

BRIDGING THE GAP BETWEEN FUN AND FITNESS: INSTRUCTIONAL TECHNIQUES
AND REAL-WORLD APPLICATIONS FOR FULL-BODY DANCE GAMES

by

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ABSTRACT

Full-body controlled games offer the opportunity for not only entertainment, but education and exercise as well. Refined gameplay mechanics and content can boost intrinsic motivation and keep people playing over a long period of time, which is desirable for individuals who struggle with maintaining a regular exercise program. Within this gameplay genre, dance rhythm games have proven to be popular with game console owners. Yet, while other types of games utilize story mechanics that keep players engaged for dozens of hours, motion-controlled dance games are just beginning to incorporate these elements. In addition, this control scheme is still young, only becoming commercially available in the last few years. Instructional displays and clear real-time feedback remain difficult challenges.

This thesis investigates the potential for full-body dance games to be used as tools for entertainment, education, and fitness. We built several game prototypes to investigate visual, aural, and tactile methods for instruction and feedback. We also evaluated the fitness potential of the game *Dance Central 2* both by itself and with extra game content which unlocked based on performance. Significant contributions include a framework for running a longitudinal video game study, results indicating high engagement with some fitness potential, and informed discussion of how dance games could make exertion a more enjoyable experience.

Dedicated to my parents and grandmother.

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CHAPTER 1: INTRODUCTION

Motivation

Full-body interfaces, or 3D user interfaces which use the movement of a person's body as an input device, have become more prevalent in the commercial game industry. No longer only found within research labs, the market penetration of 3D user interfaces through home video game consoles has given widespread attention to this type of input device. The Nintendo Wii Remote, PlayStation Move, and Microsoft Kinect have all been successful devices with sales in the millions, indicating that a substantial amount of console owners are interested in moving their bodies while playing games.

The combination of a full-body interface and a game is sometimes referred to as an exertion game. While many commercially available games are created for entertainment purposes, these games can be used to fatigue the body for some desirable outcome, such as physical therapy or learning a body-based skill. Exertion games have the opportunity to make a large impact in a person's life, not only for fun but for positive good.

One area which is a prime focus for exertion games is making fitness more entertaining. Many people find exercising a chore rather than an enjoyable activity, but professional game development can engage a person even when exercise seems too challenging, boring, or repetitive. Motivated by external pressures such as health concerns and physical attractiveness, many people wish for the results attained by a regular exercise program but have trouble maintaining, or sometimes even initiating, such a behavioral change [22, 26]. But research suggests that once an exercise routine is followed for several weeks, people begin to develop intrinsic motivation and will continue to work out [88]. Therefore, a system that can engage a person who is not currently doing enough

cardiovascular activity might help improve their overall health.

Dance rhythm games are currently one of the best genres for initiating that change. Even before full-body game controls were so readily available, games controlled by dance pads were being used for fitness purposes [12, 40]. In Höysniemi's international survey on Dance Dance Revolution, 41% of respondents said the game was their only source of physical activity and 87.5% of self-reported overweight respondents reported weight loss [44]. The goal of a dance game is easy to understand and directly relatable to a player's body, so interaction can begin immediately. Dance games are populated by catch music, a known factor in making exercise more enjoyable [30]. And while people are often afraid to let others watch them dance, games such as *Dance Dance Revolution* developed their own sub-cultures [2, 95].

However, the amount and depth of narrative content in body-controlled dance games is still quite low. There is not as much focus on long-term play, instead depending on local multiplayer and casual party settings to entertain [31]. The genre hasn't caught up to the depth of engaging content found in other console games, possibly because game developers believe their target audience isn't interested in these things [51]. This matters because engaging content promotes long duration of play over time, and for an exertion game, this is the goal, either for fitness, education or physical therapy.

Full-body dance games require further study to bring out their full potential as impactful exertion games. They need to be easy to play and understand. Their capability for teaching dance moves or causing physiological changes in the body needs to be further explored. And they need to include more ways of enticing the player to continue play for long-term use.

This thesis work contributes to the design and evaluation of exertion games, specifically those in the dance and rhythm gameplay genre. Dance games provide a unique opportunity to provide exertion because they are a very popular type of game which promotes intrinsic motivation. Millions of

people play dance games. They have the potential to impact a person's life positively by making healthy activities, such as cardiovascular activity, more enjoyable.

Thesis Statement

By incorporating clear instructional imagery, quick, simple feedback and motivating narrative content, full-body dance games can improve the quality of experience and long-term engagement, increasing their potential to improve the well-being of the people who play them.

Research Contributions

In order to improve the well-being of a person through full-body dance games, many diverse aspects must be operating together in a user-friendly manner. From a technical standpoint, the system must be capable of instructing the user, detecting the accuracy of their input, and conveying how well they performed. These elements of a dance game provide unique challenges. The capability to detect human movement has improved greatly over the years, but the less discrete questions surrounding human preference and experience have not been as thoroughly addressed. Our research focuses on the design of human computer interaction studies of these lesser explored areas. We present the following contributions:

- **An investigation into visual instructional displays.** One of the most difficult problems is the complexity of visual instruction. Unlike other types of skill-based activities, such as learning a musical composition, playing a rhythm or dance game does not expect the player to know the move list ahead of time. This makes for a challenging real-time game experience, which is rewarding for some control schemes that use button inputs on a hand-

held controller. But the use of the human body as an input device greatly increases the set of potential input moves, and complexity in the visual interface must be simplified. We built the game prototype RealDance to explore how different visual systems for instructional displays affect experience and performance [17].

- **An investigation into visual and non-visual feedback.** Another difficult problem is delivering clear and quick feedback to a player on how to improve their technique. When the control scheme expands to include the full movement of a player's arms and legs, it can be difficult to display mistakes in real-time using only visuals, especially since the player's attention is focused on the next sequence of moves. We built the game prototype Vibraudio Pose to investigate the potential use of per-limb audio and vibration feedback [15].
- **An investigation into the teaching potential of full-body dance games.** Even if the input, detection and feedback methods are well constructed, there are many unanswered questions as to the viability of dance games to be used as more than entertainment. Aside from anecdotal speculation, the question of whether or not these games could teach someone to dance had not been answered from a research standpoint. We built Teach Me to Dance, an unencumbered dance game prototype, to explore the differences between learning dance moves with a game interface versus a video of a human instructor [16].
- **An investigation into the exercise potential of full-body dance games.** Finally, dance games, like other types of exertion gaming, are considered to be capable of being useful tools for improving physical fitness. From a physiological standpoint, there are two important questions to ask: does this game have the potential to lead to adherence? And if this behavior is adopted, does this lead to an actual difference in fitness? The first question can be answered through the process of standard fitness and body composition tests, but proving the second is much more difficult. In order to answer these questions, we built the Dance Enhanced study and website as a companion to the commercial game *Dance Central 2*.

- **An investigation into the effects of narrative content on long-term engagement.** Some studies suggest that linking games and exercise would help people who desire healthier lives but needs better engagement to drive them [7, 75, 107]. In their review of health-related papers presented, Baranowski et. al. conclude that “research is needed on the optimal use of game-based stories, fantasy, interactivity, and behavior change technology” [5]. So one tactic worth investigating is if the addition of more engaging game content would improve adherence. Dance Enhanced explored this with an implementation of character-driven storylines, competitive leaderboard, and a decorative dance club.

Thesis Overview

This dissertation is separated into several chapters. Chapter 2 is a discussion of related work across dance, health, and computer science fields. Chapters 3, 4, and 5 contain a detailed description of our early experiments based on 3DUI game prototypes. Chapter 6 describes the design and execution of a longitudinal study on the fitness aspects of dance games. Chapter 7 lays out the results of this experiment and Chapter 8 discusses the study’s strengths and limitations. Chapter 9 outlines a plan for continuing the work in the future. Finally, Chapter 10 concludes with a discussion of the future for full-body dance games and a review of our research contribution.

CHAPTER 2: RELATED WORK

The related work for this research stretches between many disciplines. The design of a dance game has roots in the study of dance, the history of rhythm games, and the development of body-controlled human-computer interfaces. In this section, we bring these diverse areas together and show how each plays a part in our research.

Dance and Exercise

The benefits of maintaining regular cardiovascular exercise are well-known, especially its potential to prolong human life [90]. Maintaining a regular fitness routine faces several hurdles. Many people have a strong desire to improve their health through exercise, but it comes from external sources. There is a strong link between intrinsic motivation and exercise adherence [89]. In another example, cross-sectional studies on Japanese adults revealed that people who were intrinsically motivated to exercise were likely to exercise for six months or longer [64].

The last several decades have seen an increase in cardio exercise in entertainment media. Aerobic dance first became popular via Jane Fonda videos in the early 1980s. It eventually branched into simpler forms of cardio exercise because of injury concerns [55]. These cardio classes were not as physically demanding as traditional dance instruction, but exercise set to music has been known to motivate people more so they were still effective [30]. Dancing is also known to improve mental health as well as physical well-being [65].

Research with children suggests games and dance-based games are a potential alternative to other types of exercise. A group of children was given the chance to either ride an exercise bike or do an interactive dance application, and dancing was preferred [29]. More recently, a study on 11 to

14 year old boys on several games, including *Dance Central*, showed a large difference in calories burned between the full-body controlled games and a regular console game [93].

Dance Notation

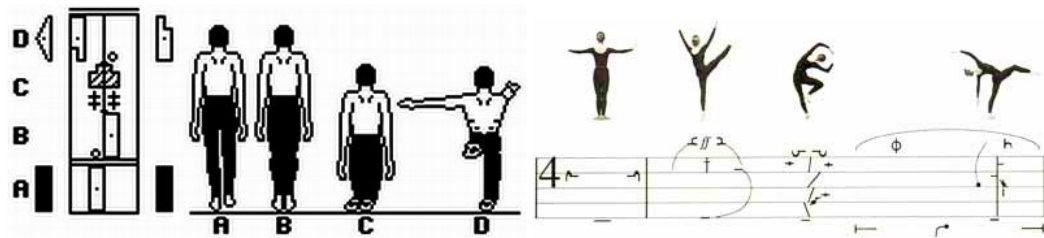


Figure 2.1: Left: Labanotation [35]. Right: Banesh Movement notation [46]. Shown with representative humans depicting each move, but these are normally absent.

One difficult problem in designing dance games is the conversion of human movement into written notation. Long before digital displays, written dance notation was developed as a means for preserving choreography, in practice as early as 15th century [36]. Two modern examples are shown in Figure 2.1. Labanotation has become the most standardly used iconic representation of dance movements. Computer scientists such as Herbison believed it could be incorporated in computers with video as recording devices [39]. Projects such as LabanDance convert notation into 3D computer animation, a difficult challenge given the complexities of both formats [110]. Reading notation has also been shown to help children understand dance better [108]. However, with many different shapes, positions, coloring methods, and staves for placement, Labanotation literacy entails a steep learning curve because it was created for choreography and archival purposes, stressing precision and accuracy over readability. Each element must include information not only on timing, but on each body part and how it will move in a 3D space. This is relevant to our research because the same challenge faced by dance games with unencumbered interfaces, where dance moves are displayed on screen prior to their execution, and in that situation simplicity

and readability is necessary.

Digital dance research has been around since at least 1993, when a team of engineers studied usability software for choreographers [14]. Dance instructors have also experimented with remote learning programs such as WebDANCE [54]. But most dance research has focused on blending technology and performance. Examples include observing two dancers remotely collaborating in a virtual world [113], real-time recognition for virtual collaboration [102], and using a 3D user interface to paint dance artistically in a virtual environment [106]. Qian et al. have also used multiple systems of motion capture simultaneously to track dancers [84] while Eaves et al. studied the effects of real-time virtual reality feedback on ballet instruction [25]. In terms of dance instruction, some studies have used wearable force feedback devices [24, 72]. It is only recently that video games have been explored as potential choreography methods [57]. One notable experiment on the choreography potential of the game *Just Dance* was conducted in 2012 by Kramarova [57]. Combining computer systems and human dance has led to some interesting possibilities for performers, but few concrete conclusions as learning devices.

Advances in the Game Industry

The relationship between dance games and exertion gaming dates back to the original exercise video game periphery, the Power Pad, and the title *Dance Aerobics* in 1987. While the actions usually correspond to buttons on an analog game controller, themed experiences through custom hardware controllers such as dancing on a game pad or playing a guitar shaped controller are popular as well. Mimetic controllers have existed in console gaming since the original NES was bundled with the Zapper light gun. Unencumbered interfaces in console gaming have been around almost as long, with the release of the Sega Activator in 1994. But most of these systems were financial failures due to clunky control schemes, extraneous hardware and limited technology.

Since then, a variety of alternate controllers have been released, mainly for music, dance and singing scenarios [9]. The most well-known dance pad game, *Dance Dance Revolution* (or DDR), was influential both in terms of popularity and its own cultural significance [44, 95]. For some, DDR became an outlet for creative free styling [2]. Its four arrow floor mat, operated with the player's feet, was the staple dance game input device until the Nintendo Wii became popular.

However, the concept of a dance game has since existed not just as an exertion interface, but as part of a gaming genre called rhythm music games. Rhythm music games, sometimes referred to as sight-reading music games, feature gameplay that incorporates eye and body coordination with music. To score well, a player must translate visual cues into actions and perform them at the appropriate time. Dancers often appear as part of the aesthetic of rhythm games, although rarely do the dance animations have to do with player input.

The advent of the Nintendo Wii remote (Wiimote) has brought 3D spatial interfaces [11] to the consumer market and the forefront of gaming [58]. However, only a few rhythm music games on that console made use of 3D spatial interaction. For example, *Dance Dance Revolution Hottest Party* uses the Wiimote and Nunchuk to add other actions to its four arrow patterns, but their only function is a simple shake of the controller that can be completed in almost any position and in any direction. While this does require the player to use their entire body, it is not much different than pressing a button because any orientation or maneuver will trigger a correct response as long as the timing is right. Recent titles such as *We Cheer* and *Just Dance* use Wiimotes held by hand. The systems have no knowledge of the player's body parts other than hand motion, but these games are commercial successes nevertheless.

Visual Instructional Interfaces

Video game companies invent new visual interfaces as often as they invent new games, and yet they do not often publish papers about their discoveries. While investigating the inherent difficulties in describing dance moves visually, we looked at 77 rhythm games from the last decade, since game companies do not often write academic papers about their work. Early on, gamers became accustomed to a stream of icons that represented directions or buttons on the controller. When the icons get to a certain point on the screen, the player executes the action, which usually involves a button press or tilting an analog stick a certain way. This visual interface is well-suited for analog controllers and of the games we looked at 61% of them use this method with little variation, including *Rock Band*, *Guitar Hero*, *Dance Dance Revolution* and all of the games similar to it (which in most cases use the same four arrow system as well).

Another 18% still use a stream of icons, but arrange them radially around the screen. Often the icons emerge from the middle of the screen and project out in eight directions. Having the icons situated differently may be a way to make it difficult to follow, adding challenge for the player. Gameplay sometimes involves the analog stick as well. Notable examples of this are *Gitaroo Man* and *EyeToy: Groove*. Another interesting variant is *Hatsune Miku: Project DIVA*, which places the icons in constantly shifting streams across the vibrant music videos playing in the background. The unpredictability of this seems to add challenge while keeping attention on the stories unfolding behind the icons.

However, the latest generation of gaming devices has introduced some new kinds of human computer interaction. The Nintendo DS uses a stylus and touch screen in addition to analog buttons. While some games chose to continue the reliable icon scrolling method of visualization, a new form of rhythm gameplay evolved that supported using the two dimensional touch screen to its fullest capability. In the Japanese game *Osu! Tatakae! Ouendan* players must tap circles in the

correct order and in the correct rhythm. Using a stylus, they trace lines on the screen to the pace of the song. This was well received and allowed iNIS to create follow-up titles *Elite Beat Agents* and *Ouendan 2*, but we were able to find only two other games which used a similar interface even though *Ouendan* was released in 2005.

The trace lines from those games were also utilized in the game *We Cheer* to a much greater degree. In this game, the player holds a Wiimote in each hand similar to pom-poms. Using color to differentiate left from right, intricate arrowed lines form on the screen and an icon moves along them to indicate the timing of the motion. This interface allows for easy description of movement along the xyz axes and clear distinction between large and small moves. But it also has few followers; we found only one DS game (*Princess Debut*) and an upcoming pop star game for the Nintendo Wii with similar attributes.

Some other game interfaces exist on smaller scale, such as the eidetic gameplay found in *Space Channel 5* and some *WarioWare, Inc* minigames. In these cases the player watches the game do several actions and then must mimic them successfully. Another game, *Unison*, expects the player to watch the on-screen avatar and determine from their movements how to shift the analog sticks on the controller. These interfaces are the least popular but do represent some interesting ideas.

The Kinect launch, brought a new wave of interfaces to necessitate the change over to full-body controls. In January 2011, Game Developer Magazine published a post-mortem of *Dance Central* [21]. The developers state their goal from the beginning was to teach real dance moves. Their experiences reveal many of the problems inherent in this genre. The small screen space dedicated to the player's form and the training mode which focuses on audio cue repetition imply their usability testing had similar results.

Konami, creators of DDR, released *Dance Masters* around the same time. Geared towards gamers, the moves are conveyed with icons and silhouettes. The player is projected into the virtual world

as large as the dancers. This game has been given lower reviews because of its lack of a training mode and high difficulty [109]. A third title, *Dance Paradise*, resembles casual party games with its bright colors and stylized avatars. It does not include any player representation, only pre-recorded animations, which some found disappointing [86].

Narrative Structures in Dance Games

One last area of relevance within dance game research is the merging of narrative and game mechanics. It is important to consider because engaging narrative structure can form a source of reward that increases enjoyment for players [18]. But the exact meaning of narrative in games is complicated and hotly contested. So for the sake of this discussion, we will define the following terms:

1. **Gameplay Mechanics:** The action performed by the player. The direct method of player input, such as body movements or button presses on a controller.
2. **Feedback:** The reactions to their performance. The output produced by the game. Anything that informs the player through visual, audio or vibration feedback regarding the outcome of their interaction.
3. **Narrative Content:** Anything which contributes to the story or world within the game, even in titles without a lot of dialogue or description of environment.

This definition is supported by game researchers such as Kenny Shea Dinkin, who has taken the standpoint that any elements surrounding the basic mechanic of the game can be considered part of the storyline. In his work with Kids, Casual and Social games, Dinkin laments the lack of compelling narrative in these genres [23].

The same is true for dance and rhythm games. For example, one feature known to encourage intrinsic motivation is the feeling of triumph shared by a community, commonly found in first-person shooters and MMORPGs [65]. Some community aspects are making their way into dance games; *Dance Central 2* informs the player of the collective score of all Xbox 360 players and *Dance Masters* ranks you internationally. No one has yet studied the effect of this on keeping people playing over a long period of time. Another popular feature is avatar customization, which is incredibly popular in MMORPGs and fighting games. This is much less emphasized in rhythm games, extending to choice of dancer and a few outfits.

Linear plotlines have had their place in this area, although they are not as popular here as in role-playing games. An early PlayStation 1 dating simulation, *Tokimeki Memorial 2 Substories: Dancing Summer Vacation*, created scenarios where the player would take characters on dancing dates. The indie game *Sequence*, released in 2011, is an RPG where battles are fought using streaming arrows that must be pressed on beat. The DS game series *Ouendan* framed its rhythm game sessions as motivational cheering exercises to help characters achieve their dreams. In *Princess Debut*, the player learns to dance with several eligible young men, eventually choosing one as a love interest. Some full-body dance games, such as *Dance Dance Revolution X*, *We Cheer 2* and *Dance Central 2*, frame their play in a narrative where they must prove their skills to the other characters in order to improve their in-game status. These story elements certainly enhance gameplay, but are not intended to be the sole engaging concept.

Virtual Reality and 3D User Interfaces

Before there were commercially available motion controlled games, there were 3D user interface systems being invented and evaluated in research labs. The technology present in current body-controlled game interfaces was preceded by navigation and interface experimentations in computer

science, usually for exploring virtual worlds. One way a person can be brought into a virtual world is by motion capture, or mocap, [68] which records the body's movements in space and has several entertainment and military applications. The methods vary, including magnetic, mechanical and accelerometer-based tracking, but the dominant version is optical tracking. Body tracking has enabled interesting applications such as virtual Tai Chi [19] and Martial Arts [38]. The Body Music system [56] uses interaction in a physical space to entertain while teaching different values of music. Related to dance and music, as well as being similar to the Wiimote hardware, the Senseble system [4] is used to track dance movements using accelerometers and gyroscopes attached to the ankles and wrists.

3D user interfaces have also been used to investigate audio and tactile feedback in a limited degree. There is some work in training methods, such as simulating ballroom dancing using tactile feedback to mimic the lead [32]. Alahakone et. al. has written a review of current uses of vibrotactile feedback in therapy and learning systems [1]. Several researchers have also compared multiple feedback types against each other. Jerome did an extensive study comparing visual, audio and haptic cues in military simulation [49].

The effectiveness of different levels of force-feedback has been explored with 3D selection tasks [77]. In mobile computing, there have been studies examining the usability of nonvisual feedback [42]. Researchers have explored wearable devices that use haptic output to communicate with a human user [74, 97]. In general, vibration cues perform well in these investigations. However, we found no publications on the effectiveness of different types of feedback in full-body video games prior to our work. The video game industry has been using audio and tactile cues for many years, but there are only a few academic papers relating to them, such as analyzing suspense building techniques in horror video games [78].

Exergaming

The conclusion that games and exercise are a successful combination has been reached by many academic groups, but there is some difficulty in forming cohesive definitions and conclusions as a community. There are many definitions of exergaming and similar terminology, making discussion sometimes confusing [112]. Furthermore forming a cohesive vocabulary about exergaming is still an open area, with Mueller's taxonomy on exertion games being one of the few papers dealing with the subject [71]. Similarly, the history of exergames has not been well documented. Bogost catalogued a historical approach to commercial exergaming, but there are many interesting prototypes produced in research labs that are not well known. [10].

The effectiveness of exergames as cardiovascular fitness has been measured in the past [75]. Multiple studies using many different game strategies such as dance games [60, 66, 100, 103], sports games [34, 37], and games using traditional exercise equipment [107] have shown, when played regularly, that they can meet some standards for cardiovascular fitness. Exergames have also been used to fight obesity in specific sub-populations such as teenage girls [73], blind children [69], post-menopausal women [47], and college age students [92]. Outside of the health and pediatrics communities, Mueller has examined other methods of evaluating exertion games, but there still are many ways to push this further [70].

The combination of all these fields is what informs our work and the development of current full-body dance games for improving a person's well-being. The technology to display instructions, detect movement and give different types of feedback is now possible, but many questions remain in terms of human preference, performance and engagement.

CHAPTER 3: VISUAL INSTRUCTIONAL INTERFACES

Before 3D motion controllers were commonplace, the dance and rhythm game genre already had a large variety of unconventional game controllers. Sometimes in the form of a dance pad or a musical instrument, but often a handheld controller, while the physical structure changed over the years the inputs would still translate to discrete signals. This allowed the visual display to be relatively simple, usually a variation on a stream of multicolored icons. But when dance games evolved past this input method, so did the complexity of possible movement, resulting in instructional methods becoming one of the most difficult problems for this game genre.

In 2008, we built the RealDance game prototype to explore the capabilities of the Wiimote as wearable devices. We wanted to explore how much variety of movement could be detected using accelerometer data. But our investigation was slowed when play testing revealed that streaming icons across a small part of the screen required a lot of quick memory recall for the player. Even if the system could detect some difference in movement, the players struggled to understand what they were supposed to do next.

We began to investigate dance notation and previous rhythm games to draw inspiration for investigating better ways to display instructions in real-time. What we found is that some games were using the entire 2D plane of the screen instead of a vertical or horizontal stream. By taking advantage of the entire screen with a human avatar in the middle, the positioning of the relative body parts becomes easier to comprehend. We designed a within-subjects experiment to explore preference and performance between three different visual systems based on these observations: Timeline, Motion Lines, and Beat Circles. Timeline was in the style of popular streaming icon interfaces, while Motion Lines and Beat Circles were 2D spatial interfaces with different methods of describing timing.

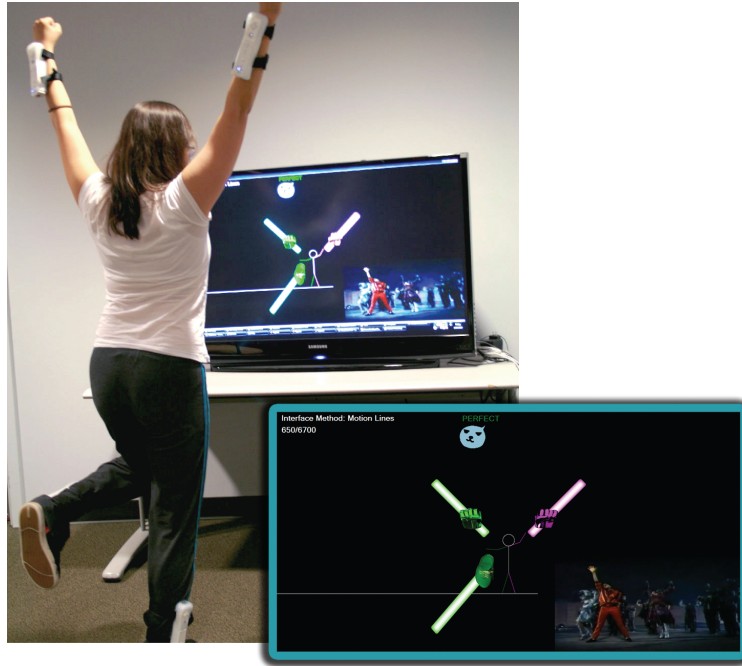


Figure 3.1: The RealDance system in action. The Motion Lines interface is pictured.

