groove).

Strongly Agree Agree Neutral Disagree Strongly Disagree

I enjoyed playing DanceBeat more than other rhythm dance games.

Strongly Agree Agree Neutral Disagree Strongly Disagree

I noticed when DanceBeat changed the tempo of the song.

Strongly Agree Agree Neutral Disagree Strongly Disagree

I would consider using DanceBeat as part of an exercise program.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Below please feel free to add any comments:

DanceBeat: Pretrial Questionnaire (with responses)

ID # __________

Please circle the answer where appropriate.

Age: ____(20.2(2.4))

	(12)	(11)
Gender:	Female	Male
	(19)	(3)
Occupation:	Student	Other:___________

Have you played other rhythm dance games (Dance Dance Revolution, StepMania, In the Groove) before: (19) Yes (4) No

If yes, which dance rhythm games have you played?

(18)	(2)	(2)	(1)
Dance Dance Revolution	StepMania	In the Groove	Other____________

Respond to the following statements by circling the word(s) that best describe how you feel about the statement.

I have played a significant amount of dance rhythm games.

(0)	(5)	(3)	(6)	(9)
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

I enjoy playing dance rhythm games.

(1)	(12)	(10)	(0)	(0)
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

I spend a significant amount of time playing video games.

(4)	(4)	(5)	(1)	(9)
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

DanceBeat: Post-Trail Questionnaire

I enjoyed playing DanceBeat.

(6)	(16)	(0)	(1)	(0)
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

I enjoyed playing DanceBeat as much as other rhythm dance games (Dance Dance Revolution, StepMania, In the Groove).

(8)	(10)	(4)	(1)	(0)
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

I enjoyed playing DanceBeat more than other rhythm dance games.

(4)	(5)	(12)	(2)	(0)
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

I noticed when DanceBeat changed the tempo of the song.

(20)	(3)	(0)	(0)	(0)
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

I would consider using DanceBeat as part of an exercise program.

(7)	(12)	(2)	(2)	(0)
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Below please feel free to add any comments:

I would consider using it as an exercise but without chaning tempo

:)

Definitely see a need for a program like this. Love that it workes in conjunction w/ Heart Rate.

Great game? I broke a sweat

It was fun

Good Fun

I can see how others could enjoy it, and how it would be a good choice of exercise for beginners. Personally I enjoy getting exercise from other alternaitves.

Just the tempo. It'd be really neat if you could be like "heart rate 125" or something. The drastic changes in the tempo where a bit confusing

If more skilled at such games I imagine the tempo change would not have been so catastrophic but the game could get very hard with a sudden change, or just with being faster inn general. I can feel myself working up a sweat though.

Note-step allignbment not quite on

Tempo Changes too extreme/sudden

I liked how it sped up once I was feeling less exhausted. It was fun!

Neato! I will keep my eyes open for the finished product :)

15 Appendix E

Poster

- **We are testing a new rhythm dance game and we need your help!**
- **This is a research study to determine the effectiveness of physiological feedback controls in active video games.**
- **Participation takes about 45 minutes.**

All you need to do is dance!

To Participate Contact: Graham Baradoy Research.UofC@gmail.com

16 Appendix F

Script

Script: Physiological Feedback Controlled Exercise Video Game

Section 0 – Consent and Pre-Trial Questionnaire: Welcome to the physiological feedback controlled exercise video game study. Before we begin, please read over the consent form. If you have any question, please do not hesitate to ask. After reading the form, if you wish to continue participating, sign the form on the last page. <Wait until participant is finished with the from> Here is the pre-participation survey. This is used to help inform your decision to participate. Please fill it out and let me know when you are finished. You do not need to share the results of this questionnaire. <Wait until finished pre-participation questionnaire> The pre-participation questionnaire is used to help inform your decision to participate. Please consider the suggestions of the questionnaire before continuing to participate. If you wish to continue to participate, please fill out the pre-trial questionnaire and let me know when you are ready to proceed.

Section 1 – Fitting the Heart Rate Monitor: Here is the heart rate monitor that you will be wearing for the study. Your heart rate and game score will be recorded throughout the study. Here is a picture of how they are fitted. <Images shown (images not yet available)> There are change rooms at the end of the hall <Direction to change rooms will be pointed>, please fit the heart rate monitor to yourself and return.

Section 2 – Sitting Heart Rate: I will now measure your sitting heart rate. This will involve you sitting in this chair and relaxing for five minutes. I will turn on some music that I hope you find relaxing.

Section 3 – Game Score:

Next you are going to play a rhythm dance game called DanceBeat.

The concept of *DanceBeat* is pretty simple. The colored arrows will scroll up from the bottom of the screen toward the top. When a color arrows overlaps the grey arrow at the top of the screen, hit the button on your pad corresponding to the direction of that arrow. When you step, a grade will appear near the center of the screen saying how accurate your step was.

<After the level> You have five minutes to take a break.

Section 5 – Workout: If you are ready, there are two more levels of DanceBeat for you to play. These will be longer levels than the one you played before. There will be five minutes between each level for you to rest. <After each level> You have five minutes to take a break. <After Each break> If you are ready, please come back to the dance pad for another level.

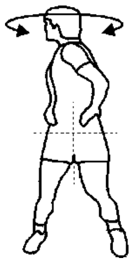
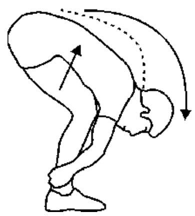
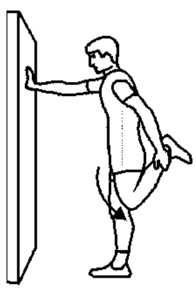
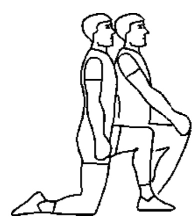
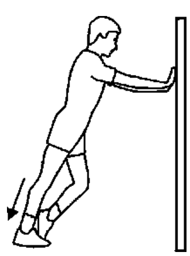
Section 6 – Post-Trial Questionnaire: That is the end of the exercise portion of this study. Could you please return to the change room so that you can take of the heart rate monitor and return it. <Wait for them to return> One last thing, there is a post-trial questionnaire I would like you to fill out. <Wait for the questionnaire to be filled out> Thank you very much for participating in the study!

17 Appendix G

Stretches

Stretch Routine

Focus on controlled movements and multiple sets
Hold each position for 2-3 seconds. Repeat each position 3-5 times.

Start from top down		Torso Rotations	
		Hamsting and low back	
		Quadricep stretch or Front lunge	
		Side Bends	
		Calves	

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