Our evaluation was based on points scored in the game and questionnaires. The results showed that players had significantly higher scores when using Motion Lines and Beat Circles than with the Timeline. They were also easier to follow and icon position was less confusing. This led us to conclude that 2D spatial interfaces were better ways of instructing a person to move their body in real-time.

The RealDance System

The RealDance game prototype, shown in Figure 3.1, used four WiiMotes attached to the wrists and ankles [17]. Since RealDance required a player to use both arms and legs, the player needed to know *which* of their four limbs to use, *where* they are expected to move, and *when* they are expected to move in the dance sequence. Thus, it was important not only to detect these full-body

gestures, but to also understand how to best convey the visual cues needed during gameplay.

The goal of RealDance was for players to feel like they are dancing naturally and not for a video game. We wanted them to focus on improving their performance. Using readily available commodity hardware they received feedback directly tied to how well they complete each movement. RealDance did not rely on button pressing, a staple of video game controls that disrupts the feeling of dancing. The player was not spatially tethered to a specific location either. Movements which are recognizable as gestures are scored for acting within a certain time window.

To implement our prototype, we needed a way to attach Wiimotes to the user. The requirements for these wearable attachments included comfort, adjustability and secure positioning. We measured the arms and legs of roughly twenty people of variable height, weight, and gender and used this data to design Velcro straps for the forearms and shins. These straps were weaved into modified Wiimote jackets. Our prototype was implemented in C#, using the Bespoke XNA 3DUI Framework [105] in a Windows environment.

Gesture Scoring

The gesture scoring in RealDance had three major concerns. First, a range of movements needed to be detectable to match the variety in dance. Second, these movements needed to be reliably distinguished from one another. Third, “cheating” needed to be eliminated. When using motion detection devices like Wiimotes, players can “cheat” using the ambiguities inherent in accelerometer-based input. In many rhythm games intended for full-body movement, players can obtain perfect scores without getting up from the sofa. This is far from the game designer’s intent, and would work against any desired exertion purposes like fitness or therapy.

For each gesture in the choreography, we considered an interval T based on the expected duration

of the movement. This segmentation was completely independent of the input. Each gesture in the choreography was scored independently, so spurious motions in between expected gestures are not penalized. The only inputs to the system were the acceleration vectors \mathbf{A} from the Wiimotes. We use $w \in W = \{LH, LF, RH, RF\}$ to refer to the four limbs (left hand, left foot, etc.) when necessary. Similarly we will use $d \in D = \{x, y, z\}$ to refer to the individual dimensions, and $t \in T$ to refer to individual instants of time.

An impulse motion, such as a punch, was characterized by a rapid deceleration occurring when the arm is fully extended. In a dance, this instant should line up with a strong beat in the music. We scored an impulse motion by considering a one-beat interval $T = [t_0 - 0.5, t_0 + 0.5]$ centered around the expected beat. For the Wiimote corresponding to the relevant limb, we then selected the time sample t_k in the interval T corresponding to the maximal acceleration in the negative Y direction, the long axis of the Wiimote,

$$t_k =_T -\mathbf{A}_{t,y}. \quad (3.1)$$

If this maximal acceleration was below a threshold, then we concluded that no punch occurred, and the score was zero. Otherwise, the score S_T was computed from the distance to the expected beat t_0 :

$$S_T = 1 - |t_k - t_0|. \quad (3.2)$$

If the gesture involved multiple limbs, the maximal acceleration value must be greater than the threshold for all involved Wiimotes. The average of all the t_k was used to compute the score.

An impact motion, such as a stomp, was distinguished from an impulse motion by the presence of

a sudden shock when two surfaces collide. This produced an easily identifiable change in acceleration values (jerk) over all three dimensions. In order to score an impact motion for one Wiimote, we first computed the change in acceleration vectors for each pair of adjacent time samples. We then selected the time sample t_k corresponding to the largest magnitude of jerk,

$$t_k = \underset{T}{\operatorname{argmax}} |\mathbf{A}_t - \mathbf{A}_{t-1}|. \quad (3.3)$$

If this maximal jerk value for the interval was less than a threshold, we concluded that no impact occurred, and the score was zero. Otherwise, the score is calculated in the same way as for an impulse.

Visual Information

The instructional interface presented the dance sequence the player was expected to perform. This included three pieces of information for each move: *which* body part(s) to move, *where* to move them, and at *what* time. Three interface prototypes were created based upon the findings of the rhythm gaming survey.

Common Screen Elements

Common screen elements across all three interfaces were used to motivate and inform the players. The first motivating screen element used was an overall score, shown in the upper left corner of the screen. The score was computed by rating each move as a Miss, Okay, Good, or Perfect. This rating was presented to the user by a label as well as an enjoyable cartoon character expression. Lastly, each dance sequence was accompanied by a song and its music video.



Figure 3.2: Icons representing each limb.

The informative screen elements were kept constant as much as possible. The icons used to indicate the body part(s) to move were similar across all three visual interfaces (see Figure 3.2). Hands and feet icons were represented by a closed fist and a shoe, respectively. To differentiate between the sides of the body, the icons were colored green for left and purple for right. A stick figure character performed the dance sequence along with the player.

Timeline

The Timeline interface, as shown in Figure 3.3 (left), was inspired by games like *Dance Dance Revolution* and *All Star Cheer Squad*. The player knew which limb to move by the icon, where to move them by directional arrows and when to move them by when they streamed into a box at the left side of the screen. The icons stream along from right to left, similar to musical notes, with vertical lines representing beats of the song. We chose this streaming style over far to near streaming (for example in *Rock Band*) because the side scrolling method is most common in dance rhythm games, and having the icons start deep in the viewing plane would make them tinier and harder to distinguish. This interface takes up little visual space compared to the other interfaces

but places a heavy representational burden on the icons; it takes a skilled illustrator to transform a moving pose in 3D into a 2D square.

Motion Lines

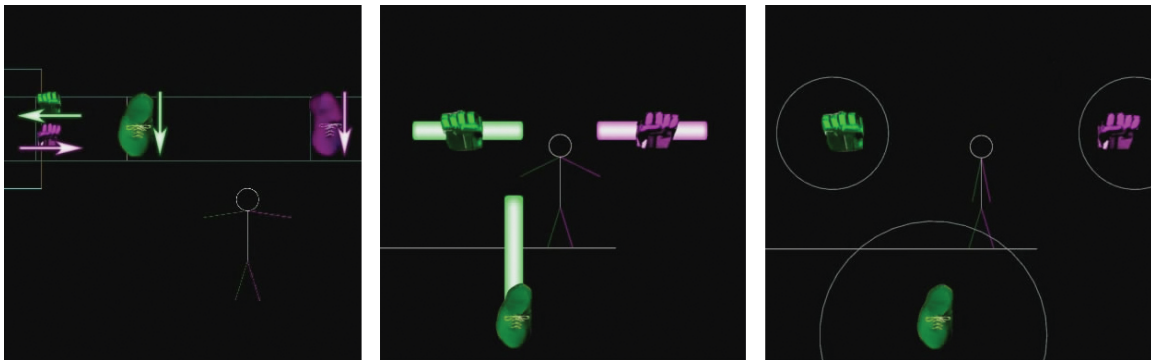


Figure 3.3: The three interfaces displaying the same moves. Left: Timeline. Middle: Motion Lines. Right: Beat Circles.

The Motion Lines interface, as shown in Figure 3.3 (middle), is inspired by games like *We Cheer*. The player knows which limb(s) to move by the icon, where to move them as indicated by the path line's relative screen position and when to move by the appearance and movement of the icon along a path. For consistency, the path is the same color as the icon. In this interface, the spatial area of the screen is utilized as the icons are presented around the stick figure. Additionally, repeated motions present overlap problems but are still viewable when they are placed behind the more recent action. One potential benefit of Motion Lines is the ability to show duration and potentially show pauses. This is exemplified by a step move, where the icons tracing back and forth on the path indicates timing and could pause along the path for added difficulty.

Beat Circles

The Beat Circles interface, as shown in Figure 3.3 (right), is inspired by games like *Osu! Tatakae! Ouendan*. The player knows which limbs to move by the icons, where to move them as indicated by the positioning of the icons around the central stick figure and when to move them by the disappearance of the collapsing circle. Beat Circles uses much of the screen real estate, like Motion Lines, but does not suffer from the Motion Line overlap issue.

Motivation and Feedback

There were similarities between the three interfaces. These elements give more information about what the player should be doing and what the system perceived them doing. An overall score for each session appeared in the upper left corner. This score was computed by giving a point value for whether a move received a rating of Perfect, Good, Okay, or Miss. For each move a cartoon character avatar changed its expression to reflect the results. In addition, each song was accompanied by a music video.

We also displayed a stick figure avatar that roughly performed the expected moves when the user is supposed to be doing them. Almost all rhythm games that use dancing as a motif have animated or motion captured characters moving in the background during gameplay. In some games, such as *Dance Dance Revolution*, this is purely aesthetic and has little bearing on the step pattern. But other games such as *Unison* and *We Cheer* are designed so that the characters alone can guide the player to do the expected movements. For this reason, we included an avatar to test its influence on the experience.

Usability Study

We conducted a usability study comparing Timeline, Motion Lines, and Beat Circles, in the context of our RealDance video game prototype, by examining each visual interface's effectiveness in conveying dance sequence information and assisting the player in providing a rewarding experience. Based on early pilot studies, we hypothesized that players would score higher with either the Motion Lines or Beat Circles interfaces than with the Timeline interface, because Motion Lines and Beat Circles inherently provide the spatial information needed to perform the movements required in RealDance. This inherent spatial information is not present in the Timeline interface because it exclusively uses icons to present not only the timing information, but which limb to use and where to move it. As a result of the complexities of using the Timeline interface in RealDance, we also hypothesized that players will prefer Motion Lines or Beat Circles over the Timeline interface.

Subjects and Apparatus

Twenty-four (13 male, 11 female) participants were recruited from the University of Central Florida and the surrounding area with ages ranging from 18-29. Of the 24 participants, 19 had no formal dance experience, and of those six do not dance socially. Seventeen participants played video games more than once a month and 14 had played DDR at least once. The experiment duration ranged from forty minutes to an hour and fifteen minutes, depending on how long the user spent with the questionnaires. All participants were paid 10 dollars for their time.

The experimental setup consisted of a dual-core desktop PC with an nVidia GeForce 8500 graphics card, using a 50 inch Samsung DLP 3D HDTV display with a refresh rate of 60 Hz. Graphics were displayed at a resolution of 1920 x 1080. Participants had an area of approximately six square feet in front of the Samsung display to interact with the game. An opaque plastic curtain enclosed the

space so that only the moderator and participant were present during the experiment. This was done for privacy and the comfort of the participants. The experiment moderator sat to the side of the study space and controlled the software via a wireless mouse.

Experimental Task

The task participants performed was to play RealDance by moving their arms and legs in time with the music when instructed to do so by the interface. Two songs were chosen for the experiment. In the practice sessions, the GhostbustersTM theme song was used because of its slow, catchy tempo. For the actual experimental task, we chose ThrillerTM by Michael Jackson. This song is also well known and has the added benefit of a recognizable dance sequence.

For the experiment, the dancing choreography was designed to focus on movements that were easiest to differentiate visually and matched the Thriller dance routine well. In total, there were 13 unique movements that participants had to perform (see Table 3.1).

Experimental Design and Procedure

We used a three-way within-subjects factorial design where the independent variable was visual interface technique (Timeline, Motion Lines, and Beat Circles) and the dependent variable was the dance routine score. The maximum obtainable score for the Thriller gameplay sessions was 6700 points. One hundred points were awarded for a “Perfect” move, 75 for “Good”, 50 for “Okay” and 0 for a “Miss”. Compound moves were scored from 0 to 100 for each body part. Both the overall score and the score for each individual movement was recorded. In addition, we measured participants’ preferences for each interface using a post-technique questionnaire that asked participants to respond to a series of 12 statements using a seven-point Likert scale (1 equals

strongly disagree and 7 equals strongly agree) and three open-ended questions on what they liked, what they disliked, and what they found frustrating about each interface. Room was also provided at the bottom for additional comments (see Appendix A).

Table 3.1: The individual moves in the particular routines we used.

Hand	Foot	Compound
Left hand up	Left foot steps	Both hands upward
Left hand side	Right foot steps	Both hands to the right
Right hand up	Left foot kicks	Left hand left/right hand right
Right hand side		Right hand up/left foot kicks
		Left hand up/right foot kicks
		Jump (both feet stepping)

The experiment began when participants entered the enclosed space. Participants were given a consent form explaining what they would be asked to do. Next, they filled out a pre-questionnaire that asked about their dancing and video game experience. Participants were then shown a sheet of icons (see Figure 3.2) which appeared in all three interfaces: the four icons designating body parts, the cartoon face avatar, and the stick figure. Once participants were familiar with these icons, the moderator helped attach the Velcro Wiimote sleeves to the participants' arms and legs so that they were tight, but not uncomfortable.

After being suited for the experiment, participants were introduced to the scoring elements on the screen. For each visual interface, the moderator read a description of the interface, then guided participants through two practice sessions. The practice runs were identical. After the practice session, participants would play RealDance with Thriller. After each gameplay session (two practice trials and one real trial), participants were given the post-technique questionnaire for the given visual interface. Thus, participants played the RealDance game nine times, three for each interface. To reduce ordering effects, we randomized the gameplay sessions across participants. There are six different permutations for ordering the three interfaces; since there were 24 participants, each

permutation occurred four times. After completing the gameplay sessions, participants were given a final post-questionnaire used to gauge their overall preferences.

Results

Learning Effects

Although we randomized the ordering of the gameplay sessions, the choreography was the same for each interface. To ensure the data was unbiased, we compared the overall scores of each participant in a repeated measures one way analysis of variance (ANOVA) to see if the scores improved based on the order of the gameplay sessions. The results showed there was no significant improvement in scores ($F_{2,22} = 0.306, p = 0.738$) based on gameplay session order, indicating that our counterbalancing was sufficient for removing any order bias.

Overall Score Analysis

A repeated measures one way ANOVA was performed to determine if visual interface type had a significant effect on overall score. Visual interface type was found to be significant ($F_{1,40,22} = 8.68, p < 0.05$).¹ The mean scores are shown in Figure 3.4. To further explore how overall score varied due to visual interface, a post-hoc analysis with three pairwise comparisons was conducted. To control for the chance of Type I errors, a Holm's sequential Bonferroni adjustment [43] with three comparisons at $\alpha = 0.05$ was performed. Participants in the experiment scored significantly higher with Motion Lines ($t_{23} = -4.38, p < 0.0167$) and Beat Circles ($t_{23} = -3.26, p < 0.025$) than with the Timeline interface. There was no significant difference between scores for Motion

¹Since the test violated the sphericity assumption, a Greenhouse-Geisser correction was used.

Lines and Beat Circles ($t_{23} = -1.20, p = 0.243$). This result implied that in a game where all body parts are used, participants performed better in the two interfaces that were spatially oriented to the player, taking advantage of the entire screen.

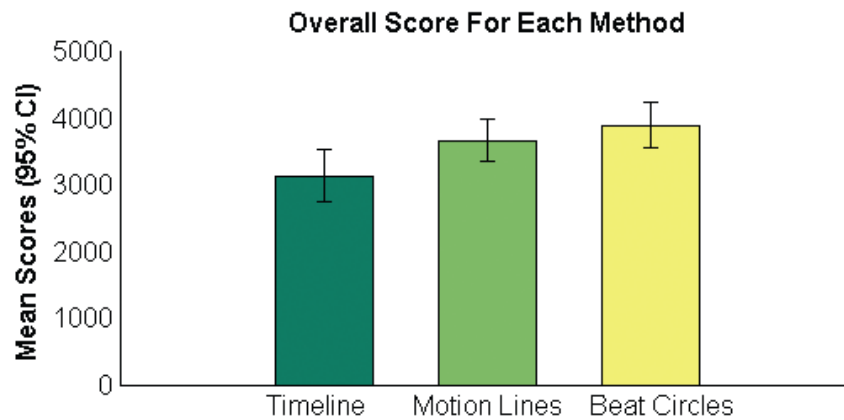


Figure 3.4: Overall Score Means

Detailed Score Analysis

To further analyze the results, we broke the overall score into movement types based on whether a single hand, single foot, or compound movement consisting of two feet, two hands or one foot and one hand was used. In the RealDance's Thriller sequence, there were a total of 52 movements participants had to perform consisting of 13 hand moves, 22 foot moves, and 16 compound moves. To calculate hand and foot scores, the total score for these moves were summed and divided by the number of moves for each type for each participant and then the mean was taken across all participants. Since compound moves have two moves associated with them, each compound move score was divided by two first then followed the same procedure as the hand and foot scores, ensuring all scores were out of 100 points. Table 3.2 shows the means and standard deviations of each move type for each visual interface.

Table 3.2: Mean scores broken into move type for each visual interface. Standard deviations are in parentheses.

	Hand	Foot	Compound
Timeline	48.39 (17.48)	52.32 (16.46)	40.69 (15.95)
Motion Lines	59.29 (16.27)	64.58 (14.65)	44.40 (14.13)
Beat Circles	64.18 (18.87)	60.93 (14.93)	52.44 (16.12)

A repeated measures two way ANOVA was calculated on the detailed score data with visual interface type and move type as the independent variables. Both visual interface type ($F_{1,43,22} = 9.95, p < 0.05$) and move type ($F_{1,58,22} = 22.32, p < 0.05$) as well as their interaction ($F_{4,20} = 2.42, p < 0.05$) were found to be significant.² From these results, we were most interested in understanding how a particular visual interface affected participants' scores for each move type. Thus, we conducted a post-hoc analysis with nine pairwise comparisons, controlling for the chance of Type I errors using Holm's sequential Bonferroni adjustment [43] at $\alpha = 0.05$. Of the nine comparisons, participants scored significantly higher when performing foot ($t_{23} = -3.98, p < 0.0056$) and hand ($t_{23} = -3.50, p < 0.00625$) movements using Motion Lines in comparison to foot and hand movements using the Timeline. In addition, participants scored significantly higher when performing hand movements ($t_{23} = -3.16, p < 0.0071$) with Beat Circles over hand movements with the Timeline. Note that comparisons between Beat Circles with compound movements and the Timeline with compound movements ($t_{23} = -2.61, p = 0.016$) as well as Beat Circles with foot movements and the Timeline with foot movements ($t_{23} = -2.30, p = 0.031$) were not significant due to the Bonferroni correction. These results further indicate that both Beat Circles and Motion Lines provided an interface to RealDance that makes it easier to understand the required dance movements over the traditional Timeline interface.

²Both visual interface type and move type violated the sphericity assumption, so Greenhouse-Geisser corrections were used.

Questionnaire Analysis

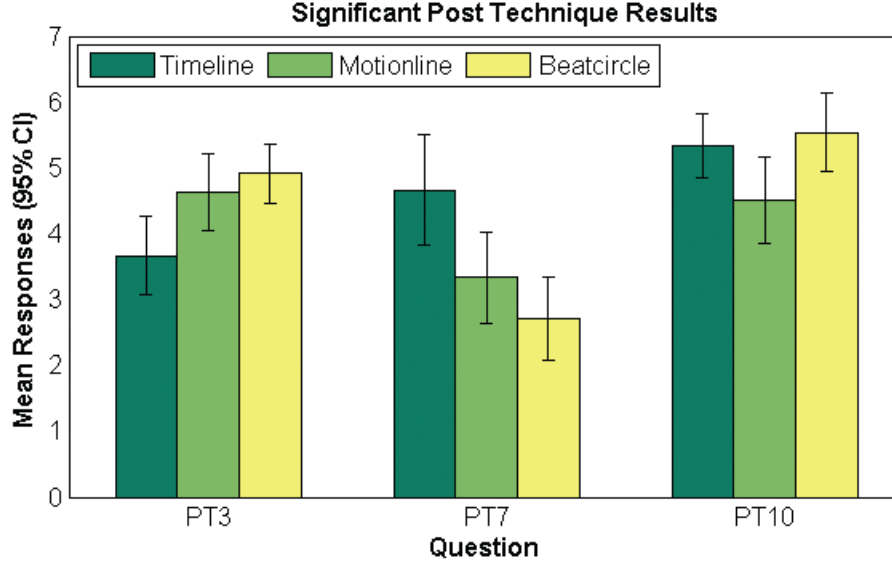


Figure 3.5: Post-technique questionnaire results. The full questionnaire can be found in Appendix A.

For each post-technique questionnaire, participants were asked to respond to twelve statements (See Table A.1 in the Appendix) using a seven-point Likert scale (1 equals strongly disagree and 7 equals strongly agree) to gauge their reactions on each visual interface. To analyze the data, we conducted Friedman tests on each statement across the post-technique questionnaires followed by Wilcoxon Signed Rank tests when appropriate. For each Wilcoxon Signed Rank test, three comparisons were made and Holm’s Sequential Bonferroni adjustment [43] was used at $\alpha = 0.05$ to control for the chance of Type-I errors. Three out of the twelve statements were found to be significant (see Figure 3.6) and are discussed below.

Easy to Follow? Significant differences were found with which interface was easiest to follow ($\chi^2_2 = 7.32, p < 0.05$). Beat Circles was considered significantly easier to follow than the Timeline ($Z = -2.69, p < 0.0167$). Motion Lines was also significantly easier to follow than the Timeline

($Z = -2.39, p < 0.025$). However, there was no discernable difference between Beat Circles and Motion Lines ($Z = -0.80, p = 0.424$). These results correlated with the score data to support that users found it easier with a mirror-like interface that utilizes spatial information.

Position of the icons more confusing? Significant differences were found with each interface's ability to present information on where to move ($\chi^2_2 = 13.62, p < 0.05$). The Timeline was considered more confusing than either Beat Circles ($Z = -3.08, p < 0.0167$) or Motion Lines ($Z = -2.38, p < 0.025$). Once again, there was no significant result when comparing Beat Circles to Motion Lines ($Z = -1.71, p = 0.087$). Because of the nature of the Timeline, participants could not use the position of the icons as a hint for moving their limbs.

Score matched how well you felt you did? Significant differences were found with how well participants felt they did based on their score ($\chi^2_2 = 6.19, p < 0.05$). Beat Circles was significantly better than Motion Lines in this category ($Z = -2.50, p < 0.0167$). No significant differences were found between Beat Circles and the Timeline ($Z = -0.76, p = 0.46$) and between Motion Lines and the Timeline due to the Bonferroni correction ($Z = -2.0, p = 0.046$). Some participants were unsure about how fast they were supposed to move with Motion Lines. Since the scoring system was held constant between the visual interfaces, participants expected to give a strong acceleration at the end of each move. With the Motion Lines, many participants moved slower at first and were not going in the correct direction when the icon reached the end of the path line. Participants also may have been influenced by the fact that, overall, they scored better with Beat Circles.

In addition, participants were asked to respond to open-ended statements for each visual interface. See Table A.1 in the Appendix to refer to questions PT13 through PT16.

Timeline. More than half of the participants noted that they liked being able to see the next series of moves approaching, which was particularly true of those who did not play a lot of video games or had no experience with visual timelines in similar fields. One participant stated, "Maybe it's

because I have music training, but I liked being able to glance slightly ahead like with sheet music.” Even though this interface provided a lot of advance knowledge, many participants still found it difficult to know when to start an action. One participant said, “It was hard to know how to move, when to start moving for a step, and how/what angle to move my hands.” Several participants also felt confusion between left and right, or hand and foot icons. Some participants found the interface to be “too quick.” One participant stated, “The steps at some points were too close together and didn’t seem to give enough reaction time.” Other timeline based games such as DDR often include options to space out the icons; however, the timing must remain the same, so putting physical space between them means that the velocity of the icons must be greater. This would make the icon scrolling look even faster. Finally, several participants, specifically those who were familiar with other rhythm-based games, suggested having multiple timelines, perhaps one for arms and one for legs, to lessen confusion. This is a fair assessment since many sight reading games do so, but it would not solve left/right confusion or speed issues.

Motion Lines. Almost half of the participants noted that Motion Lines gave them a better sense of where to go. One participant responded, “It was a more natural representation of movement. The screen acts like a mirror, showing paths for the user to move their body parts along in an intuitive way.” In addition, several participants stated Motion Lines made it clear which body part they had to move, which is another benefit of using the screen in its entirety as a visual indicator. One major issue with Motion Lines that half of the participants mentioned was dealing with repeated movements. Many participants found this frustrating as it was difficult to know ahead of time if a movement should be repeated. Finally, a few participants mentioned confusing their feet in Motion Lines, especially the diagonal kicks that went along with punching your arm diagonally. This was an oversight in our implementation, since stepping gave a back and forth motion to help the user know when to lift their leg in the air but the kicking motion did not. We plan to address these issues in future versions of the RealDance prototype.

Beat Circles. Half of the participants noted that the icon position with Beat Circles helped them know where to move. One participant stated, “The direction of the movement was visually ‘there’.” There was no need to guess where your limb needed to end up.” Several participants also felt the timing was much easier with this interface. As with Motion Lines, there were problems with repeated movements. In the case of Beat Circles, the issue was overlapping circles. A majority of the participants mentioned this issue. At one point in the choreography there are several steps with the right foot, then several steps with the left foot. Since they are close together this caused overlapping circles that many found overwhelming. Three participants also mentioned that the stick figure was not necessary: “The stick figure actually confused me being so prominent in the scene.” The description of this interface in the experiment mentioned the stick figure as a reference point for where the icons are positioned, so that may be why people discussed the stick figure on this questionnaire but not the others.

After the experiment, participants were asked to choose one of the three visual interfaces in response to a set of eight questions (see Figure 3.6) and to explain why they chose the interface they liked the most and the least. Chi-squared tests were run on each question to determine if the responses were not uniformly distributed. Only PQ1 was found to be significant ($\chi^2_2 = 7.63, p < 0.05$), indicating participants felt they performed the best with Beat Circles. Although none of the other questions were found to be significant, the graph in Figure 3.6 shows an interesting trend: except for which interface participants liked the least, Timeline was the least chosen interface for each question. In addition, the Timeline was only favored in six out of the 24 responses (25%). This data seems to correlate with the other results, indicating that the Timeline is not the most ideal interface for a full body rhythm game such as RealDance.

When asked to explain why they preferred the Timeline interface the most, participants mentioned that they found it easy to prepare for future movements. One participant stated, “This interface gave an easy to understand prediction of when each motion would happen and how many times

to complete each movement.” Out of the 10 participants who chose Motion Lines as their most preferred interface, eight chose it because it was easiest for them to follow and the other two thought it let them best feel like they were dancing. For Beat Circles, most said they preferred the interface because they found it to be easy to use. Timing was also mentioned as being very easy to follow in this interface.

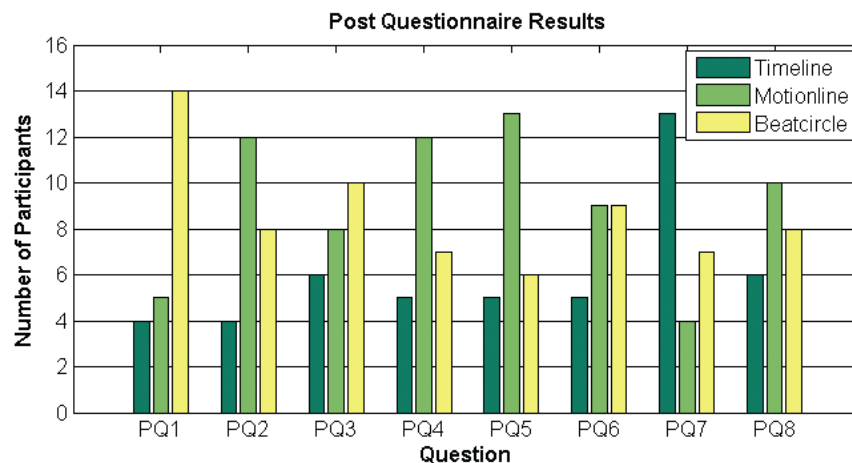


Figure 3.6: Post-Experiment Questionnaire Results. The full questionnaire can be found in Appendix A.

Most people chose Timeline as their least favorite interface. Many participants claimed that the Timeline interface was difficult to understand. One participant stated, “I had to read into the arrow symbols too much, by the time I comprehended them, they had gone past the Timeline. Too much work!” Another user noted that the Timeline interface seemed like it was meant for discrete controls like playing a musical instrument, but not well adapted to a full body dancing game. For those participants who least preferred Beat Circles, they felt it was difficult to determine the exact motions they needed to perform. One participant stated, “It was easiest to follow and most aesthetically pleasing (though it didn’t clarify the exact notions as well as the motion lines).”

Discussion

The results of both the performance data and the self-reported questionnaires indicated that the Timeline interface is the least adequate in a full-body dance video game. Participants performed the worst with it, found it harder to follow and thought the positioning of the icons was most confusing. This was in spite of the fact that most of them had played many video games and that the Timeline interface is used by almost all current rhythm games. As more rhythm games use 3D user interfaces, designers should focus on incorporating spatial interfaces like Motion Lines or Beat Circles as part of presenting visual information to users.

However, participants struggled with repeated moves for both spatial interfaces. One way to deal with this problem in Motion Lines would be to implement a partially transparent icon moving prior to when the person actually must execute the action. Another option is to have a section of the screen show a small version of the next move, similar to how Tetris shows the player what the next piece will be. This design was implemented in the dance simulation game *Princess Debut DS*, a Motion Line interface which shows tiny screenshots on the top screen of the DS console. In the case of Beat Circles, it would have been easier to tell the circles apart if they had been colored to match the left and right icons, or had thicker lines as they approached the execution point.

The Timeline interface made it easy to distinguish repeated movements, but participants struggled with differentiating left/right and hands/feet. Comments by some participants noted that the hands and feet could appear on different lines to address this, and over time many gamers memorize color associations. Even so, as the dance movements become more complex, the limited space of the Timeline is problematic. With all the variety possible in human movement, creating icons for each creates a representational burden and is much less intuitive than using on-screen position for disambiguation.

Timing was a complaint found in discussion of all three interfaces no matter which interface the participant liked the least. This shows that many people have a different idea of what makes timing hard, but it also highlights how crucial it is to enjoyable gameplay. Judging by these comments, knowing when to move was the most important issue to the participants, more important than what moves they were asked to do. Users also suggested the possibility of combining interfaces. Game designers interested in the best possible solution should take the strengths and weaknesses of each into account.

Summary

Three different visual interfaces were studied to determine how they convey information to the player in RealDance, a full-body dance-based rhythm game. This study concluded that the Time-line interface, the current dominant rhythm game interface, is not the best at relaying information. Instead, participants performed better with interfaces that used the entire screen to help differentiate left and right movements. Participants also found these spatial interfaces to be easier overall. Finer-grained design tradeoffs of each interface were also identified and reported. We believe the results of our study will improve the visual interfaces for RealDance and are applicable to any full body rhythm game.

CHAPTER 4: NON-VISUAL FEEDBACK ROLES

After building RealDance, we felt we had made progress in understanding how a dance game could better explain to a player what movements they should perform. But another element which poses a difficult problem is delivering clear feedback on mistakes during play. Older games focused on whether the correct button was pushed and the accuracy of timing, but with a player's entire body involved, information on erroneous movement is a vital part of improving performance. But relying on the visual aspect of the display may not be the best way to convey this information, as players are focused on the instructional portion of the screen during play. In the RealDance experiment, several participants stated they had difficulty knowing what to do with visual feedback alone [16]. We received several comments that having a vibration or audio cue could help them understand what body part needed to move.

The visual screen itself poses another problem when moving towards an experience similar to real world dancing. A dance class will usually take place with a designated front direction, but spins and direction changes are common. A video game operates on the assumption that players face forward towards the screen all of the time. Audio and vibration feedback delivered through our wearable Wiimote system could solve this problem as well, by giving relative per-limb feedback when the user is not able to see the visual instructions.

We built the game prototype Vibraudio Pose (see Figure 4.1) to investigate the potential for audio and vibration to be used as positive and negative feedback indicators. We conducted a study comparing experience and performance as players sought to replicate simple yoga inspired positions with their bodies. Visual feedback and negative vibration feedback were both very quick ways to communicate to the participants. Vibration was preferred to audio as a feedback mechanism. From these results, we conclude that wearable devices can provide clear and quick feedback when

focused on tactile communication.

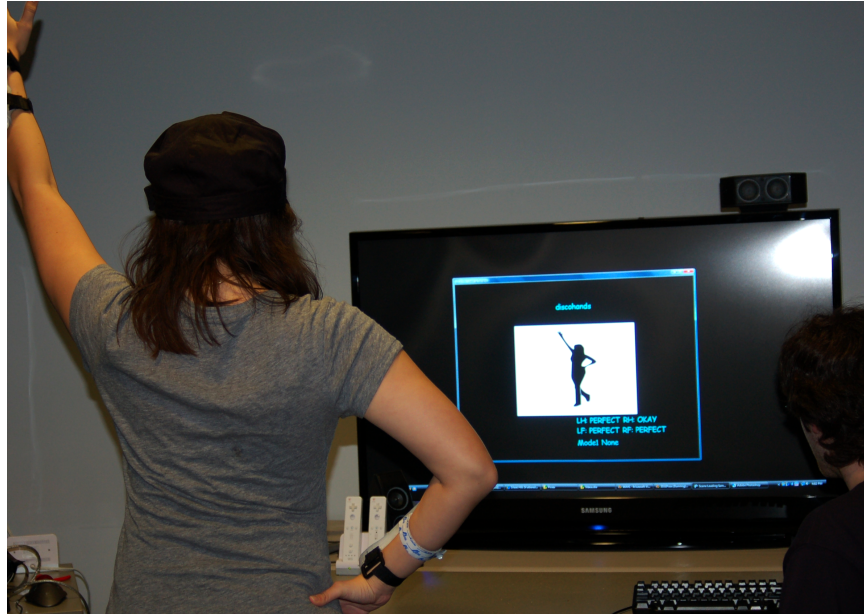


Figure 4.1: A participant and moderator during a practice session of Vibraudio Pose.

To aid in the understanding of our research, we define the following terms which will be expanded upon in later sections.

1. **Type:** The type of feedback refers to whether it is visual, audio or vibration, sometimes grouped together as visual and nonvisual.
2. **Role:** The purpose of the feedback in the game, whether it is positive or negative reinforcement.
3. **Conditions:** The experimental tasks were divided into a control Visual Only condition and three non-visual conditions: Positive Only, Negative Only, and Both Positive and Negative.
4. **Mode:** Users were divided into four groups performing different sets of conditions where the type did not change its role, numbered Modes 1-4.

System Design

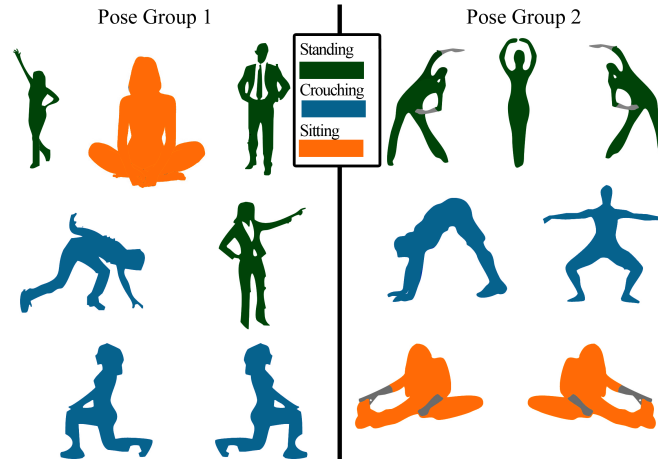


Figure 4.2: Images used in Vibraudio Pose game prototype, color coded by the category of the pose: standing, crouching or sitting.

The Vibraudio Pose game prototype allowed users to learn different body poses. An image of a human in a still position was shown on the screen, and the player tried to mimick the pose. Depending on the game settings, the prototype gave visual, audio, and/or vibration feedback. Our system was implemented in C# using Microsoft's XNA coupled with a 3D user interface framework [105]. We used four Nintendo Wii remotes (Wiimotes) for both input data and feedback delivery. These Wiimotes were attached to the user's wrists and ankles so that both arms and both legs could be detected and selectively used to provide feedback.

We used pictures of human silhouettes to show users how to do the required task. These poses were chosen based on how well the training system could define them uniquely, how well participants could distinguish between them, and how well most participants could physically recreate them. Three of the poses were seated, five were crouching and six were standing. The poses were divided into two groups of seven, requiring roughly equivalent skill (See Figure 4.2). These groups were

created as part of our experimental design and their difficulty was determined during an initial pilot study.

To train the poses prior to the study, the principal moderator performed each of them and recorded the average accelerometer data over an eight second interval. During gameplay, the player's accelerometer data was compared to these averages for each limb, producing four scores representing how far they deviated from the training data. Using different thresholds, the scores were grouped into four broader word based scores: PERFECT, GOOD, OKAY and MISS. Our pilot study included participants of both genders and a variety of heights and weights to ensure robust gameplay.

Audio Feedback

Because we wanted to limit the complexity of our experiment as much as possible, we limited the sound feedback to a single note at the frequency 3240MHZ from the Wiimote hardware itself. This was played at the maximum volume allowed by the on-board circuitry.

Vibration Feedback

Likewise, we chose to keep the vibration variables to a minimum. The Wiimote software we used only has discrete on or off states for the rumble through the controller. For the most part they were similar in intensity, though occasionally a difference in current battery level would make one of the Wiimotes stand out more. This occurred around 15% of the time. Also worth noting is that sound is a vibration, and there is a natural audio feedback which accompanied all vibration in our implementation.

Per Limb Feedback

Our system presented non-visual feedback per limb; each arm and leg was receiving information independently. There was a fair amount of confusion between body parts experienced by the average person when only visual feedback is available. Even if faced with a human figure and told that the figure is mirrored, it is likely that the player will become confused. Having a cue from specific limbs was an important part of the game prototype so that future software implementations could better instruct complex movements.

Temporal Variation

Unlike our previous experiments [17], Vibraudio Pose did not rely on fixed time intervals for scoring; users were instead challenging themselves to get into the poses as quickly as possible as a measure of skill. Because the timing of the feedback was something that we could modify, we implemented the scoring system so the feedback would be delivered in timed intervals; for example, if the positive feedback type was audio, it might beep with long pauses if the current score was OKAY, more rapidly when the score became GOOD, and finally continuously play when the score became PERFECT.

Usability Study

In order to test user performance and experience, we designed a formal usability study. All users played Vibraudio Pose but the type and role of the feedback was different depending on which mode they played (See Table 4.1). For the most part our experiment was exploratory in nature; however we developed two hypotheses based on our experience with the pilot study participants:

1. H1: Audio would rate poorer than vibration overall due to its difficulty to detect per limb
2. H2: Users would prefer non-visual feedback despite slower task completion times

Table 4.1: The four modes defined by the role each feedback type plays and the conditions experienced by the user. The * indicates that condition occurred in that mode.

	Feedback Types		Conditions			
	Audio	Vibration	VisualOnly	PosOnly	NegOnly	Both
Mode 1	Pos	Neg	*	*	*	*
Mode 2	Neg	Pos	*	*	*	*
Mode 3	Pos	Pos	*	*		
Mode 4	Neg	Neg	*		*	

Participants and Apparatus

We invited 32 participants (10 female, 22 male) with a mean age of 22 ($\omega = 3.32$). Almost all of them were students (14 undergraduate, 10 graduate). These participants were found through email mailing lists and fliers around our university. Only 2 expressed issues with hearing audio. Most were avid video game fans with 10 out of 32 playing games several times a week and another 8 playing monthly. The majority also took part in frequent physical activity, with 20 people claiming to exercise several times a week and 27 listing at least one sport or athletic hobby. Two people had back issues which made it difficult to put their hands on the ground; we allowed them the use of a chair to lean on for assistance.

Vibraudio Pose was run on a dual-core desktop PC with an nVidia GeForce 8500 graphics card, using a 50-inch Samsung DLP 3D HDTV display at a refresh rate of 60 Hz. The participants were

behind an opaque plastic curtain in a space that was roughly five by five square feet. The moderator operated the program by keyboard controls in front of them (see Figure 4.1).

Experimental Design

In our experiment, there were three feedback types: visual, audio and vibration. There were four conditions studied: Visual Only, Positive Only, Negative Only, and Both Positive and Negative. This accounted for all permutations of audio and vibration feedback. We do not incorporate the Visual feedback in these iterations because it is our control case when there is no other feedback. Visual was present in all practice rounds but taken away for each play round except for the Visual Only condition. Initially it was thought that having a feedback type for a positive reinforcement and a negative reinforcement was a good idea as this is implemented in some commercial video games (for instance, there might be a rumble when you are hurt and when you receive treasure). However, in Vibraudio Pose feedback was constant. It is used to continuously give an indication of how well the player is doing; each limb is always producing a score from PERFECT to MISS. In our initial pilot study, using the same feedback type for both positive and negative reinforcement confused participants because it is difficult to distinguish the contextual role without visual reinforcement.

Between Subjects Modes

In addition, participants struggled with remembering the role for each type of feedback. With this in mind, we chose to use a between-subjects approach for cases where the role of a type of feedback changed; for example, the same user never experienced audio as positive and later as negative. We divided our participants into four different groups as shown on the left side of Table 4.1.

Within Subjects Conditions

These four modes were further broken down into the following conditions: Visual Only, Positive Only, Negative Only, and Both Positive and Negative. The Visual Only condition was used as a control, while the others were the experimental conditions. Each participant performed all conditions within their mode. For Modes 1 and 2 users experienced four versions of the experimental task with no two participants experiencing the same permutation. In Modes 3 and 4 there were only two conditions because the other two would have been redundant considering the presence of just one role. Half the participants had one first and half had the other first. Using this mixed design experiment, we accounted for all conditions.

Experimental Task

Each condition was tested using an experimental task with a practice and play round. Each round was made up of seven different poses randomly ordered to prevent learning effects. The participant would receive pose group 1 to do for the first half of the experiment regardless of the order in which they did the within subjects tasks. Again, based on the pilot study most participants would memorize these poses by the halfway point and so pose group 2 was used for the second half (See Figure reffig:vbposes). The poses were kept independent of the conditions and the groups were roughly equal in difficulty. For each pose the screen displayed the image of the pose, its name, and a score output for their four limbs: left hand, right hand, left foot and right foot. Between poses, the game paused and the participant was instructed to get into a neutral pose (standing with arms at one's sides). If the correct position was not detected in 30 seconds, the pose timed out.

After the practice round was completed, the play round began. During this round the visual assistance was taken away. In the Visual Only condition, participants still faced forward but were not

shown the instructional image for the pose. They had to use the name of the pose and the score output per Wiimote to determine what to do. After fifteen seconds the image would appear to help them. All other conditions required the user to turn around and face the wall of the enclosed space rather than the monitor. The moderator then read the names of the poses aloud. No further verbal assistance was allowed until fifteen seconds passed, after which the moderator would give the same information as the image as it was assumed to be a memory problem. We recorded the completion time during the experimental task and had participants fill out a post-experiment questionnaire (See the Appendix A).

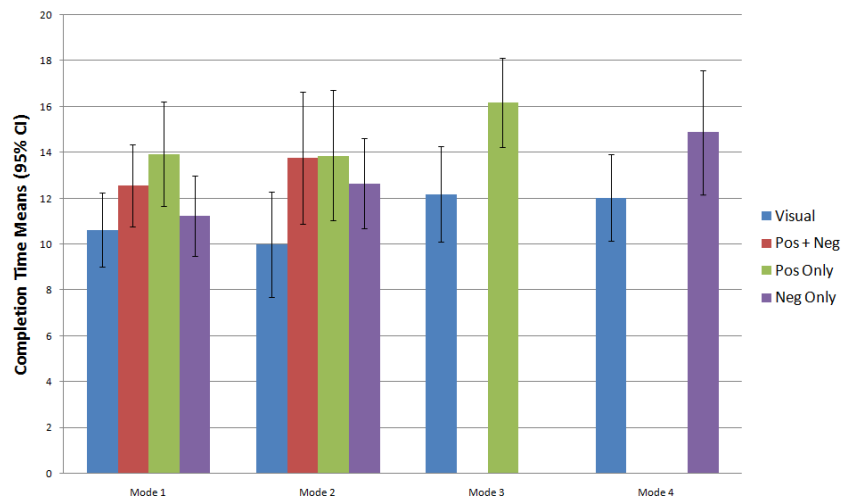


Figure 4.3: Completion time means across all modes.

Results

We analyzed our data across the four modes based on performance and preference. We ran a 2 (Conditions: Visual Only and Both Positive and Negative) by 4 (Mode) repeated measures mixed ANOVA on the average completion times (See Figure 4.3). For the questionnaire analysis we chose non-parametric testing because the data was ordinal.

Completion Times

We found significance ($F_{1,28} = 21.7, p < 0.05; \eta_{2,p} = 0.437, OP = 0.9994$) across feedback conditions. Between modes yielded no significant differences, ($F_{1,28} = 2.31, p = 0.098, \eta_{2,p} = 0.20, OP = 0.952$), at the 0.05 level. In addition, we ran a 2 (positive and negative feedback only) by 2 (Modes 1 and 2 only) repeated measures mixed ANOVA on completion times and did not find significance for the conditions factor ($F_{1,14} = 0.027, p = 0.873, \eta_{2,p} = 0.002, OP = 0.053$) but did find significance for the interaction between feedback and mode ($F_{1,14} = 5.85, p < 0.05, \eta_{2,p} = 0.30, OP = 0.614$). The between modes factor was also not significant ($F_{1,14} = 0.159, p = 0.696, \eta_{2,p} = 0.011, OP = 0.066$).

Furthermore, we conducted analysis using t-tests and controlling for the chance of Type I errors with a Holm's sequential Bonferroni adjustment at $\alpha = 0.05$ [43]. We then found significance when both vibration and audio were on, between Mode 1 and Mode 3 ($t_{14} = -2.9, p < 0.05, d = -1.55$). When audio was positive and vibration negative, the completion time was much less than when both audio and vibration were positive. With adjustment, the Visual Only condition was not significantly faster than the Both condition, but it was close enough that it's possible with more participants it would have been. For Modes 2 ($t_7 = -3.06, p = 0.018$), 3 ($t_7 = -2.6, p = 0.035$) and 4 ($t_7 = -2.78, p = 0.027$) the Visual Only condition was nearly significant and in Mode 2 ($t_7 = -4.82, p < 0.0125, d = -1.05$), the Visual Only condition was significantly faster than the Positive Only condition.

This was surprising since from observation participants seemed to be faster in Visual Only; however this fact supports the merit of non-visual feedback. Also of note is Mode 1 being excluded from even close to significant results, indicating that of non-visual feedback modes, Positive Audio and Negative Vibration was the fastest of the modes that we tested. It also indicates the Negative Only condition was comparable in speed to Visual Only, regardless of how feedback was assigned

to the roles.

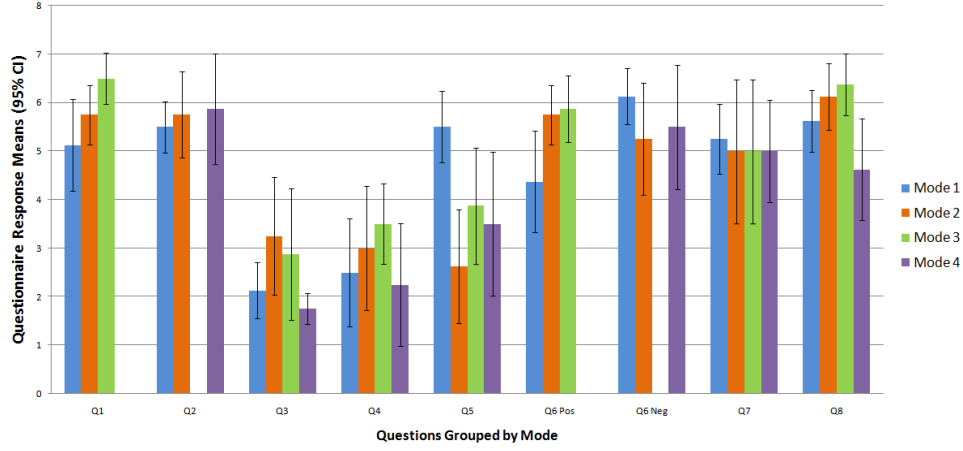


Figure 4.4: Questionnaire response means using a seven-point Likert Scale. Q1 regarded positive reinforcement and Q2 regarded negative reinforcement, so modes without those roles were not given that question. For Q6, each mode received a different set of questions specifically for their permutation of feedback type x role. The graph groups the questions by positive and negative for comparison. The full questionnaire can be found in Appendix A.

Questionnaire Data

We ran Kruskal-Wallis tests on the participants' questionnaire data, which identified significance in audio detection per limb ($\chi^2_3 = 9.1, p < 0.05$) and using vibraudio feedback ($\chi^2_3 = 8.864, p < 0.05$). Using Mann-Whitney tests, we found that more people had trouble detecting audio coming from each Wiimote in Mode 1 than in Mode 2 ($Z = -2.79, p < 0.05$). Perhaps because of the greater need to know per limb data when negative, the participants noticed the audio better. Also using a Mann-Whitney test we found that more people thought the system would be better for learning in Mode 2 ($Z = -2.26, p < 0.05$) and 3 ($Z = -2.44, p < 0.05$) in comparison to Mode 4. This implied that having no positive feedback at all made it hard for them to learn, but that positive feedback that was audio only was almost as bad. It was much different from the score results, which indicated Mode 1 had the better completion times.

Discussion

Our results confirmed our initial hypotheses to varying degrees. The completion times showed having only visual feedback was faster for most people. The questionnaire data lead to many other interesting trends, discussed below, which supports the claim that vibration was preferred over audio. In addition, it seems that most people were evenly distributed between preferring Visual Only or non-visual feedback, except for Mode 1.

Histogram Data

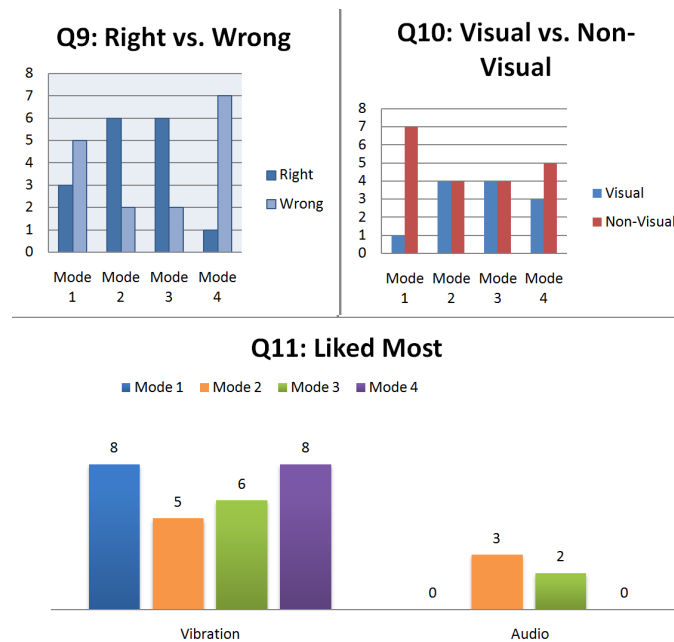


Figure 4.5: Comparisons of the preferences per mode, represented in histogram.

Aside from the statistically significant results, we created Figure 4.5 to show how some of the other questionnaire data implied other connections. Users were asked whether they preferred to be told when they were right, or when they were wrong. The majority of the time users chose whichever

condition vibration was used in, especially in Mode 4. Also, all but five participants preferred vibration to audio. This implied that vibration makes more of an impact on their experiences. Additionally, across Modes 2, 3, and 4, half of the participants preferred Visual Only and half did not. But in Mode 1, only one person out of eight preferred Visual Only. This indicated that participants seem to enjoy positive audio, negative vibration more than others. Games using non-visual feedback should consider this setup for the most enjoyable experience.

Write In Questions

Did you prefer the Visual Only mode to the other modes? Those who preferred Visual Only mainly said it was faster or easier, with a couple focusing on the fact that they could not remember without having a picture in front of them. If they preferred nonvisual, the reasons most often given were that it was more fun, more unique, or more challenging. However several people thought it was the easier method.

Which type of non-visual feedback did you like the most? Very few people preferred audio, but when it was liked best it was due to familiarity or ease of use. The vast majority of participants liked vibration because they felt it was simpler to detect, more comfortable to feel, and easier to distinguish spatially.

Which type of non-visual feedback did you like the least? Three out of the five who disliked vibration said it was hard to tell what was vibrating. Since most people did not have that problem, it could be that some people are less sensitive to vibration feedback. Those who disliked audio stated most often that it was hard to distinguish per limb, which we expected. But what was interesting is that this came up much more often when audio was used in the positive role, ten times compared to three. When audio was used in a negative role, it was considered annoying or distracting by six people, but nobody given audio in the positive role complained about it in this

way.

Memory Recall

One of our concerns in doing this experiment was that users would be influenced by their ability to recall the poses beforehand. During the pilot study, participants sometimes remembered the next pose in the sequence from the practice round; they would already be in position and receive much faster scores. Because of this we enforced the neutral pose and organized the poses into two distinct sets.

However, there were many participants who seemed frustrated by the memory issue and in fact focused on it more than the feedback from the system. Prior to the experiment they were told each pose would have a name for later recall and during the play round they were reminded to use the feedback to assist them. Some still had trouble but the experiment was designed to test whether the feedback could help a person into different physical positions without the need to remember them.

3DUI hardware

It is also worth noting how our physical implementation might have altered the results. The Wiimote was able to do everything necessary for this project, but it is bulky as a worn device because of its multiple buttons and infrared camera. Ideally a smaller wireless device capable of audio and tactile feedback and accelerometer input would improve our prototype.

Summary

In games utilizing the entire body as an input device, the near limitless ways that the player can move imply that the user is not always going to be looking at a visual display, and even so may be confused by what they are asked to do. In this work, we have shown that using audio and tactile feedback is just as valid a technique as visual feedback, and in some cases provides additional benefits. Participants seemed to perform comparably between non-visual in the Negative Only and Visual Only conditions. Users preferred vibration to audio and implicitly preferred feedback roles when they were utilizing vibration. Between modes, they preferred and performed best when audio was positive and vibration was negative. These results present the benefits of non-visual feedback in full-body interfaces.

CHAPTER 5: AVATAR-BASED INSTRUCTION AND LEARNING

Our previous experiments taught us new information for developing instructional and feedback interfaces. But one drawback to our prototype was the wearable Wiimotes as input devices. While Wiimotes are relatively inexpensive and useful controllers, they were not meant to be attached to a person, resulting in the devices feeling bulky to wear. Camera-based 3D game systems such as the Sony Eye and the Microsoft Kinect provide a lower barrier to begin play. For non-traditional gamers, older adults and young children, playing exertion games unencumbered means no mechanisms to hold, wear, or stand on. We theorized that this type of game interface would become more popular than wearable interfaces, and thus warrant exploration.

When designing an aspect of the game to study, we noted that the physical actions of a person playing an unencumbered dance game are almost identical to that of a person learning a dance instructional video in their own home. Many video game controllers resemble real objects such as fishing rods, musical instrument, tennis rackets, and guns. These alternate controllers are mimetic interfaces meant to mimic the action of the gameplay [51]. In some cases, especially music games, these controllers are directly relatable to real world counterparts. Some guitar game controllers are equipped with strings and piano teaching tools like Synthesia use a game-like timeline interface with an actual digital keyboard [52]. These observations led us to question if dance games could also directly relate to the activity they are emulating. We wanted to know if dance games could teach someone to dance.

Our next dance game prototype, Teach Me to Dance, used an Optricam depth camera so that we could explore unencumbered interfaces. We compared a rhythm dance game visual interface to a video of a person teaching the same move set. This study resulted in unexpected information regarding player experience, as we discovered how self-representation on the screen altered per-

ception of performance. We learned that game-inspired interface elements were not a substitute for footage of a real human dancer, but participants overall preferred to have access to both visual elements. Most importantly, we discovered that multiple sessions and a higher degree of aesthetic polish would have improved the study, lessons taken to our next project.

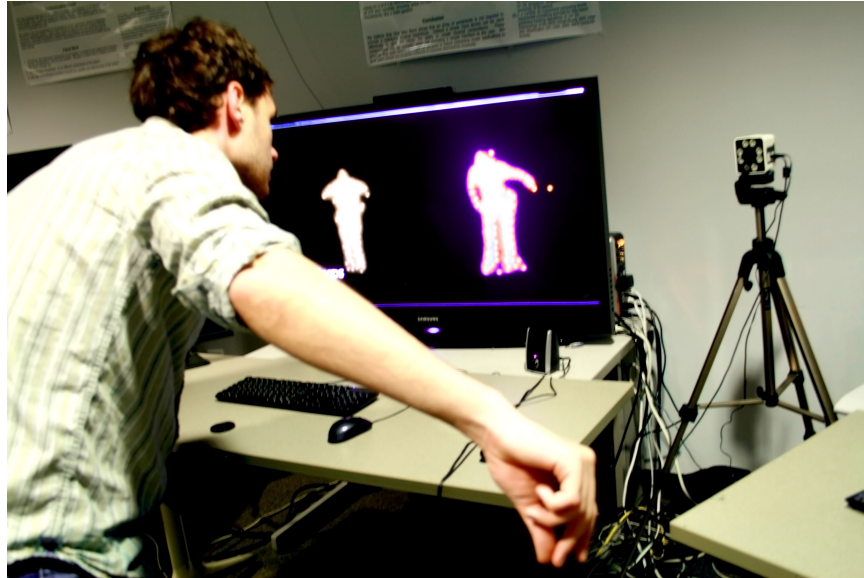


Figure 5.1: Our dance choreography game with Game Only visuals. The orange silhouette (left) shows the player what to do and the purple silhouette (right) shows the player's position.

We designed a study that compared three different dance game visualizations: Video Only, Game Only, and Both. We speculated that three elements in particular would influence our results and formed the following hypotheses.

Self-Representation. To self-conscious players, an animated avatar is more encouraging than a reflection of the player's body. We hypothesized that those with dance experience will enjoy seeing their own silhouette more and those who exercise and/or dance less will prefer to see an instructor doing it skillfully.

Preview. Many rhythm games feature a timeline of upcoming moves [17]. These games often

use twitch gameplay that tests hand eye coordination. In contrast, teaching choreography involves repetition until a routine can be performed from memory. We predicted that frequent gamers and those with memory troubles will prefer modes where they can see the next moves easily.

Learning Curve. In the past, most dance games were restricted to a few button inputs. But the human body is much more complex, with many combinations of body parts and positions that have to be communicated. Conveying detailed movements is additionally hampered by the translation of 2D screen to the 3D body space. We hypothesized that most users will prefer seeing a human instructor compared to not having one because it will be more familiar.

We used self-reported questionnaires to record data on user preference, and two different methods of judging performance: algorithm-based and human-assessed. The rest of this chapter describes our system, experiment, and results.

System

We developed a dance game prototype which teaches a routine using different visualizations. With the average person's abilities in mind, we modeled the dance instruction on a cardio fitness class rather than a professional dance class. The choreography we used is from the *So You Think You Can Dance: Get Fit* workout DVD [76]. In this video, the dance instructor teaches a routine with simple, cardio-oriented moves that are both easy to understand and easy for our algorithm to recognize.

Our system used an Optrima Opticam depth camera and the SoftKinetic human pose library to detect the player's 3D volume as they dance. This data was streamed into our game, which was coded in C# using Microsoft XNA. The SDK provides us with 15 samples (frames) per second, each sample containing 150 centroids representing the foreground object (the player). We built a

simple heuristic based scoring mechanism which used training data of each move to determine its accuracy. To make the heuristics more robust between different users, the user stood still during the first frame with their arms at their sides and their natural width and height is used as a scaling factor.

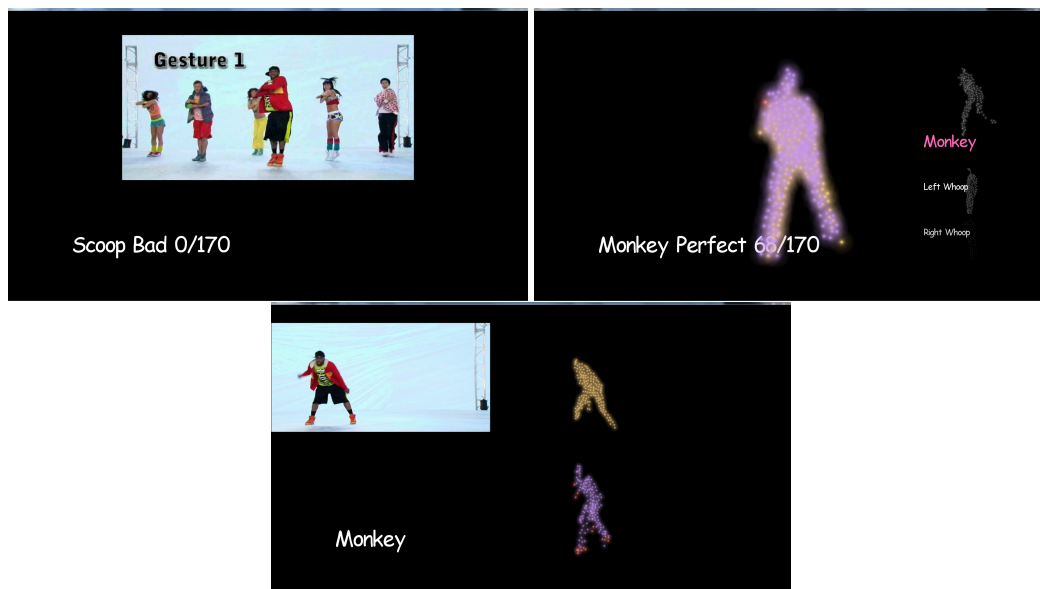


Figure 5.2: Screenshots of the three display modes. *Top*: Video Only (Full Routine), *Middle*: Game Only (Full Routine), *Bottom*: Both (Training mode, which was performed first in all modes)

Our prototype provided feedback, computed real-time scores, and recorded performance data. The dance was divided into ten *moves* which were four beats long, then further divided into poses that were evaluated by camera samples captured within a window of time. Similar to gesture recognition algorithms, user motions were observed by a sensor and related to predefined positions. However, the goal of recognition is to determine the user's intent, while in this case we only need to evaluate the accuracy since we already know what move the user is trying to perform. Therefore, the scoring asserted that the move is correct past a certain confidence value, then evaluated the timing. For each pose, the user earned a score corresponding to the narrowest time interval during which at least one of the frame samples satisfies the heuristic function. These scores were displayed

as the words PERFECT, GOOD, OKAY or MISS to emulate the look of a rhythm game.

Visual Elements

We created three different visualization modes for the prototype: Video Only, Game Only, and Both. Video Only was designed to mimic the scenario where a person buys a cardio fitness video to practice alone at home. The Game Only, as previously described, was designed to emulate a full body dance rhythm game. Finally, Both combined all the elements into one display. Each mode used a different set of visual elements (see Table 5) but the audio of the source material was used in every mode. These elements gave different feedback and were implemented based on their use in commercial games.

Table 5.1: A breakdown of which visual element was used in which mode.

Visual Element	Video	Game	Both	In Training (%)
Move Name	Yes	Yes	Yes	Yes
Score	Yes	Yes	Yes	No
Instructor Video	Yes	No	Yes	Yes
Instructor Silhouette	No	Yes	Yes	Yes
Player Silhouette	No	Yes	Yes	Yes
Next Move Timeline	No	Yes	Yes	No

1. **Move Name.** One of the main challenges for users was telling the moves apart, so we assigned each move its own unique name to aid in recollection: Scoop, Walk, Pocket, Monkey, Left Whoop, Right Whoop, Airplane, Pop, Snaps, and Jump.
2. **Score.** When performing the Full Routine, each move would be scored in real time as either PERFECT, GOOD, OKAY, or MISS. At the end of the song, a percentage score (Earned/Total Possible) was displayed. The score was not present during the Training, so the player could focus on learning.

3. **Instructor Video.** We also used video clips of the human instructor. There were eleven clips in total: ten for training and one for the full routine. It was only present in the Video and Both conditions.
4. **Instructor Silhouette.** When deciding on an instruction method for the game interface, we reviewed many past dance games and brought in our knowledge based on past studies [17]. However, after piloting GUIs that used paths and icons, our attempts lacked the polish needed to properly convey the moves. In the end, we chose to use a human avatar. Without a team of artists our implementation choices were limited, so we decided to use the centroid particles from the depth camera. By doing this, the player could directly map themselves to the instructor's form. The instructor data was pre-recorded footage from a team member with two years of experience in hip hop dancing. It was positioned to the side or above the player during training and overlaid on the player silhouette during the full routine. See Figures 5.1 and 5.2.
5. **Player Silhouette.** The user's body was also displayed using centroids. Red particles indicated points at which the player data differed from the instructor. The player silhouette is the only indication of what the player actually looks like performing.
6. **Next Move Timeline.** In most rhythm games, the players are not expected to memorize the routine beforehand; instead upcoming moves are indicated by a preview method, usually in a timeline of scrolling icons similar to musical notation. While this method is not necessarily the best for full body interfaces [17], we chose to use scrolling move icons because of their use in the game *Dance Central*. The sliding animated buttons get brighter and larger as they move up into the current move spot. The player can see the name of the current move and the next two upcoming moves. Small recordings of a person performing each move are shown next to the move name.

Experiment

We conducted a user study to compare performance and experience between our three visualization modes: Video Only, Game Only, and Both. In terms of our hypotheses, we predicted participants with little experience in dance or exercise would prefer not to see themselves on-screen, that gamers or those with low memory would like the Next Move Timeline, and that all participants would find the Instructor Video easiest to follow.

Subjects

30 participants were recruited through flyers, email lists, and at gym classes at the University of Central Florida. 19 were male and 11 were female. Their ages ranged from 18 to 32 (mean 22.9). Eighteen were computer science/computer engineering students.

Users were also divided up by dancing, gaming, fitness, and memory experience. Since we only had three participants with extensive dance training, we sorted participants into two groups: no experience and at least a year of dance classes. For game experience, we considered the user to be a novice if they played games rarely or not at all, and an expert if they played weekly or more. Another factor we examined was the physical fitness of the participants. We used the short form of the International Physical Activity Questionnaire (IPAQ) to categorize our users based on their self-reported physical activity [20]. The majority of our users rated themselves very highly. Four users were in category 1 (least activity), fourteen were in category 2, and eleven were in category 3 (most activity).

In addition, our previous work revealed that many participants have low self-efficacy due to assumed memory problems [15]. We used the Prospective and Retrospective Memory Questionnaire (PRMQ) [94] to classify users by their self-reported memory capabilities. We considered only the

overall memory capability since prospective and retrospective differences did not clearly relate. The absolute range of these scores was from 32 to 67. Users with a score below the mean (50.2) were considered 'low memory' and users with the mean or higher were considered 'high memory'.

We designed a between-subjects experiment where each user was presented with one of three visualization modes: Video Only, Game Only, and Both. We collected three kinds of data: the user's performance, as measured by our sensor-based scoring system; scores from a panel of judges post-experiment; and questionnaires filled out by the users.

Our experimental task was broken up into several phases. We wanted to test the user's perceptions and performance based on different conditions, but also their overall preference, so the different visual options were only revealed halfway through the study. We formulated the task into *structured* and *unstructured* sections. We first ensured each person is trained an equal amount of time, then given an opportunity to keep practicing to assess their motivation to continue. The experiment took an hour on average.

1. **Preparation.** At the beginning of the task, the user was led into an enclosed space where only the moderator and he or she was present, then told that the researchers were investigating software that teaches dance choreography and given a consent form to read.
2. **Questionnaire 1.** The participants recorded their demographic information as well as their self-reported IPAQ and PRMQ scores.
3. **Training.** The participants then began the task. This was the structured part of the experiment. Participants learned ten dance moves through a series of training segments. Each move was repeated several times and then repeated in small sequences. Each participant did the same sequence of training to ensure they would have the same preparation regardless of starting mode.

4. **Full Routine and Test.** After training, the participants were asked to do the Full Routine to music three times. Then, they were asked to perform under Test mode, where the participant must do the routine completely on their own, with a blank screen and different music of similar beats per minute. This was purposely challenging; we intended to analyze their confidence and to see if the moves could be translatable in a completely different environment (for example, taking a hip hop class then going out to a club).
5. **Questionnaire 2.** This survey involved their preferences and perceptions. They did not know that there were other visualization modes (See Table A.3 in the Appendix).
6. **Final Routine.** Next, they were told that two other display modes existed. They were asked to perform using each of the other two modes once (randomly ordered). Then, the moderator stated they would need to do the Test condition one last time, but they could practice as much as they wanted using the training segments and the full routine on any visualization mode. We wanted to encourage the participants to practice more if they desired.
7. **Questionnaire 3.** Finally, they filled out a shorter questionnaire repeating some questions and asking their preference between modes. When complete, they were thanked and compensated for their time.

Results

For our analysis, we divided users by initial mode, dance experience, game experience, IPAQ scores and PRMQ scores. These categories were then compared to several different performance metrics using between-subjects ANOVA. We also used non-parametric testing on our questionnaire data to look for significance.

Performance

We judged performance in three different ways. First, we took the mean of the initial three full routine attempts on Practice mode. These were performed before the players knew that any other visualization modes existed, giving an unbiased impression of their efforts. Second, we looked at the time the participants took to practice when given free rein during their unstructured section. Finally, we gathered a panel of judges to give an expert opinion of their performance post-experiment.

We did not find any significance among participants related to their mean scores or their time spent in independent practice. For scoring, having no significance might imply issues with our implementation, or simply that visuals had no impact on actual performance. We calculated the total time spent between when they began unstructured practicing and when they finally began the final test. Participants prepared in a variety of ways: repeating on several different modes, practicing the training videos again, and sometimes standing still and remembering in their own head. For the most part, dancers and those with high memory scored better, and those with no dance experience took longer to practice. But since these results are not significant we can only make suggestions about what this might indicate.

Design and Task

In the last part of the experiment, the participants performed the dance one final time with no visuals and different music. This is a very difficult challenge, especially for novices with a short exposure to a dance. We wanted a human perspective in three categories: Moves (how accurately they remembered the moves), Timing (sense of rhythm), and Flair (how graceful and smooth their movements appeared). Our first judge had twelve years of experience as a cultural dancer and three years as a ballet teacher. Our second judge had seven years of experience focusing in ballet and

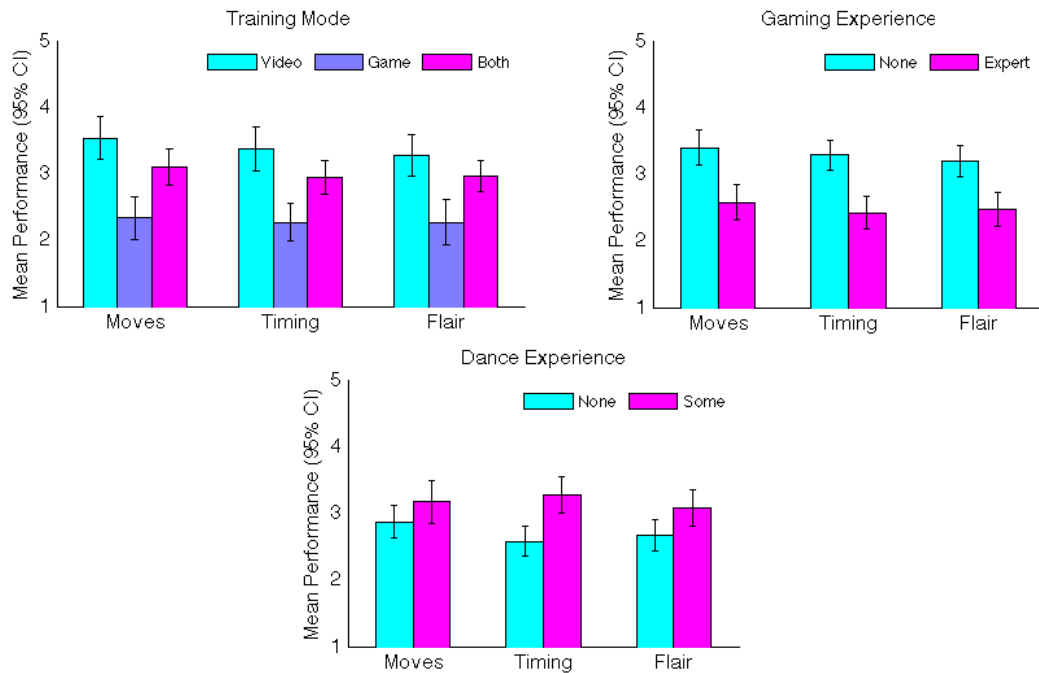


Figure 5.3: Post-experiment review in three categories: moves, timing, and flair. We had three human judges grade all of the videos anonymously on a scale from 1 to 5, with 1 being the worst and 5 being the best.

tap. Our last judge had no dance experience but was an expert rhythm gamer who participated in *Guitar Hero* tournaments. We held individual judge sessions so no judge was aware of the others' scores.

The judges were first shown all routine and training videos. The participants were randomly sorted for each judge and the data was in centroid format so the participants were not identifiable. Scores were between 1 to 5 in the three categories (1 being worst and 5 being best). For each participant, we took the mean of the three judges for Moves, Timing, and Flair and compared against our participant demographics (See Figure 5.3). All three judges scored the contestants similarly despite their different backgrounds.

Those starting with Video Only had a higher score in Moves and Timing over Game Only.

(Moves: $F_{2,27} = 3.859, p < 0.05$, Timing: $F_{2,27} = 3.66, p < 0.05$) While this division does not indicate what mode they preferred the most or practiced the most on, it does indicate that having trained on Video Only made participants more likely to remember moves and have good timing.

Non-gamers scored significantly higher in moves, timing, and flair. (Moves: $F_{1,28} = 5.044, p < 0.05$, Timing: $F_{1,28} = 6.803, p < 0.05$, Flair: $F_{1,28} = 4.554, p < 0.05$) There are too many other variables between gamers and non-gamers to make a concrete conclusion from this finding, but this may illuminate the difference between learning choreography and playing rhythm games, as discussed in our Introduction. Most of our expert gamers were familiar with dance games such as *Dance Dance Revolution* and *Pump it Up* but this experience did not transfer to their performance.

Dancers scored higher than non-dancers, but not significantly higher. (Timing: $F_{1,28} = 3.565, p = 0.057$) The timing results were almost significant between dancers and non-dancers. This could be expected since rhythm is an important part of dancing. Having professional dancers or participants with much more experience might have made a larger difference between these two groups.

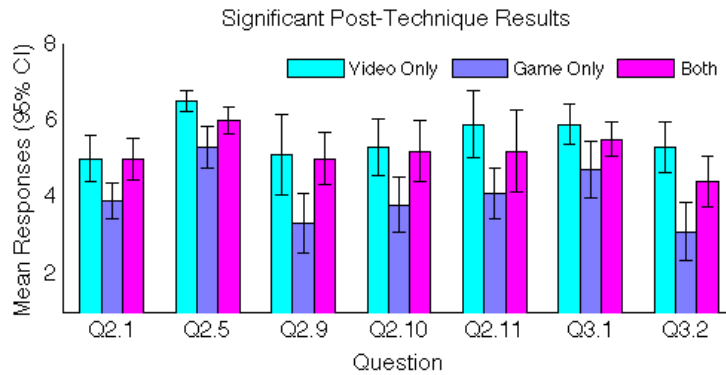


Figure 5.4: Significant results from the questionnaire. The full questionnaire can be found in Appendix A.

Self-Reported Questionnaire

Our participants filled out two questionnaires (see Table A.3 in the Appendix). Questions 1 to 11 were graded using a 7-point Likert scale (1 for Strongly Disagree and 7 for Strongly Agree). We found the most significance by comparing the between-subjects condition of starting mode. The results are displayed in Figure 5.4. Our data suggests that Game Only mode was much less preferable to the other two modes.

- Game Only was significantly harder to understand than Video Only and Both. ($\chi^2_2 = 6.858, p < 0.05$)
- Video Only was significantly more enjoyable than Game Only. ($\chi^2_2 = 9.372, p < 0.05$)
- It was harder to tell what was wrong in Game Only over Video Only and Both. ($\chi^2_2 = 6.640, p < 0.05$)
- Video Only was almost significantly more engaging than Game Only. ($\chi^2_2 = 5.861, p = 0.053$)
- Video Only felt that their memory factored into performance more than Game Only. ($\chi^2_2 = 7.290, p < 0.05$)
- Those who started on Game Only felt like they understood it better at the end of the experiment, changing the significance ($\chi^2_2 = 9.1, p = 0.092$) The mean for Game Only participants rose from 3.9 to 4.7.
- Those who started on Game Only thought they performed better at the end of the experiment. ($\chi^2_2 = 9.459, p < 0.05$) Those which started on Game Only rated their performing ability higher after seeing the other modes. (from 4.2 to 5.3).

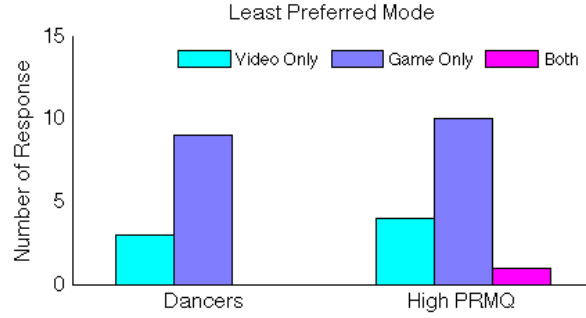


Figure 5.5: Least preferred display method from questionnaire data.

Discussion

For the other questions, we had found significant difference when we asked which interface they liked the least (See Figure 5.5). Dancers ($\chi^2_2 = 10.5, p < 0.05$) and those who scored high on the PRMQ ($\chi^2_2 = 8.4, p < 0.05$) significantly chose Game Only as their least favorite interface. This correlated with our other data. We believe these two groups in particular had little interest in Game Only because they did not need the help of the timeline as much as non-dancers and those with a lower memory score. We found no significance between non-gamers and gamers, and no significance between IPAQ results. As outlined in our introduction, there were three main concepts that we wanted to investigate. Our results revealed interesting perceptions in these areas.

Self-representation should be minimal in order to keep the player motivated when they exhibit self-conscious tendencies. As reported in [114], users of exercise games often have low self-efficacy and tend to easily find reasons to be frustrated. This reinforces other reports that dancing often makes people feel embarrassed [104]. Most people felt better about their performance when they could not see themselves performing, even with no significant difference in their scores. However, while this increases the user’s enjoyment, it does not help them learn. Users are likely to continue to have a negative opinion of their abilities if they take their skills out in public

and receive poor feedback.

This implementation of preview visualization was helpful to some users, but not as desirable as the instructional video. We did not find significance in those with low memory or expert game experience. We were able to conclude that those with high memory dislike the Game Only mode significantly more than those with low memory, possibly because they found the additional elements unnecessary. Four out of the five participants that chose Game Only for best interface were in the low memory group, perhaps preferring it because of the preview method.

New interfaces have a learning curve which affected preferences. The majority of users preferred Both, then Video Only, then Game Only to a lesser degree. We theorized that those who had learned on modes including the game elements would be more confident in using them. Instead, many participants switched to a different mode when given the chance (6 from Video Only, 9 from Game Only, and 5 from Both).

Summary

The visual interfaces of a dance rhythm game are not yet a replacement for choreography instruction. Players need to feel sufficiently comfortable, and their own reflection should be minimized. Previewing upcoming moves is helpful, but not as helpful as a human trainer. In addition, the perception of performance was influenced by visual feedback even if the actual performance was no different. The goals of a dance training system are somewhat different from those of a casual full body rhythm game, and developers of dance games should try and make flexible products that cater to either preference, as casual players might eventually wish to grow into serious students.

CHAPTER 6: DANCE ENHANCED: METHODOLOGY

In the previous chapters, we tackled instruction methods, feedback types, and teaching tactics in video games with 3D user interfaces. We designed a series of user studies that refined our approach to studying human behavior and preference with full-body dance games. With what was learned from Teach Me to Dance, we wanted to design a study that would explore the engagement potential of these games over a long period time. We decided to focus on physical fitness, a popular area of research for exertion games.

In a longitudinal study on *Dance Dance Revolution*, researchers reported that the participants began to feel bored after 4 weeks of play [63]. Repetition often leads to boredom, which drives people away from engaging in an activity. For exercise, it's important for people to maintain a continuous schedule over a long period of time [33]. Even if an exertion game is easy to play and provides adequate fitness benefits, it is only valuable as long as it is still being played.

Game researchers have been studying increasing motivation for years, applying the principles of flow, presence and immersion [99]. There's also been work to suggest that narrative adds to experience [18]. As described in Chapter 2, many games feature various types of story integration in order to improve experience. However, exercise games do not have a large variety of stories, making it difficult to compare how effective such additional content will be. Few of these elements arise in dance rhythm games, yet many of them are present in game genres with long playtime or replay value, such as role-playing games or adventure games. And the academic community has not evaluated how different types of story elements affect the dance game experience, outside of a few studies of *Dance Dance Revolution's* sub-culture popularity [2, 44, 95].

These elements may contribute to long-term play and deserve to be evaluated on an individual and combined basis. There may be interesting data on how narrative can be integrated into dance games

and what effect it has cultivating intrinsic motivation. By investigating the engaging qualities of different narrative structures on the play habits of dance game players, we postulate that we can learn more about retaining players longer. To investigate how different narrative frameworks will impact a player's engagement in a body-controlled game, we built the Dance Enhanced study, which uses a website with augmented play experiences and the game *Dance Central 2*.

Dance Enhanced was a two by two between-subjects long-term usability study. We sought to answer the following questions:

1. Can a body-controlled dance game be considered adequate cardiovascular fitness?
2. Does the environment where the dance game is played have an effect on the participant's motivation to exert themselves?
3. Does the addition of extra narrative content usually found in other engaging game genres increase motivation and adherence?

The first question was addressed using standard methods of fitness evaluation before and after the four-week exercise intervention. Our study was heavily influenced by the work of Mejia-Downs et. al. who investigated the effects of a dance-pad game as a six-week exercise program [66]. It was one of the first investigations in using a full-body dance game, which might provide more fitness benefit than the dance-pad games which only use the legs.

The second question was addressed with our first variable: the environment. One group, the Lab group, participated in a controlled testing environment with a moderator. In the Home group, participants were allowed more control of their own progress by playing in their own homes. These conditions offset each other's positives and negatives. In Lab, the moderator was able to accurately measure physical progress by confirming the session play took place and that surveys were filled

out. However, many people have jobs, classes and other outside factors that would affect their willingness to do extra play sessions.

Conversely, in the Home group participants might be more likely to do the activity because they can choose the schedule and feel comfortable in their own environment. But we would not be able to verify their scores, which are self-reported, and there are many possible variables which exist in that location, such as other people watching or the size of the space. Therefore, by comparing the results of these two studies we would be able to balance the strengths and weaknesses against each other.

The third question was addressed by our second variable, narrative content. One group played the game *Dance Central 2* with no additional material, and the other group had access to extra functionality on the Dance Enhanced website. Testing the game without any other material acted as a control in this experiment since no previous study has assessed how motivational *Dance Central 2* is on its own. In total, this gives us four conditions: Lab None, Lab Content, Home None, Home Content.

Table 6.1: The participant groups for the Dance Enhanced study, formed with two variables with two conditions each.

Lab + None	Lab + Content
Home + None	Home + Content

Study Design

We designed a study to investigate these conditions, shown in Table 6.1. Preparation for this study involved organizational overhead, website content development, choosing the appropriate game software.

Software: Dance Central 2



Figure 6.1: This screen capture of Dance Central shows the basic method of play.

Because creating a commercial game of this scale would be a daunting task, we constrained the workload by using pre-existing web technology.

Dance Central 2 is a Kinect dance game which emphasizes real hip hop dance moves. The player chooses a song, character and venue, then follows a detailed character's movements. A scrolling set of cards showing human silhouettes and move names assists the player in understanding what move to perform next (See Figure 6.1). Several indicators of score and performance are integrated into the GUI and graphics. There are several menu options for different types of play, which are described below.

Dance Mode The main gameplay mode allows players to peruse the song list or make their own playlist. Before performing a song, the player can also choose Break It Down mode, which goes through every movement in a song and verbally assists the player in learning the moves. During this mode the player can slow down the avatar's movements and follow along at a lower speed. There are other modes, such as Dance Battle, that require two players, but we did not investigate

these modes during the study.

Crew Challenge The game features a story mode where the player must impress the different crews of Dance Central. In each section, the player is asked to prove their skills by earning over a threshold of stars, at which point they will play a more difficult final song. If they pass the song, they will be given a card signifying they can represent that crew. After five crews are battled, a villain named Dr. Tan challenges the player to dance off against his robots in a playlist of all the previous final songs. The experience can be completed in one to two hours, with options to keep earning stars to unlock new outfits for the crew members.

Fitness The fitness option provides the player with a way to track their fitness data. These features are broken up into two sections: Session, which is reset when the console is turned off, and Lifetime, which is a cumulative number across all recorded sessions. The features which are being tracked are Duration, Calories Burned, Songs Played, and Calories Per Song. For this study, we recorded the Lifetime Duration and Lifetime Calories Burned as tracked by the game for our participants. These features are tracked whenever the fitness option is on, even when playing the other dance modes. They are only recorded when gameplay is occurring, not during menu or pause states.

Other Features Dance Central 2 does feature several factors that make it interesting for players. If connected to the internet, top scores can be compared with the top scores of Xbox friends for each song. The crew challenge mode unlocks new outfits, stages and characters when it is completed. However, each character only has two outfits, and the leaderboard feature does not extend to the fitness statistics.

Dance Enhanced

Dance Enhanced is a website containing everything participants needed for the study. This website was the most versatile solution to explore this research, giving us the flexibility to work in a variety of user study conditions. The website features served two purposes: for all participants, they facilitated the study design to make it easier to collect data and organize appointments. For participants in the Content condition, the website was also a place to play with the narrative content provided. There was also an admin section of the website, which provided the moderator with graphs for each person in the study and compared the participant totals on an internal leaderboard.

Moderator (Day 28)

Enter Your LIFETIME Total Below:

	Hours	Minutes	Seconds	Calories Burned	Heart Rate
Day 28	25	33	22	2100	

Notes

Save Changes

Use this button if you need to update or log your scores for a past day.

Update Scores by Day

Figure 6.2: After every session, the participants would log into the website and record their updated data from the game's Fitness page.

Dance Enhanced included the following components:

1. **Core Backend** The website runs on the WordPress content management system. WordPress has username and password functionality built-in, as well as an easy to customize plugin system for us to build our specialized features. WordPress uses MySQL databases and HTML,

CSS and PHP to run. The website is also aware of the start date of each participant and what day they are currently on in the study. This knowledge comes from the moderator setting the start date manually during the Day 1 session. This information is used to update several of the modules and control which email reminder to send.

2. **Input Scores** The experiences on Dance Enhanced are augmented by their performance in the Kinect dance game. *Dance Central 2* has many methods of scoring: each passed song level gives the player a rating out of five stars, totals of diamond and green gems earned, and a numerical point value usually in the millions. We could have used these scores for data, but they would have been hard for players to remember and record if many songs are played at once. Furthermore, we did not want to punish players who are playing at different difficulty levels.

For these reasons, we used the data that is accumulated from the fitness mode in the game. This data is automatically calculated when Fitness mode is enabled, and the participants can check on their totals at any time in the Fitness menu option. These statistics include:

- (a) Lifetime Duration: Gives the total time played in hours, minutes and seconds.
- (b) Lifetime Calories Burned: The game gives a value of calories burned after each song is played. The accuracy of this number was not known at the time (although we investigate it ourselves in Chapter 7). However, it is a useful metric for players to understand how much they exert themselves while playing.

All users would input the data themselves on the website, though sometimes the moderator would assist them in their first week. Each day, the Input Scores day would automatically update to the correct day of the current participant's study. If internet problems or forgetfulness resulted in a day being missed, an option on this page would allow them to go back and input the score correctly before updating the current day's total.

3. **Modules** Dance Enhanced featured different *modules* that represent narrative experiences.

These modules can be turned on or off per user, in order to study their different impacts. We used this ability in pilot testing to explore which modules were strongest, but in the end kept them all for the Content condition groups. Modules are described in Section 6.

4. **Schedule Calendar** Even in a study with only one appointment, the overhead involved in scheduling participants can be immense. From the beginning, we knew a scheduling software solution was necessary to give the participants the freedom needed to organize their play sessions, as well as keep the moderators up to date on the latest changes. The software also allowed the moderators to set the hours of availability.

Participants could reschedule their lab appointments using an embedded system by the Appointy service. Appointy allows participants to cancel, reschedule and receive reminders about their appointments, which cuts down on administrative work for the study investigators and makes it more convenient for the participants.

5. **Email Reminder** One of the dangers in this study is the potential dropout rate for participants after a few weeks. In order to combat this, we established a set of emails which would be delivered to the participants every three to four days. These emails were sent depending on what day of the study each participant was on. The emails were identical except that those with the website content were given an additional statement about what content was now unlocked on the website. We found that the email reminders were a useful way to keep participants reminded of the study, as they would often trigger emails to the moderator about upcoming appointments or questions. In addition, survey links in the emails helped the participants remember to do the surveys at home which allowed them more time in the lab for dancing.

The released content schedule was added after the long-term pilot. During the pilot, all content was available to the participant from the very beginning. We found that the pilot

participants became less enthusiastic as the weeks passed because the content in the game and the website did not change, something that has also occurred in other studies [111]. We decided to have the content unlock every few days in the actual study. We wanted to see if this method would draw the participant back to the website, and in turn if they would adhere to the study better. From the beginning, Chapters 1 and 2 for every character were available and the Beach item set. The rest unlocked on the schedule in Table 6.2

Table 6.2: Every few days, the participants were sent an email to remind them to continue participating. If they were in the Content group, they would receive additional reminds of content which had unlocked.

Day	Reminders (Content)
1	Welcome Message and Reminders
4	Reminder (Golf Items Unlocked)
7	Survey Due (Chapter 3 Unlocked)
10	Reminder (Yacht Items Unlocked)
14	Survey Due (Chapter 4 Unlocked)
17	Reminder (Subway Items Unlocked)
21	Survey Due (Chapter 5 Unlocked)
24	Reminder (Penthouse Items Unlocked)
27	End of Study Reminder
28	Final Study and Survey Reminder

6. **Activity Tracker** One of the benefits of using web technology is tracking online data. We built a WordPress plugin to track how much time is spent in each module and see if there is a noticeable preference between them. The results are examined in Section 7.
7. **Questionnaires** All of the survey data was filled out within the website. This reduced strain for the moderators by removing the need to input the data from written forms, and saved on

paper waste as well. The surveys were embedded SurveyGizmo forms which securely save the data and can export it to SPSS for data analysis.

Journal

Another way in which we sought to organize the participants was the creation of a written journal. Journals contained several pages of information about the study for easy reference, the username, password and address of the study website, contact information, and a section for the participants to write their progress throughout the study. Even though some participants found the use of a paper record redundant, this tool provided to be useful for times when the internet in the lab was not working. It also helped them remember their passwords. Comments written in the journals were typed up and recorded for later analysis.

Modules

The following sections describe the content modules on the Dance Enhanced website. These modules were designed based on features commonly found in other genres of games. This extra content was used to investigate if its presence would have an effect on players of a dance game.

Story

Following the lead of rhythm games such as *Elite Beat Agents*, this module added story segments to Dance Enhanced. For every 30 minutes of play recorded by the Duration statistic, participants earned a token to unlock a cut scene from one of four characters. The player could choose to unlock all of one character's scenes first or the first scenes of every character first.



Figure 6.3: A decision tree mapping the dialogue of Emilia Chapter 3. Each of four characters had five chapters of roughly the same length.

The static cut scenes used artwork from *Dance Central 2* to represent the characters. Using the JS-VINE library, we implemented text and image scenes with branching dialogue [27]. Players clicked through the pre-written discussion between a character and themselves. Each of the four character arcs with five chapters each. In total, over 8,000 lines of dialogue were created.

The characters chosen were two male, two female from different crews within the game. The group was picked based on variety and feedback from a group of game designers that volunteered their feedback on project. The storylines covered different motivations and topics to account for a reader's particular taste. The different stories included:

- **Emilia** An enthusiastic beach girl, you find Emilia looking for students for a cardio dance

course she has created. You become her assistant, convincing other members of the city to take her class seriously. Finally, the Glitterati try to humiliate her but together you're able to overcome their challenges and become a new fitness sensation.

- **Glitch** As part of the competitive breakdancing crew, Glitch wants to show his partner that he can win a one-on-one tournament. But he keeps losing to a robot from Dr. Tan's army. After training with you, Glitch is able to beat the robot, Eliot, in battle, but then learns that he will be deactivated for failure. The two of you race into the robot factory to rescue Eliot from his fate.
- **Lil'T** You take a part-time job from the Flashforward crew at their family golf course. Taye, the older sister, has been disappearing at night, and her younger sister Lil'T confesses to you that it's her dream to become a private investigator. The two of you track down leads regarding mysterious rigged battles, but along the way you forget to take care of the golf course and get in trouble. But when Lil'T is kidnapped, it's up to you and Taye to find her using the clues from your investigation.
- **Angel** On your way to a free cruise you won, you and Angel are taking the subway when it mysteriously stops. Angel decides to pass the time by telling the story of how he met his dance partner, Miss Aubrey. More dance crew members show up on the subway over time, and despite the ridiculous circumstances, get into the story. However, it soon becomes clear that the subway train is being stopped by super-villain Dr. Tan. Miss Aubrey shows up to save them, but in the end it is the rest of Angel's story that Dr. Tan wants to hear.

We used the dialogue from the game to characterize and inform each storyline. The main villains, the Glitterati and Dr. Tan, are also characterized as antagonists in the game. Effort was made to keep everything consistent between the story chapters and the game itself, as any storyline chapter could be played before, after, or not at all in comparison to another chapter. Each chapter had

several branching pathways and took about five to ten minutes to read through. Figure 6.3 shows a flowchart of Emilia: Chapter 3 to give a more detailed idea of the narrative approach. The story chapters can be read online at <http://www.evaluation.net/thesis>.

Leaderboard

We incorporated an overall ranking board to give participants a sense of their progress in comparison to others. The question of cooperative versus competitive play has been acknowledged [28], but only a few papers have explored it with exertion games [93]. The Leaderboard related to the fitness scores from *Dance Central 2*, comparing Lifetime Duration and Lifetime Calories Burned.

Table 6.3: Data on the final day in the seeded Leaderboard. This data came from the pilot participants so that the current participants would be able to surpass them (with enough effort applied).

Pseudonym	Day 28 Calories	Pseudonym	Day 28 Duration
BilboSwaggins	2239	BilboSwaggins	9:25:43
m4st3rch13f	2109	Freshie	8:49:23
Freshie	2092	m4st3rch13f	8:09:34
afkinect	2038	Nonny	6:44:13
Shirley Temple	1647	Shirley Temple	6:13:13
Nonny	1397	keyboardcat	5:25:36
keyboardcat	1060	afkinect	5:23:40
Sporty Spice	893	Sporty Spice	3:54:27
24dancer	755	24dancer	3:22:27

The leaderboard condition required no content creation, but needed to be carefully organized. We did not want to use real participant data as the study went along, because not only were participants going to be starting at all different times, but the experience would be different depending on who

was active in the study at the same time. Players would see the results of others at all different stages of their fitness intervention, becoming an uncontrolled variable as different players will have different opponents and they may feel it is impossible to overcome the high scores of people who are further along.

So we devised a seeded leaderboard system. When the user logs in, the module checks what day they are on in the study, and grabs the corresponding data for the previously created leaderboards from the database. So when the participant was on Day 5, the Day 5 data of everyone else would show as well. During the pilot, the data was fabricated based on created personality patterns, resulting in the top positions on the leaderboard being much higher than most pilot participants. For the actual user study, we used the data from the pilot participants. Since this was the result of real people, their behavior patterns were more realistic. All leaderboard data was given pseudonyms that were unrelated to the pilot participants.

The participants were aware that the data would be matched up based on day, but they were told this data was from other participants currently in the study. They picked out their own pseudonym to complete the illusion. Apart from the existence of separate None and Content groups, this was the only deception in the user study.

My Dance Club

In this module, the player's performance allows them to decorate a small virtual world. The number of Calories Burned is transformed into currency used to buy items for a virtual dance club and studio. The items were organized into sets based on the backdrops of *Dance Central 2*, so that they would follow the theme of the story chapters and the Crew Challenge in the game. There were five item sets with fourteen items each and a special always available statue that was worth 500 calories to give a high end goal to strive for. In total, 71 items were available.

Table 6.4: A small set of the available club items, representing the subway area of the game. There were five sets of items available.

Subway Items	
Open Guitar Case	20
Garbage Can	20
Traffic Cone	20
Noir Poster	20
Extra Speaker	20
Disc Art	20
Purple LED Chair	30
Light Controls	30
Stage Lights	30
Karaoke Machine Deluxe	30
Stereo Setup	30
HiDef Poster	50
Art Gallery	50
Deluxe Stereo	100

The implementation of My Dance Club was an isometric view of a two-dimensional room. The items were drawn or photographed objects fitted to the isometric space. We implemented a drag and drop JavaScript interface that allowed items to be bought, toggled to fit either wall, and stored in a bin underneath. A side store-like area contained the items which were available for purchase. The design was meant to emulate common mechanics found in Facebook and mobile games.

In order to reward having a high total amount of calories, we implemented a selection of backgrounds which unlocked after a threshold was reached. The backgrounds featured a new wallpaper and floor covering. Since they couldn't be seen until they were unlocked, each was given a mysterious sounding name to encourage curiosity, such as "The Diamond Dream" or "The Optical

Illusion”. Like the club items, the calorie cost was adjusted based on feedback and final scores during the full-length pilot study.



Figure 6.4: These example clubs updated every day like the Leaderboard, to further integrate the personas of the competing players. The different backgrounds could be unlocked by increasing total calories burned.

Finally, to add a sense of competition, we created nine pre-made clubs to go along with the personas on the leaderboard. The items were restricted by the calories earned by the personas and only updated when those personas would have been on the website. These clubs were displayed on the bottom of the My Dance Club page. We hoped these would encourage participants to decorate their club for others to see and inspire them to think of new ways to play. See Figure 6.4 to see the example clubs on Day 28.

Pilot Study

We conducted three pilot tests of increasing scale in order to develop the study with as few errors as possible. First, we needed to decide on the software necessary for this study. We ran an exploratory test with several people unfamiliar with these titles to help decide which to use. This first group of four people played three different dance games (*Just Dance 3*, *Dance Central 2*, and *Dance Masters*) to gauge initial feelings. We also considered the difficulty of measuring data and navigating menus between these games. In the end, *Dance Central 2* was chosen as the best subject matter for this study. It features several popular songs that people found relatable and people felt the dance moves were most likely to exert the body.

The next pilot study was a test of the usability of the website. Five participants borrowed copies of the equipment for two weeks and used the prototype of the website to explore content and input their data scores. We used this pilot to fix errors in our implementation and judge initial interest in different areas. Within this group, the Story and Dance Club areas seemed most liked.

After much preparation over several months, a full-length pilot study was run in the Fall 2012 semester. The physiological tests were omitted from this study, focusing on the flow of the other sessions and the website content. This pilot was intended to narrow the scope of the narrative content on the website and remove unexpected issues. Home and Lab participants were both run. Also, some participants only had access to certain modules (instead of just None and All, we also had Story Only, Club Only, and Leaderboard Only participants).

The design of the pilot study was identical to that of the formal user study design, except for the removal of the fitness tests and the slackening of eligibility conditions. There were fourteen participants (7 Home, 7 Lab). Their opinions and experiences were very enlightening and solved a lot of issues. We quickly ran into trouble with having a person's data only on one device at a time,

which led to the use of USB flash drives for Xbox profiles. Another complicated issue was the assignment of website time for all participants at the end of a session. We realized that with such busy schedules, participants would never check the web content unless required to at least open the page once a session.

This pilot study was instrumental in the final success of the study. In addition to modifying the flow of the experiment, we learned of some misconceptions that participants had and we were able to rectify them by modifying moderator scripts. We also saw some fluctuations in body weight before and after the study, though that alone was inconclusive to indicate a positive response at this stage. One pilot participant displayed a much greater ability to do the dance routine at the end of the four-week period, as opposed to the Day 1 session where he had to stop for water several times.

But in the end, all three narrative content modules on the website were liked strongly by different people, so we decided to keep them all for the full study. In order to narrow the number of total participants needed, we chose to focus on only two narrative conditions: None, which would only be the base game, and Content, which would include all three content types.

Procedure

Once the details were resolved from pilot testing, the study was executed over a four month period in the Spring 2013 semester at the University of Central Florida. The specifics of our implementation are below.

Table 6.5: Demographics and baseline data for participants that finished the user study.

Age (years)	Lab None	Lab Content	Home None	Home Content	All
Mean	20.73	20.45	22.80	19.60	20.78
SD	2.90	2.51	2.95	1.34	2.65
Sex	Lab None	Lab Content	Home None	Home Content	All
Female	11	9	5	4	29
Male	0	2	0	1	3
Height (cm)	Lab None	Lab Content	Home None	Home Content	All
Mean	162.61	167.18	161.29	167.03	164.66
SD	4.80	8.99	4.02	5.92	6.82
Weight (kg)	Lab None	Lab Content	Home None	Home Content	All
Mean	71.03	72.02	62.52	72.98	70.35
SD	9.90	14.15	4.82	2.56	10.68
BMI (kg/m^2)	Lab None	Lab Content	Home None	Home Content	All
Mean	26.83	25.60	24.00	26.18	25.86
SD	3.37	3.42	4.82	1.64	2.98
RHR (bpm)	Lab None	Lab Content	Home None	Home Content	All
Mean	90.18	89.09	83.80	84.20	87.88
SD	8.85	12.39	15.66	13.54	11.72

Recruitment

We used a variety of recruitment methods including Facebook posts, emails to school groups, mailing-lists, and flyers. Signups were slow until a campus-wide email blast sent by our provost to the student body, which was in a large part responsible for the success of this study. Even with a campus of over sixty thousand students, only around 300 people signed up for our orientation sessions. Acquiring an orientation attendee as a participant was only successful around 30% of

the time. However, this was enough to retain enough numbers for our user study in the end. See Section 8 for more specifics on retention levels.

Study Participants

For this study, we recruited within a population of college students. Exercise motivation is a challenging problem for many populations, but we felt video game solutions were particularly well-suited to this group since they would have some familiarity and interest.

After reviewing our time constraints for the spring semester, we attempted to recruit 54 participants with 16 in each of the Lab conditions and 11 in each of the Home conditions. After scheduling complications and dropouts, we ended the study with 32 participants: 11 in each Lab group and 5 in each Home group.

Potential participants needed to be filtered for eligibility based on BMI, age, and willingness to adhere to our requirements:

1. BMI Range between 22 and 32.
2. Age Range between 18 and 30.
3. PAR-Q form with no YES answers.
4. No recent participation in another clinical trial (within 30 days).
5. Not pregnant, lactating or trying to become pregnant.
6. No recent weight loss of greater than five pounds (within 30 days).
7. Agree to maintain current diet and not use weight loss diet products during study.

8. Agree not to engage in exercise other than the dance game for this study.

The participants were volunteers that we did not compensate monetarily in order to not bias the results. At the end of the study, they were provided a copy of their individual fitness changes.

Sessions

Table 6.6: An overview of the sessions

Orientation: Informed Consent and Presentation	30 mins
Pre-Experiment: DXA and $\dot{V}O_2$ Max Test	30 mins
Day 1: Tutorial, Surveys, Gameplay with Mask	1.5 hours
Play Sessions: Gameplay and Website	30 - 60 mins
Day 28: Surveys, Gameplay with Mask	1 hour
Post-Experiment: DXA, $\dot{V}O_2$ Max, Exit Interview	30 mins
5 - 17+ Sessions	4 - 16+ hours

The study required five unique types of sessions: Orientation, Pre-Experiment Session, Day 1 Session, Play Sessions, Day 28 Session, and Post-Experiment Session. By the time the actual study was underway, these sessions were fairly streamlined for efficiency and participant comfort. The participants were presented with an explanation of the sessions in the Orientation, the consent form, and in the journal which they kept with them until the end of the study.

Orientation (30 mins)

From our pilot study, we anticipated that our age and BMI requirements, along with our exercise restrictions, would result in few qualified participants compared to those that were interested. In

order to efficiently reach the most people, we held sessions attended by one to seven people in which the same material was given. These people did not know each other unless they had arrived together. Participants signed up for Orientation through the Appointy website, which was reachable outside of the Dance Enhanced website for this purpose.

Orientation took place in the research laboratory where all the fitness tests will be taken. These sessions would begin with each participant being screened for eligibility. They would individually be taken away from the group to determine their weight and height to see if their BMI was within the 22 to 32 range. Body weight and height was measured using balance beam scales and a scale mounted height measure. Body mass index (BMI) was be calculated by dividing body weight in pounds by height in inches squared. If the BMI was acceptable, they would be asked to clarify their age was between 18 and 30. Then the participants would fill out the Physical Activity Readiness Questionnaire, a measure of potential risk in their ability to do the study [101].

Once all remaining people had completed this process, they were shown an orientation that explained the details of the study, what they would be expected to do, and what we were trying to research. Participants will be told that they can stop participating in the study at any time. If they chose to volunteer, they would read over the informed consent and once signed, the moderator would help them schedule their Pre-Experiment and Day 1 appointments.

Almost every participant who made it through the presentation would choose to participate. Sometimes they would decline because they were unable to give up other physical activity. In general, however, the use of the Orientation method was an excellent way to recruit participants.

Pre-Experiment (30 mins)

The Pre-Experiment session was used to evaluate the fitness of the participants before the study began. Participants were instructed to wear sneakers and comfortable clothing, avoiding garments that have zippers, belts or buttons made of metal. If female, a female moderator would show them how to use a dipstick pregnancy test and accompany them to the restroom to complete the test. They must have a negative serum pregnancy result before using the Dual X-Ray Absorptiometry scanner. Then the participant's weight and height was measured, with shoes and extra clothing removed. They were asked their age and a trained member of our staff prepared them for the DXA scan. They were asked to lie still, except for breathing, on a padded table for approximately five minutes. The percentage of fat and lean body tissue as well as the distribution of lean and fat body tissue was measured by using the GE Lunar DXA machine.

Afterwards, participants were outfitted with a chest-worn heart rate monitor for a maximum oxygen consumption ($\dot{V}O_2$ max, mls O_2 /kg/min) fitness test. They would run on a treadmill for five to twelve minutes. The speed would be increased 0.2 and the incline would increase 0.5 every 30 seconds until they reached a point of maximum effort. Once the exercise scientist determined they were at that point, they would begin walking in a cool down at a lower speed until their heart rate lowered back to normal levels. The participants would be given a brief description of what they would be doing at the Day 1 session. They would also be told which group they had been placed in, Lab or Home, so they could expect whether they would be taking equipment home or not.

Day 1: 1.5 hours

This session served as a tutorial and explanation to the study, as well as initial data collection. To gather RMR, MC, and METs throughout the four-week intervention could be taxing to the

participant, as wearing the breathing apparatus involves a cumbersome head mounted device and several moderators interacting. This could have potentially taken away from the enjoyment of the game, causing them to exit the study early. Thus, we decided to only collect this data during special Day 1 and Day 28 sessions.

First, the participant would be shown their journal and how to log into the website, to make sure they understood their username and password. They were shown how to fill out a survey, then left to complete the Initial survey. When they were finished, their weight was noted and they would sit in a chair and breathe through a two way valve attached to the breathing mask for twenty minutes. This number was used to determine the resting metabolic rate (RMR) for the participant so it could be removed from the exertion from the dance game later.

After this was measured, participants would put on a chest strap heart rate monitor and given a tutorial on playing *Dance Central 2*, which covered the arm-controlled menu selection and emphasized how to determine that they were logged in and tracking fitness data. They were allowed to choose a different character if they wanted, then they would play through the Steady playlist twice. First, they played by themselves in order to familiarize themselves with the game. Then they would play through the exact same playlist again while outfitted with a head-mounted breathing apparatus attached to the metabolic cart. The tubes were held by a lab assistant that was careful not to watch the participant directly while they danced, in order to minimize self-consciousness.

The Steady playlist consists of seven songs at a slow pace, lasting a little over nineteen minutes with pauses in between to load songs and tally scores. They do not require many fast difficult movements, so the exertion while playing them was expected to be low. However, we chose this playlist because it would be less intimidating to people who were unfamiliar with dance games. It would also make it easier for them to complete the moves with the breathing apparatus attached, which understandably hindered movement. Heart rate was recorded prior to the first song and in

the middle of the sixth song, about fifteen minutes later.

After the two playlist sessions were completed, participants were shown how to record their fitness data in the journal and the Dance Enhanced website. The journal was an optional step to help them in case of computer failure or just as a backup. If they were in the Content condition, they were also shown the three narrative modules on the website. They were left alone to spend the points they had earned and once they confirmed they understood how it worked, they would log out and be free to go. Home participants would schedule their final appointments and Lab participants would schedule their play session appointments.

Play Session: 30-60 mins

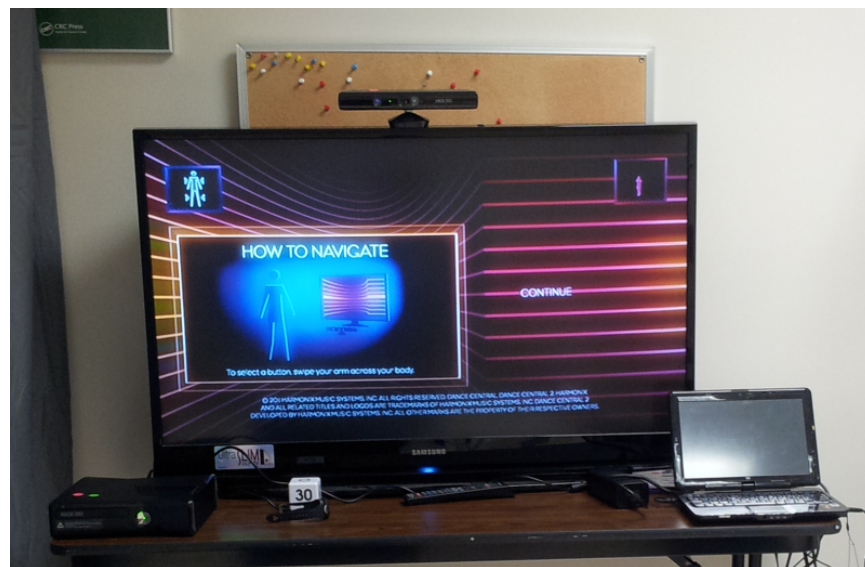


Figure 6.5: Our lab was setup with two stations for play sessions. Each station had a curtain or door for privacy, an Xbox and Kinect setup, and a laptop for website interaction.

Play sessions were available to lab participants only, as Home participants would be exercising in their own houses. During Day 1, they would be scheduled to come in three times a week for the

next 28 days. They were expected to play the dance game three times a week, or about every 2-3 days. They were able to make more appointments if they wanted.

Before arrival, the moderator would set up the Xbox with the participant's USB stick, ensure they were logged in, and make sure no one else was still logged into the computer. We set up two stations to facilitate scheduling during popular times, and so one could be available while testing sessions were occurring on the other. Participants would exercise for as long as they wished in a one hour block of time. Sometimes they would stay longer if there was not another person scheduled immediately after them.

Roughly ten minutes before they needed to leave, participants would be reminded to go on the computer and record their fitness data. Every seven days, they would fill out one of the weekly surveys. If they had access to the content they would also play with that. It was up to the participant how long they wanted to spend dancing and how long they would spend on the website.

Day 28: 60 mins

Within two days of finishing the study, the participants would come back to the lab and complete a similar procedure to Day 1. First, they would complete the Week 4 and Final surveys. Then they would be weighed and measured for twenty minutes sitting in a chair to determine their resting metabolic rate, which can vary due to many factors and should be taken alongside other metabolic testing. Also, we wanted to see if resting metabolic rate might be affected by the study. After this, they would play the same playlist as Day 1, the "Steady" playlist. Unlike Day 1, they would only play this one time since they were now familiar with the game. Not every participant was able to do this session. Due to scheduling conflicts, sometimes difficult decisions had to be made regarding dropping this data so we could record their post-experiment data instead, which was of higher importance to what we wanted to learn in the study.

Post-Experiment: 30 mins

Within a five day window of Day 28 of the study, participants returned one final time to complete another DXA scan and treadmill test. The fitness tests were performed in the same order as the first time, with the same procedures. Journals and any borrowed equipment were returned. Finally, the participants would sit with the moderator for an informal exit interview where they would talk about anything else they wanted to mention about the study experience.

Home Participants

Our initial intention was to run an equal amount of Home and Lab participants. However, after our full-length pilot, the results of the Home participants indicated less adherence to the program. In addition, much more resources were needed at a greater cost to run these participants simultaneously by lending them equipment.

Ten participants finished the study at home, with five in the None condition and five in the Content condition. The hardest part of the Home condition was keeping in contact over time. Even with the same email reminders, the Home participants were more likely to forget about the study given the many distractions of their environment. They were also more reluctant to contact the moderators for simple questions.

Several Home participants severely broke protocol and would have had to been removed from the study if they had been in the regular lab group. Despite being told the importance of not doing other activities or dancing with other people, several participants did both. Some participants also downloaded other games onto the Xbox. It was an expected risk of allowing them to have the freedom to participate on their own schedule.

On a more positive note, we did not have any incidents of equipment not being returned. And the participants which did follow protocol excelled greatly at adherence, including our top performer in the participant pool. See Section 7 for more about the outcome of these condition groups.

Conclusion

We have described a four group between-subjects study with a preliminary exploration into two variables: environment and additional content. By describing our process in detail, we may provide useful knowledge to other research groups planning similar studies. In Chapters 7 and 8, we elaborate on the results and discuss the potential impact of Dance Enhanced.

CHAPTER 7: DANCE ENHANCED: RESULTS

We collected a variety of physical and experiential data on our participants. Based on our pilot study and previous studies, we had some hypotheses for this study.

1. **Attendance will drop off over time.** The pilot participants did not always come to their sessions because their priorities were elsewhere. Even a more engaging condition did not seem to change their patterns; work and school are too important to students compared to a volunteer activity, even one they enjoy. We predict that the number of sessions will not increase between conditions, but that enjoyment will be higher in the condition with the content.
2. **People with narrative content would enjoy the experience more.** We believe that having more engaging gameplay elements will enrich the basic game and make the participants more interested in sticking with the study for the full month.
3. **Home participants will have lower retention in the study.** We believe between the Lab and Home conditions, the Lab participants will have a greater retention to the study. This was true in the pilot study, mainly because the appointment reminders would keep people on task.
4. **Exposure to the content will expand expectations for fitness games.** This study was targeted at people not very familiar with console video games. We expected them to be inspired by the types of additions that could be possible.
5. **One of the content modules will prove much more popular than the others.** After the pilot, we chose to leave all three content modules on the website. We believed for the actual study that one of them will prove universally engaging to the participants.

6. **Physical performance will not vary between groups, but overall participants will show improvement.** Fitness improvement varies in other studies on dance games, but many show a slight amount of improvement [93, 98]. We did not expect the two conditions to show a difference in physical fitness, but we believed overall there would be an improvement.
7. **The game will output larger values for Calories Burned than the real values.** Fitness games are designed to encourage the players, as they often quit playing over minor indications of poor performance. We expect that the in-game values for calories burned will exaggerate the real breakdown of the player in order to boost their confidence.

Unless otherwise stated, the results in this section pertain only to the Lab None and Lab Content groups, as the Home condition groups had too small of a sample size. Differences between the two are discussed in Section 7.

Physical Measurements

A number of previous studies on the exertion potential of games have set a precedent for recording fitness data [60, 66, 100]. In some studies, the use of BMI as the sole measurement led to uncertain evaluations [83]. We used a DXA Scanner to further breakdown the changes in the participants over time. We also took before and after $\dot{V}O_2$ max tests for the participants, in order to evaluate their oxygen consumption. We also recorded oxygen consumption during gameplay to compare with the in-game outputs.

Table 7.1: The results of the DXA test.

BMI (kg/m^2)	Lab None	Lab Content	
Mean Pre	26.83	25.60	
Mean Post	26.48	25.65	
Percent Change	-0.1%	0.2%	
Fat Percentage	Lab None	Lab Content	
Mean Pre	40.99%	38.58%	
Mean Post	41.05%	38.41%	
Percent Change	0.1%	-0.4%	
Lean Mass (grams)	Lab None	Lab Content	
Mean Pre	40099.27	42727.82	
Mean Post	39431.18	42831.18	
Percent Change	-2%	0.2%	
Fat (grams)	Lab None	Lab Content	
Mean Pre	27617.45	26017.27	
Mean Post	27287.91	25991.27	
Percent Change	-1%	-0.1%	
Significant (2-tailed) p=0.05	Within Lab None	Within Lab Content	Between Groups
BMI (kg/m^2)	0.13	0.72	0.14
Fat Percentage	p=0.82	p=0.45	p=0.23
Lean Mass (grams)	p=0.21	p=0.21	p=0.23
Fat (grams)	p=0.33	p=0.93	p=0.47

DXA Scanner

From the Dual X-Ray Absorptiometry data, we looked at five variables: weight change, BMI change, fat percentage change, lean mass change in grams, and fat mass change in grams. Eleven

participants finished the DXA post test in each Lab condition group. We compared the Lab None and Lab Content groups using independent samples t-test and found no significance (See Table 7.1). The story was similar within each condition. While some outside factors resulted in some participants losing weight, overall there was no significant change in this physical attribute.

$\dot{V}O_2$ Max

Our fitness test was a maximum effort treadmill test measuring oxygen consumption with a head-mounted breathing apparatus. We used this to determine the participant's maximum metabolic cost while running to establish maximum values for oxygen consumption $\dot{V}O_2$, heart rate (HR, beats/min), and ventilation ($\dot{V}E$, L/min). Participants performed a maximal exercise graded test to measure maximal exercise capacity using a modified Astrand exercise test on a Quinton Research model treadmill (Quinton Instruments, Seattle, WA). A Max-1 Metabolic Cart (Physio-Dyne, Quogue, NY) was used to continuously measure expired oxygen, carbon dioxide, and $\dot{V}E$ at rest and during exercise until volitional fatigue. The metabolic cart was calibrated with standard gases prior to each test. Maximal oxygen consumption will be defined according to standard criteria regarding maximum heart rate and respiratory exchange ratio at a plateau in oxygen consumption. The average of the two highest consecutive 30 second values at peak exercise will be recorded. Heart rate was recorded simultaneously by a chest-worn heart rate monitor.

The test was concluded when evidence of a subject meeting maximum exertion was reached. This evidence could include:

1. Reaching age-predicted maximum heart rate.
2. Leveling of $\dot{V}O_2$ data.

3. Respiratory Exchange Ratio (RER) reaching > 1.1 , indicating the levels of CO_2 produced increased because of intense physical exertion.

Table 7.2: The results of the $\dot{V}O_2$ Max test.

Max HR (bpm)		Lab None	Lab Content	All Lab		
Mean Pre		197.30	194.11	196.24		
Mean Post		195.30	194.75	194.82		
Percent Change		-1%	0.3%	-0.7%		
$\dot{V}E$ Max (L/min)		Lab None	Lab Content	All Lab		
Mean Pre		76.42	88.59	82.18		
Mean Post		86.96	93.49	90.05		
Percent Change		14%	6%	10%		
$\dot{V}O_2$ (ml/kg/min)		Lab None	Lab Content	All Lab		
Mean Pre		30.42	33.16	31.71		
Mean Post		34.20	33.23	33.95		
Percent Change		12%	0.2%	7%		
Significant (2-tailed) p=0.05	Within Lab None		Within Lab Content		Within All	Between Groups
Max HR (bpm)	p=0.067		p=0.46		p=0.054	p=0.80
$\dot{V}E$ Max (L/min)	p=0.074		p=0.14		$p < 0.05$	p=0.33
$\dot{V}O_2$ (ml/kg/min)	p=0.14		p=0.89		p=0.23	p=0.22

All participants as a group had significantly greater $\dot{V}E$ Max after the study ($Z=-2.415$, $p=0.016$). Ventilation is a measure of the volume of gas inhaled or exhaled, calculated as part of the determination of oxygen consumption. The $\dot{V}E$ by itself is not an estimation of overall exercise ability, and this result is largely irrelevant in terms of fitness. We include it here for the sake of completeness.

There was almost significantly less Max Heart Rate in the Lab None and All participant groupings after the study ($Z=-1.83$, $p= 0.067$) and ($Z=-1.92$, $p=0.054$). This is an indicator of increased fitness. When the body exerts itself for the same workload but the heart rate is decreased, it means the heart has to work less to produce the same amount of energy. This is caused by having a stronger heart that is able to pump more blood with less beats per minute. With a larger sample size, this result would likely have been significant.

$\dot{V}O_2$ max difference was not significant ($t_{17} = 1.284$, $p = 0.22$). There were several participants in the Lab None group that had a huge improvement between the two treadmill tests. After carefully evaluating the data, it was determined that their numbers were not physiologically possible. The reason for the jump in fitness ability was likely a low effort during the Pre-Experiment session. This is a common situation that arises from not being familiar with the breathing apparatus, which can lead to anxiety and lower results.

Because of technical malfunctions and scheduling issues, some participants were not able to complete the post-experiment treadmill test within the window. In the end, ten participants in the Lab None group and nine in the Lab Content group were included in this data set. This sample size was smaller than we anticipated, and most likely led to less power in these data points.

Game Statistics

Dance Central 2 keeps track of several fitness data scores, two of which we chose to measure in this study. The Lifetime Duration added together the total time spent dancing in hours, minutes and seconds. The duration only increases during gameplay, not during pausing or menus. But because this number was automatically calculated only under certain conditions, it was subject to human error. Several participants experienced sessions with USB glitches, accidentally turn-

ing off Fitness Mode (which stops calculating the Duration), or forgetting to log in. For these reasons, it cannot be taken as a true measure of participant duration, but in most cases provides a good estimate. We normalized what data we had by removing time recorded during Day 28 sessions, since some participants did not have Day 28 data due to scheduling conflicts. Duration was converted to minutes and compared in Table 7.3. There was no significance between Lab groups ($t_{20} = -0.462, p = 0.65$), though it is worth noting that the Lab Content group had a few participants with unusually high scores.

Table 7.3: Lifetime scores calculated within the game.

Calories Burned	Lab None	Lab Content	All Participants
Mean	1641.27	1786.46	1713.86
SD	613.53	577.41	586.12
Min	538	1115	538
Max	2841	3037	3037
Duration (mins)	Lab None	Lab Content	All Participants
Mean	420.67	444.85	432.76
SD	95.19	110.65	101.48
Min	206.98	324.32	206.98
Max	590.82	718.38	718.38
Songs Played	Lab None	Lab Content	All Participants
Mean	165.55	165.09	165.32
SD	37.14	36.34	35.86
Min	81	127	81
Max	226	242	242
Significance (2-tailed)	Calories Burned	Duration (mins)	Songs Played
p=0.05	p=0.57	p=0.65	p=0.68

The other data we chose to record from *Dance Central 2*'s fitness statistics is the Lifetime Calories Burned. Lifetime again refers to the overall number across all tracked sessions, and the Calories Burned are calculated within the game's software. See Section 7 for more information of the validity of this estimation. We also found no significance between groups for this number ($t_{20} = -0.575, p = 0.57$).

Table 7.3 also includes the number of songs each player, which was not a data point we focused on in the study. But since it was included in the game statistics, we present it here for completeness. Note that while the total number of songs was similar, the means for calories and duration were different. This is not abnormal, as the songs differed in length and the calorie estimation varied from 6 to 12 calories per song between participants. There was also no significance in this category ($t_{20} = -0.029, p = 0.98$).

Calorie Estimation

One question that arises when examining these games is how accurate the fitness feedback is for the player. Many of these games claim to count calories, but the method for doing so is often shrouded in mystery. Some games get around this problem by using their own value system such as Sweat Points in *Just Dance 3*. In the case of *Dance Central 2*, the game appears to use a calorie burning function written as part of the Kinect API¹.

On Day 1 and Day 28, our participants wore a breathing apparatus hooked up to a metabolic cart to determine the calories they were burning while playing the game. We determined each participant's resting metabolic rate (RMR) and established the metabolic cost (MC) of the gameplay activity. Metabolic and cardiopulmonary data will be continuously collected since subjects will be hooked

¹According to informal conversation with several employees at Harmonix.

to the metabolic cart and a heart rate monitor. The metabolic system described in Section 7 will be used. Prior to each testing calibrations will be conducted as described above and in accordance with the manufacturers' instructions and recommendations. The MC for all game sessions was calculated from $\dot{V}O_2$ data. See Table 7.4 and Figure 7.1 for the results.

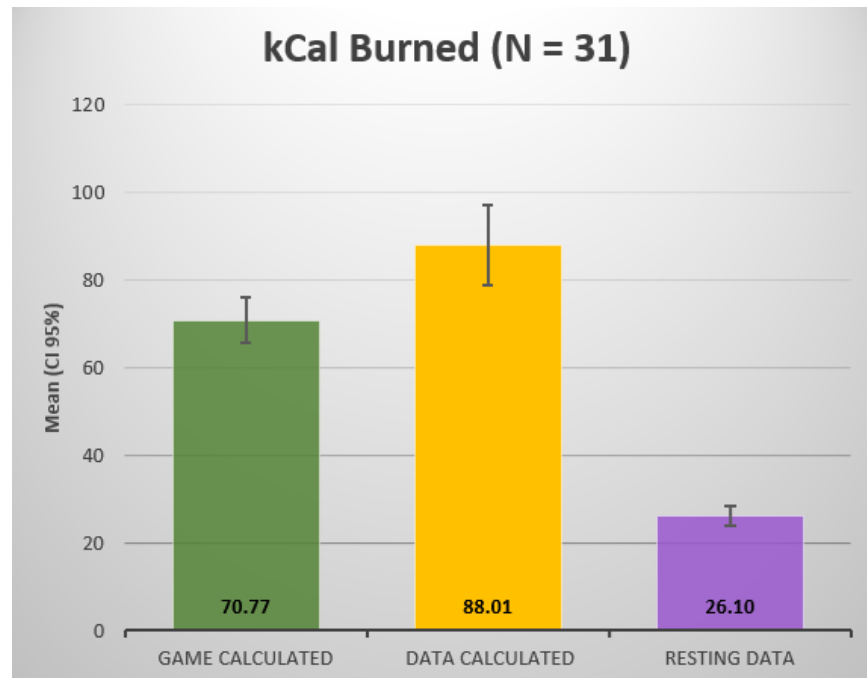


Figure 7.1: A comparison of how many calories the game estimated being expended, and the actual calories expended from oxygen consumption data.

The game estimated Calories Burned underestimated the actual Calories Burned. We compared the calculated calories consumed to the estimations from the game. We also took the calculated calories burned from each person's resting data, which was taken during twenty minutes of sitting without stimulus. Resting data can vary throughout the day and fluctuates based on many variables, so it was taken during the same session prior to dancing. We found that the game sometimes overestimated, but on average it underestimated the calories burned, with a difference of 17.23 calories between the two means. This was surprising as we expected the game would

overestimate in order to encourage the players. The estimate seemed to be particularly off when the participant was male or tall, possibly indicating that the game’s calculation method had more trouble in these cases.

Table 7.4: Comparison of Calorie Estimations (N = 31)

Type	Mean	Standard Deviation	Min	Max
Calories Burned Per Min (kCal * min)	4.57	1.35	3.01	8.38
METS	3.71	0.85	2.33	5.45

The average calories burned per minute was 4.57 kCal. This number is comparable to Smallwood’s study on schoolchildren playing *Dance Central*, where they recorded a value of 3.0 kCal [93]. The “Steady” playlist which we used for this study is made up of slow, easier songs. Because in many cases this was the first time that participants would be playing the game, it needed to be an easier song set. Also, the breathing mask is complicated to wear and would complicate more intricate movements. Players of this game on a more difficult setting would likely expend more energy [91].

When converted into Metabolic Equivalent Units (METS), *Dance Central 2* ranks at a mean value of 3.71. This estimates it as being similar in exertion to fishing, walking and water aerobics [79]. Interestingly enough, it’s also comparable to low level aerobic dancing (3.9 METS), ballroom dancing (3-5 METS), and popular dancing (3-8) METS [50].

There was significantly more exertion when playing the game than when resting ($Z = -4.86$, $p < 0.001$). We also compared the resting kCals burned to dancing exertion, and there was a significant difference, with an increase in mean of 26.14 to 88.04, or a 236% increase in exertion. This is a measurement often taken in obesity studies and it may seem to be common sense. But since

we were evaluating this game for fitness potential it was important to justify that playing this game does indeed burn more calories than resting.

Adherence

Table 7.5: Adherence by the number of sessions and average duration.

Number of Sessions	Lab None	Lab Content	All Participants
Mean	9.73	9.27	9.50
SD	1.62	2.00	1.79
Min	6	6	6
Max	11	12	12
Average Duration (mins)	Lab None	Lab Content	All Participants
Mean	39.79	45.68	42.74
SD	5.17	8.32	7.40
Min	28.58	34.94	28.58
Max	28.58	64.41	64.41
Significance (2-tailed)		Number of Sessions	Average Duration (mins)
p=0.05		p=0.57	p=0.06

Adherence is one of the most important aspect of fitness improvement, and yet also difficult to calculate [82, 85]. We examined two different metrics: number of sessions and average session duration. We adjusted each participant's number of sessions by comparing journals, website use and scheduled appointments. The number of sessions produced no significance ($t_{20} = 0.585, p = 0.57$). Both groups came to sessions around two to three times a week. Since the Day 28 session was not included in this group, the expected number of sessions was 11. Most participants did not meet this threshold, but attendance overall is still considered to be good, as other similar studies

have had trouble maintaining interest for 4 weeks [63, 111].

Lab Content participants had an average duration that was almost significantly larger than Lab None participants ($t_{20} = -1.997, p = 0.06$). Many participants in the Lab Content group stayed for longer periods of time, especially near the end of the study. Participants would also stay longer if they had missed a session so that they could make up a session. Many times, these sessions would be accompanied by comments about the Leaderboard. They often wondered who was beating them, and getting to the top of the list was a motivating factor.

Questionnaire Data

Initial

Table 7.6: Breakdown of the IPAQ scores of our finished participants. Collected at the beginning of the study.

	Low	Med	High
Lab None	2	5	4
Lab Content	2	4	5
Home None	2	3	0
Home Content	2	2	1
Total	8	14	10

The initial survey was taken when participants first arrived at their Day 1 appointment. There were several parts to this survey: a short form of the IPAQ evaluation, several questions about the exercise difficulties and game preferences, and open answer questions about what previous motion controlled games they had played. The majority of the questions are compared to their final survey counterparts in Section 7, but we discuss the IPAQ and gameplay questions here.

The IPAQ survey allows participants to self-assess their physical activity through a series of questions about their vigorous activity, moderate activity, walking and sitting habits. We scored the participants by the guidelines for IPAQ processing and analysis [20]. The participants were distributed between three categories fairly evenly, as seen in Table 7.6. Because the breakdown in each condition is similar, we can reason that no condition began with an advantage in fitness. It is relevant to mention, however, that self-assessed questionnaires are prone to bias. The baseline values of fitness from the participants would indicate the IPAQ values should skew more towards the Low end of the spectrum.

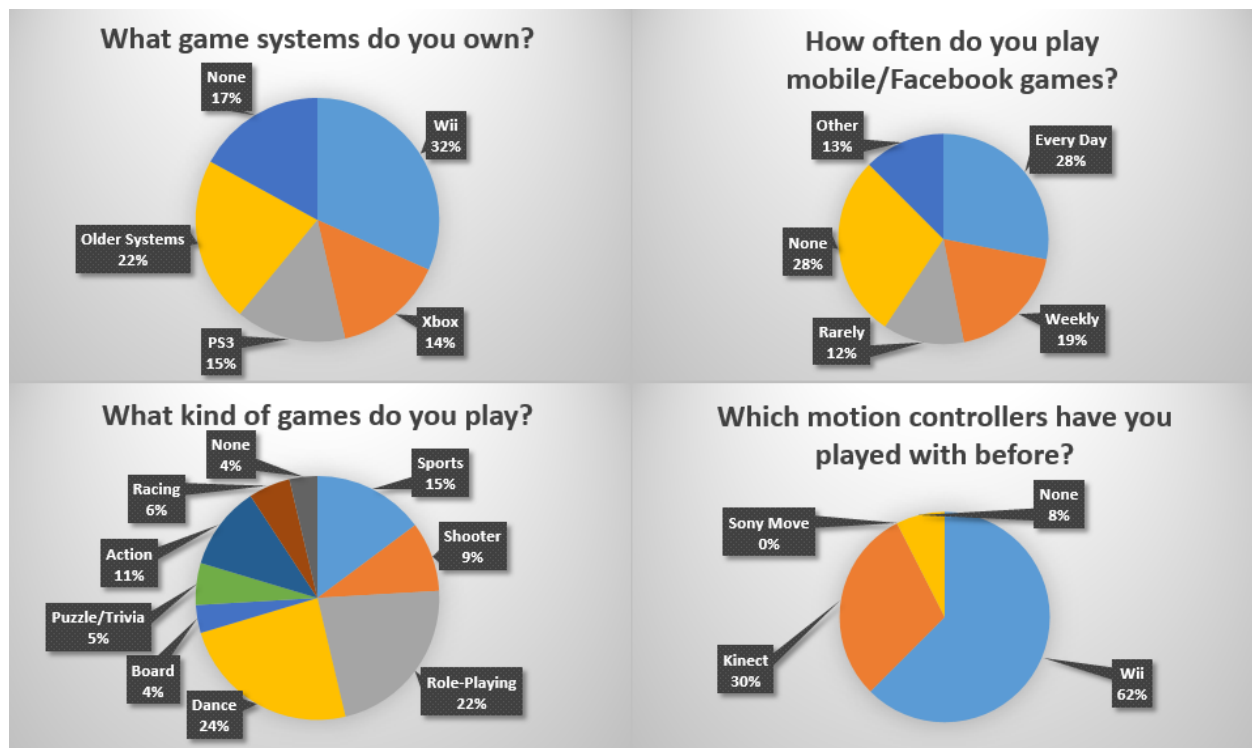


Figure 7.2: Almost every participant had played games before, and almost all of them were familiar with motion controlled games.

We also asked for information about other videogames they had experienced in the past. Some aspects of the content on the website were modeled after more casual game genres, so we not

only asked about motion controlled games but Facebook and mobile products as well. We found that even though the participants seemed to identify, on the most part, as non-gamers, almost all of them had familiarity with video games. Not only did a majority of the participants own a current generation console, they currently played a variety of game genres. Almost everyone had experience with mobile or Facebook games, with the daily users able to list off multiple titles that they maintained. The Nintendo Wii device was also well-known to the users, even though the majority of them had not played using a Microsoft Kinect before.

Weekly

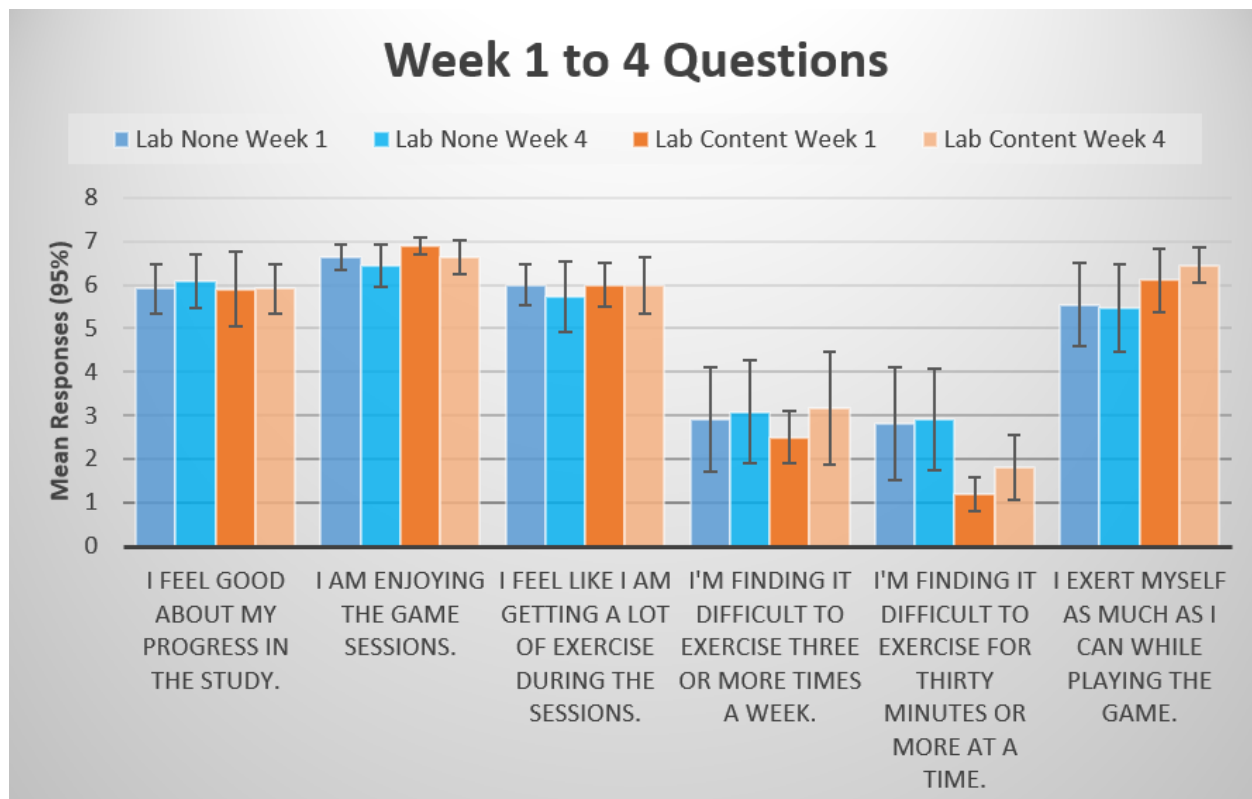


Figure 7.3: Participants answered the same questions at the end of every week in a survey. We compared the Lab conditions and the Week 1 to Week 4 responses.

At the end of each week, participants took a survey on their experiences, using a 7-point Likert scale and write-in comments. This survey was identical each time, and meant to record any change in opinion throughout their experience. However, forgetful participants sometimes missed the middle surveys, so a comparison was not always possible. We compared each survey (Week 1, Week 2, Week 3, Week 4) between condition groups using Mann-Whitney tests. Within each condition group, we compared Week 1 and Week 4 as related sample t-tests.

In the Week 1 survey, Lab Content participants found it significantly less difficult to exercise for thirty minutes or more than Lab None participants ($Z = -2.38, p < 0.05$). The Lab Content group had an extremely low answer to this question in Week 1. They seemed much more confident in their ability to exercise for longer periods of time.

But by week 4, the Lab Content had dropped almost a significant amount for this question ($Z = -1.89, p = 0.059$). The Lab Content group was finding it more difficult to exercise for thirty minutes by the end. This isn't surprising, as exercise adherence becomes more challenging over time.

In Week 4, it was almost significant that Lab Content participants exerted themselves more than Lab None participants ($Z = -1.78, p = 0.076$). While Lab None responses stayed mainly the same, Lab Content responses increased over time. While both groups were fairly high to begin with, it is interesting to see this slight trend.

The questions about difficulty of adherence only somewhat reflect actual outcomes of session duration and number of sessions. If only evaluating these results, it would seem that the participants as a whole had little trouble exercising three or more times a week, for more than thirty minutes at a time. But in Table 7.5, not many participants actually did come in three times a week. Participants did tend to stay for at least thirty minutes, however.

Final

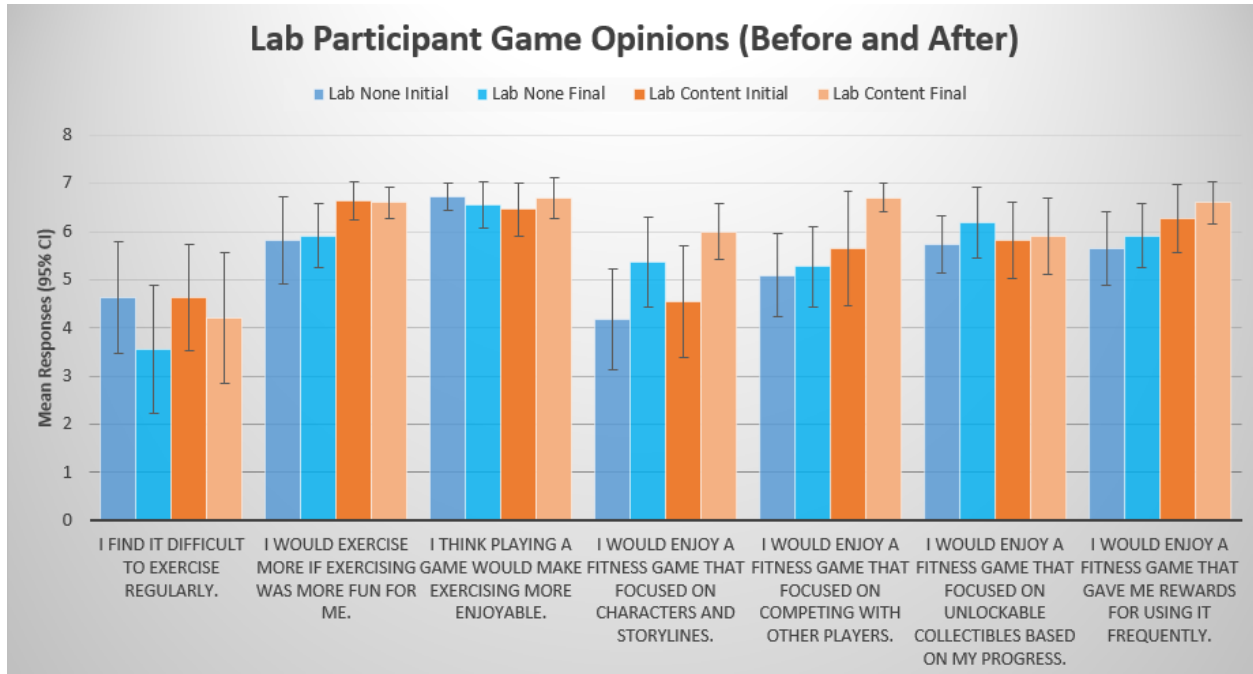


Figure 7.4: Significance was found within the Lab Content group on the question regarding characters and storylines

As in the weekly survey comparison, we used Mann-Whitney to compare the questions of the Final survey between the Lab None and Lab Content groups. The first seven questions were identical to questions asked in the Initial survey, which we compared within groups using related samples t-tests. The results are displayed in Figure 7.7.

In the Final survey, the Lab Content group significantly stated they enjoyed a game focused on competing more than the Lab None group ($Z = -2.70, p < 0.05$). While the mean during the initial test was almost the same as the Lab None group, this number jumped much higher after the study. Given the verbal and written comments about the Leaderboard, this change is likely to be because of the positive opinions associated with that content module.

Between the Initial and Final surveys, the Lab Content group significantly increased their interest in characters and storylines ($Z = -1.98, p < 0.05$). The Lab None group also had an increase in interest, but not as high as the one for the Lab Content group. We can loosely extrapolate from this that having the variety of characters present in the game alone created some positive feelings, but that exposure to the website content enhanced these emotions even more. Many of the participants talked about other games with stories and characters during their exit interview. In some cases, they felt the storyline of *Dance Central 2* wasn't as strong. But even in that case, participants had many opinions on what kind of storyline they would enjoy in a game like this. Independent of their feelings regarding this specific narrative, exposure to the characters and plot seemed to have an effect on their attitude towards dance games.

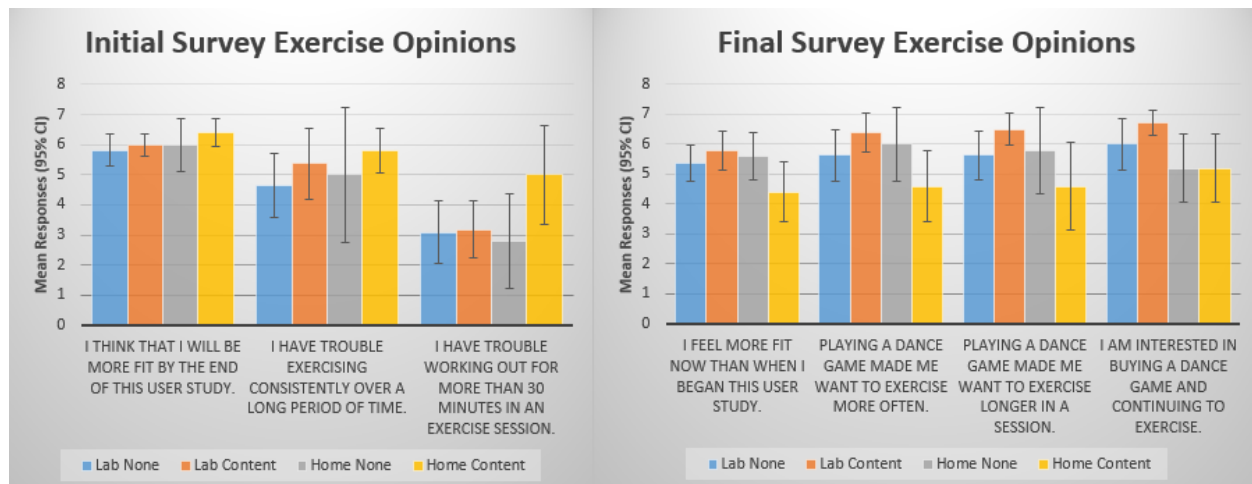


Figure 7.5: Additional questions from the Initial and Final surveys.

There were similarities among several other questions that were asked at the beginning and the end of the study, but the wording was not identical so we did not run related sample testing. In Figure 7.5, it is particularly interesting to note the difference between the Initial survey questions regarding exercising consistently and for more than 30 minutes, and the Final survey questions about exercising more often. While initially expressing trouble with exercising, both Lab groups

felt the dance game encouraged them to play more often.

Overall, opinions about the study and the game were very positive. All groups expressed interest in buying the game and continuing to exercise, and they also felt generally more fit than when they began the study. The most variability in these questions comes from the Home Content group, but it's important to note the small sample size of five and the presence of two non-compliant participants swayed the results greatly in some cases (as evident by the error bars in the graph as well).

Website Activity

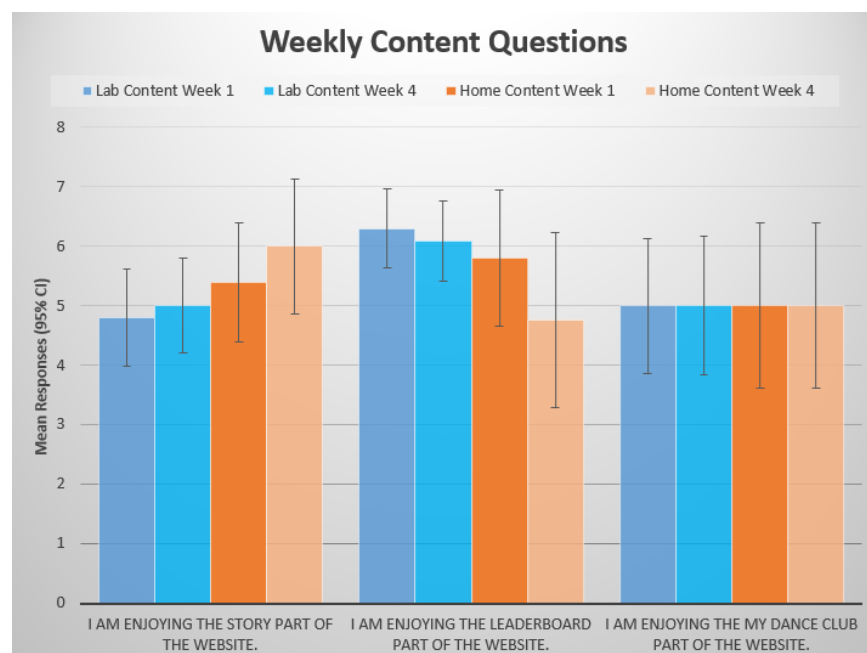


Figure 7.6: Questionnaire results from the Lab Content and Home Content groups.

For the participants which had access to the website data, we were interested in their overall activity and their experience. In Figure 7.6, the responses in the weekly surveys are shown. These questions

were only visible to the Lab Content and Home Content groups. Note that the low sample size of the Home Content group may affect the impact of their results.

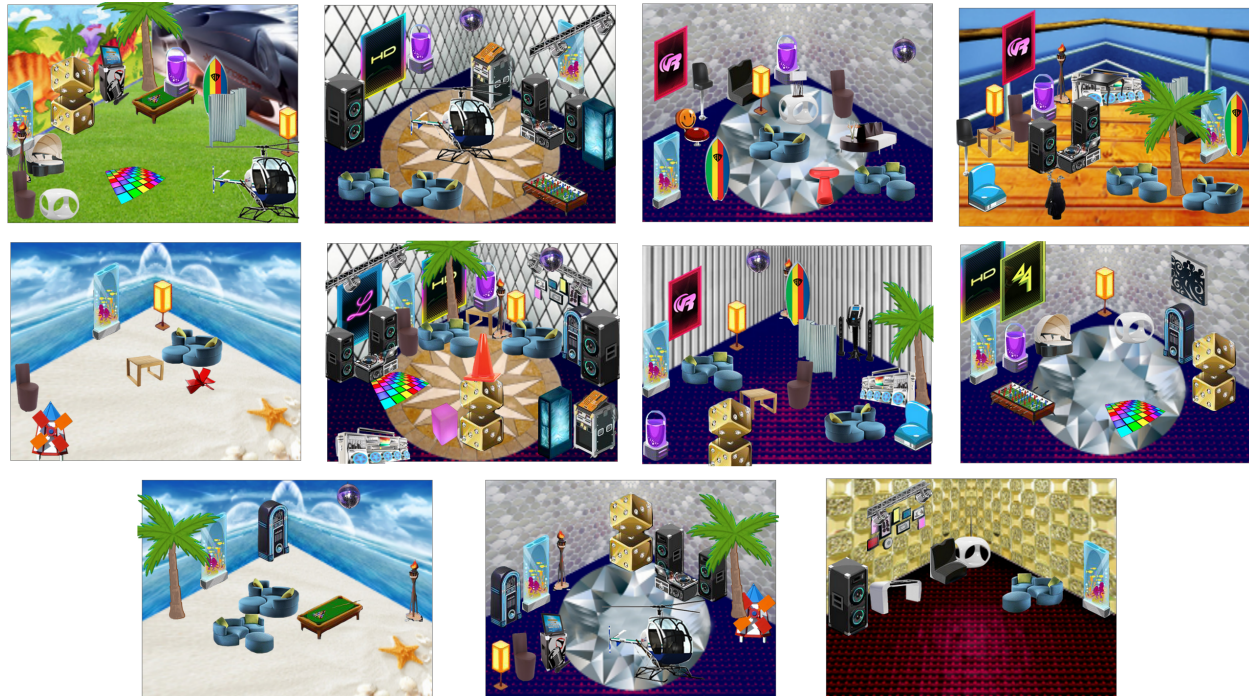


Figure 7.7: The configurations of the dance clubs on Day 28. The different items and backgrounds were utilized, with some participants hoarding objects as a mark of pride.

The My Dance Club enjoyment remained remarkably stable throughout all participants in both groups. Visually, it looks like enjoyment of the Leaderboard went down and Story enjoyment went up. But realistically, all the means are above average. The Leaderboard was most important to the Lab Content group, consistent with their other feedback. The Story module rated higher with the Home Content. These trends are also reflected in Figure 7.9.

The Leaderboard content did not update throughout the study based on time or ability, but the Story and Dance Club sections did. On average, Lab Content participants purchased 9.09 story chapters and 20.82 club items. The Home Content group had similar means, with 9 story chapters and 14.4

club items. However, the distribution in the Home group was much different (see Section 7).

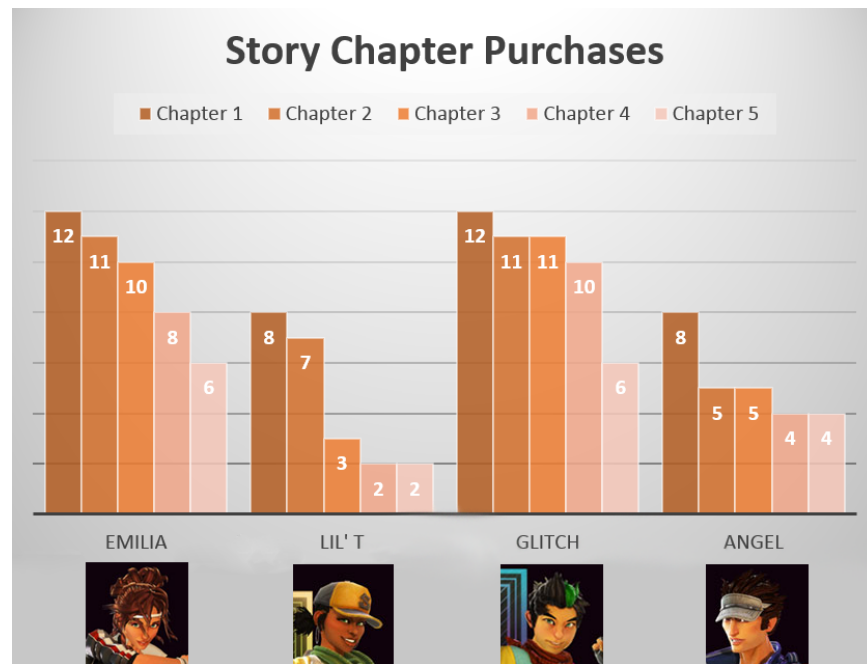


Figure 7.8: Emilia and Glitch were preferred over Lil'T and Angel storylines.

Figure 7.8 shows the total story chapter purchase of both Lab Content and Home Content groups. Few people finished all five chapters in a storyline, likely because they didn't have enough tokens. Among the four characters, Emilia and Glitch were the preferred storylines. They were also the first two listed on the page, so it is possible that participants chose them first without too much preference between the characters. But they also retained interest for almost all of the chapters. Based on the larger numbers at the beginning, it also seems that more participants chose to read several storylines at once, which would also explain the drop off later when they ran out of story tokens. Emilia and Glitch were also often mentioned in Section 7 as a favorite character. There might be a connection between that and the story chapters on the website.

Using a database and a WordPress plugin, we were able to see total visits to the website as well as how many times content participants visited the various available activities. Participants usually

visited the website after a dance session to log their scores, but they sometimes did so from home to fill out surveys and look at the content. We anticipated that users with access to content would have more total visits than those without, but they ended up being similar (Lab None Mean = 16.36, Lab Content Mean = 17.82).

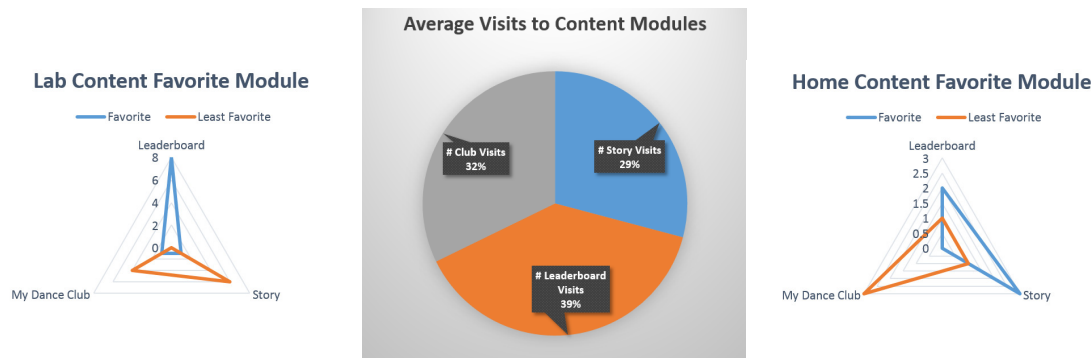


Figure 7.9: Three small graphs showing more viewpoints of the website activity. Left: Lab Content responses for favorite and least favorite module. Center: Breakdown of average visits to the different modules within the Lab Content. Right: The Home Content responses for favorite and least favorite module.

Figure 7.9 shows the breakdown of how often people would come to the website, as well as their final choice for favorite and least favorite modules. Again, the sample size varied greatly between Lab Content and Home Content, but the resulting graphs are very diverse. Whereas Leaderboard is definitely the favorite module in the Lab Content group, the Story was the favorite in the Home Content group. Some people also enjoyed the My Dance Club feature as well.

The center graph also shows that even though participants had a clear favorite, they also used all modules almost evenly. Furthermore, almost every participant agreed that elements like these would have enhanced the game experience. After all, the weekly questions show that every element ranked fairly positive. In conclusion, while Leaderboard definitely had the biggest impact on the Lab Content participants, there is enough reason to speculate that all modules had their merits.

Achievements

We also explored the achievements earned by participants to see if new information could be gained. The game has 50 achievements which can be earned through gameplay, for a total of 1000 possible points. These achievements are reached through a variety of different game modes and accomplishments, which gives an idea of the types of activity the player engaged in during the user study. Lab None had a mean of 12.91 total achievements and the Lab Content group had a mean of 14.91, with no significance between them ($t_{20} = -1.031, p = 0.32$). Achievements also are given score amounts, with harder ones worth more points. The Lab None group had slightly less total points on average, with a mean of 247.27 to 281.36, but it was also not significant ($t_{20} = -0.955, p = 0.35$).

Table 7.7 shows how many participants in each group earned which achievements. Some of the achievements were removed if all participants earned them because of the study (such as playing a fifteen minute long playlist). Other achievements were removed because no participants used them, such multiplayer achievements or completing something on hard mode. The next range of achievements with the least amount of attention hard to do with mastering all the songs in a crew's area of Crew Challenge. Only a couple of participants focused on these achievements, both within Content groups.

Break it Down mode, a way of slowing down the moves of a song to learn them better, was used by many participants. At least ten of them played long enough to nail a move or get a perfect score on the recap. This correlates with some of the comments regarding wanting to learn how to do the moves well.

Characters and Crew Challenge does seem to resonate stronger with the Content groups, as well. 12 participants defeated Dr. Tan's army by completed Crew Challenge mode, with most of these

being Content group participants. A substantial group of fourteen also earned gold stars on a song, a difficult score requiring perfection.

Table 7.7: Some of the earned achievements broken down by condition group. Achievements caused by Day 1 session or with no data have been omitted, as well as some for redundancy.

Xbox Achievements	LN	LC	HN	HC
Master the Glitterati's Routines on Medium	0	1	0	1
Master Lu\$h Crew's routines on Easy skill level	0	1	1	1
Master Lu\$h Crew's routines on Medium	0	1	0	1
Master Hi-Def's routines on Medium	0	1	0	1
Master Riptide's routines on Medium	0	1	0	1
Unlock the alternate outfits for the 10 crew members	1	1	1	1
Earn 5 stars after completing it in Break It Down	1	3	1	1
Use the "Focus on Select Moves" feature	2	4	1	2
Get a perfect score on a Recap in Break It Down mode	3	3	3	1
Play every song in the game in Perform It mode	3	3	3	1
Defeated Dr. Tan's army of robots on Easy	3	5	1	3
Dance with every crew member	3	5	1	3
Earn Gold Stars on a song	5	5	2	2
Earn 3 stars on any song on Hard	8	9	2	3
Get a score of at least 2,000,000 points	8	8	4	3
Log 5 total hours in Fitness	10	11	3	2
Earn over 100 stars	11	11	5	4

Twenty-two participants at least tried Hard mode, and almost all of them earned a substantial amount of stars, including five out of five on at least one song. A smaller group accomplished their completionist goals; only ten played every song and only four unlocked all the alternate outfits (which required getting a certain amount of stars in each area after beating Crew Challenge). From this, we gather a picture where score was more important in general (or some participants simply

didn't have time to finish everything).

Comments and Interviews



Figure 7.10: A visual shorthand for comparing common themes between groups of written data. Left: Lab None. Right: Lab Content.

The participants in this study had ample opportunity to express their opinion via write-in comments. Every survey included sections with open text input, and the participants were also encouraged to write notes on the website and in their journals. If the participant had enough free time during their Post-Experiment session, they were also given an informal verbal interview. While the subject matter was allowed to flow naturally, giving the participants a chance to express any other feelings they had about the experience, the moderator would try to get them to expand upon their thoughts.

Example keyword trends in the Lab groups are shown in Figure 7.10. We used coding to identify themes in this feedback, a technique used in other similar studies [115]. All four condition groups were evaluated. The principal investigator and two volunteers who had not seen this data before

coded this data after several passes.

First, all readers individually read all the data without making any notes. Then, during a second read through, they began to categorize similar themes by coding keywords into similar categories. Afterwards, the volunteers met to verbally discuss their codes and further define the dominant codes. The interesting trends that emerged are discussed below.

The Joy of Dance

When asked what they liked best about the study, people of all groups said they simply loved to dance. “Actually dancing” was most important, or “dancing to my favorite songs.” For some people, this was a passion that led them to try the user study. For others, they didn’t realize how much they could enjoy it until they began. Being in this study inspired some to consider taking dance classes. Overall, dancing was considered the best part of the user study.

I Love the Music

Many people also claimed the music was a big part of their enjoyment. “I can play the same song over and over” one participant said. A very popular method of play was making their own playlist, so they could “enjoy dancing to the songs I actually know.” The variety of songs in *Dance Central* 2 was well received by most participants, and stayed with them even when not in the user study: “I still have songs running in my head and the dance moves that go along with them.”

Exercise Can Be Fun

Many times, the participants stated their surprise that exercise could be fun. Some people had trouble with other forms of exercise, and found the dance game to be less painful or uncomfortable. Some people were inspired to take up running again because of their experience. Overall, many participants were impressed with the engagement level of the dance game. It “encouraged me to want to start exercising again,” or “I’m willing to actually walk my dog” were common phrases. Some participants were simply surprised that this type of game could be exercise, and others were grateful that they had found something they wanted to do.

Improved Mood

After sessions, many participants would write about their improved feelings. They felt stronger, more motivated, and overall more positive. “I feel more outgoing and happier” stated one person. Having more energy was a common comment. As the weeks went on, participants admitted to finding some struggles, but the positive feelings were still prevalent. Everything from “I want to be healthier” to “I always feel really nice after my dance sessions” was expressed afterwards. Participants also admitted to feeling proud of themselves for being active. Overall, the game left them with many emotionally positive feelings after a session of play. This is also interesting because of the relationship between low self-efficacy and exertion games, which has only recently been explored [62].

I’m Competitive

For those who had the Leaderboard content, discussion of the top people and wondering who they were was common. Expressions like “I have to be number one!” or simply stating “I’m a competi-

tive person” were common. It is interesting to note that the Leaderboard also featured a cooperative number, showing how much all the participants had played in total and how many calories they had collectively burned. Other studies have shown cooperative play to be more powerful than competitive play [98]. None of the participants mentioned this feature.

I'm a Completionist

Many of the participants focused on completing the game. There is no official way to win *Dance Central 2*, other than perhaps to finish the Crew Challenge mode (and that was a triumphant moment for some). But other participants made their own definition for winning the game. The comments section was peppered with their accomplishments, such as unlocking all the outfits for the characters, playing every song in the game, and getting five stars on every song. These were also Xbox obtainable achievements, but no participant mentioned using the list as a guide. They would have needed prior knowledge of the Xbox 360 in order to be aware of this list, so it's likely they made their own goals and strived to achieve them.

Thoughts on Gamers

Some people had unique thoughts about games and being a gamer personality. “I always want to find the final boss and beat it,” stated a participant that identified as a serious gamer. Some participants claimed not to be gamers, and yet, the Initial survey showed that almost everyone had some familiarity. Furthermore, the ones identifying as gamers had more derogatory things to say about My Dance Club, which was considered to be too casual for their tastes. The identification of a gamer is still a very prevalent sub-culture.

Another side anecdote which came up was the identity of Bilbo Swaggins, the top performer in our

seeded Leaderboard. This persona was based on pilot data from a female Home participant. Our male participants in the Lab Content group were particularly interested in who this person was and trying to beat them on the Leaderboard. They and one other female participant always referred to this person as male, possibly because of the nickname but also because of preconceptions about gender and games. Even while stating how much she enjoyed the game, a female participant said “even with games like this, guys seem to be more interested.” This becomes more interesting given the fact that our participant pool was almost entirely female, and that our real study top performer was also female (with a 14 hour lead on Bilbo’s score).

Outside Obstacles

Of course, some participants ran into trouble while engaging in the study. “I am sore after sessions” was a common thing, both expressed positively and negatively, but being tired or sick was common as well. Time management was a constant struggle: “Because of my busy schedule, I feel like I haven’t been able to give 100 percent of my effort and energy.” These same issues hinder motivation in other forms of exercise programs as well [26].

Hard Mode is Hard

Most participants started on Medium difficulty, because Hard mode was seen as being too hard, “focusing too much on specifics” and not giving them a good enough workout. Some players liked how it “really pushes you to learn some complicated dance moves” however, but this was less common. The Lab None group was more likely to change from Medium to Hard, while the Lab Content stayed with Medium the entire time.

My favorite character was...

The most popular two characters were Emilia and Glitch, with the Glitterati also being mentioned often. Some people didn't have a favorite character or pay much attention to them. But for those who did, the two most common reasons were either "I like the way they move" or he/she "looks like me." These comments were interesting, as the first is a response to their performance as a dance move instruction device and the second is relatable to how the participant identifies themselves. Many video games default to male Caucasian player characters [41], and the *Dance Central* series is refreshing for having characters of many ethnicities, genders, and in the case of the Glitterati, different implied sexual orientations (which two participants praised). Particularly polarizing was the character of Miss Aubrey, who has an elitist air about her, though she expressed fondness for the player during in-game dialogue. Some people went out of their way to explain how much they disliked her, while others felt she was their favorite character, especially the way she moved.

If I had to do this another month...

Some people expressed their impressions on having a longer user study. For some, it was an opportunity; they felt they would have done better and made more progress if the study had been several months long. But others felt that the "limited group of songs" were played out in the four-week period. Participants wished for more songs, ideally ones that unlocked based on performance (the current business model for the game allows additional songs to be purchased). Some other suggestions were made, such as having character creation, more outfits, and more story.

Definitely drinking more water

Twelve participants agreed that they were drinking a lot more water since the study began. This was the most mentioned change to diet. The second most mentioned trend was being hungry. As the weeks went by, more participants commented on how much more they wanted to eat. Some individuals gave into the temptation, while others resisted. Usually, the eating of what was considered junk food was accompanied by a guilty comment.

Home Comparison

Lab participants were sometimes disappointed by their random placement: “I would have preferred to do it at home. I would have been more comfortable.” During interviews, several people felt they would have exercised more if they had been doing it at home. But was this just wishful thinking? One of our motivations for scaling back the Home participant group was the low performance of the pilot study group. Very few of the initial group kept up a regular session schedule.

For the statistical analysis, we removed the Home participant data, as the sample size was too low to indicate significance. However, we can make some comments regarding the performance of the Home participants versus the Lab participants. As we expected, there were some people who performed very poorly in the Home group.

The average duration of the Lab participants was around 7.5 hours. Of the ten Home participants, five of them played for less than 5 hours. What was more remarkable, however, was the high end participants. Three of the home participants exercised more than 9 hours, putting them in the lead overall. And the top performer of the entire user study exercised for over 23 hours in the 4-week intervention. This wide range of adherence was also evident in the number of sessions, which ranged from 2 to 18.

The participants in Home Content seemed to be more interested in Story than the Lab group, as mentioned in Section 7. They had two of the highest totals of story chapters read, although that was related to the fact that they had some of the highest total durations to acquire those chapters.

From the physiological standpoint, the group fared roughly the same as the Lab participants, with no huge differences between Home groups or even between participants that did many more sessions.

Hypotheses Revisited

After reviewing the results of the study, we revisited our initial hypotheses to see how they aligned with our conclusions. In some cases, the data aligned with our theories, but in others we were surprised. Some of these surprises were more positive than we were expecting.

1. **Attendance will drop off over time.** In other similar studies, attendance dropped after as the study neared the end [62]. In our study, there were surprisingly few dropouts once the study began. Almost every participant who began the study continued to attend for the full four weeks.
2. **People with narrative condition would enjoy the experience more.** All participants enjoyed the dance game very much, so there was no significance between the groups in this area. However, the Lab Content group did focus their enjoyment on characters and competition more so than the Lab None group.
3. **Home participants will have lower retention in the study.** Even among our small sample size, this seemed to be true. However, a few standout participants played the game very diligently at home, showing that this type of game might work very well for certain personality types (much like any other home fitness regimen).

4. **Exposure to the Content will expand expectations for fitness games.** In the text comments, the Lab Content group had much more to say about how to make the game better. They referenced other games they liked or asked for specific features. Their interest in competition, characters and storylines increased by the end of the study. When asked how to make the study better, almost all Lab None participants had no suggestions.
5. **One of the Content modules will prove much more popular than the others.** While the Leaderboard was the most popular content module and the one the participants seemed to focus on the most, the reactions to Story and My Dance Club were not so negative as to imply there was no benefit to their inclusion. Content preference may rely on personality.
6. **Physical performance will not vary between groups, but overall participants will show improvement.** Overall, participants did not show significant fitness gains during this four-week intervention. There is evidence to imply that heart strength was improved, however. And the calorie expenditure during Day 1 session showed it has the potential to be similar to a low-energy cardio dance class. A longer intervention might have yielded more significant results.
7. **The game will output larger values for Calories Burned than the real values.** Surprisingly, the Kinect and *Dance Central 2* estimates calorie expenditure fairly well. Major differences seemed to be accounted for by gender and height. Also, the Calories Burned within the game slightly underestimated the actual expenditure. This was surprising because we expected the game to exaggerate in order to make the player feel encouraged.

Overall, the Dance Enhanced study did provide useful results on the fitness efficacy of the game *Dance Central 2*. It also developed a picture of how narrative content can affect the experience of playing a dance game for fitness, and gave some insight in how these games can further improve engagement.

CHAPTER 8: DANCE ENHANCED: DISCUSSION

The Dance Enhanced study was an exploration of additional gameplay elements and their potential impact on fitness. The undertaking of this study required a lot of time, money and determination. Some aspects of the design necessitated a great amount of organizational trial and error. We present some observations on the potential difficulties and accomplishments involved.

Strengths

Refining Study Design through Piloting

One of the successes in designing Dance Enhanced was the use of tiered pilot studies. By testing elements of the study as they became available, errors were discovered and able to be fixed in time for the actual participants. Design errors lead to unreliable data when they introduce unpredictable variables between participants. Sometimes, we had situations where some Home participants misunderstood what they were allowed to do while in the pilot study, and making slight alterations to moderator scripts resolved these issues. We were also able to incorporate new features based on what pilot participants desired. The email reminders were particularly helpful in keeping more of the participants on task.

We were also able to use the pilot tests to streamline solutions to scheduling. The use of an online scheduling tool to organize appointments saved hundreds of hours of email scheduling, as participants are often vague about their availability and like to see a variety of choices. The online scheduling software we used did not allow for appointments to be made the day before the appointment, an important feature in preventing missed appointments if the moderator had already planned the rest of their day. It also allowed canceling, rescheduling, and showed the busy and

available slots. Even more importantly, the appointment automatically sent reminder emails the day before, which was likely a huge factor in attendance.

Using Commercial Games

For this study, we chose to use a commercially available Xbox 360 game. We made this choice because not only is it a product that is actually being used by consumers for entertainment and exercise, but it provides a high level of aesthetic appeal in design, art, and music. Our previous work used games that we created ourselves, which likely had a different effect on experience because of the difference in quality. In order to get a closer understanding of how these games are impacting players, we wanted to change to a commercial game and reduce this potential difference in perception.

But because the game could not be altered, the software lacked flexibility. There was no easy way to change the menus or streamline the participant's experience for this study, meaning that tutorials had to explain a lot of extra steps that were sometimes confusing. This tradeoff also resulted in the occasional loss of data as participants logged themselves out of the game or became confused by other game options. Using a commercial product requires studying all available actions in the game in order to account for elements that could introduce error or variability.

Another issue we encountered and resolved was managing the data of many users at once. We used two Xboxes in order to facilitate the most people in sessions throughout the week. During piloting, each participant would log into their unique profile account to keep track of their stats, and it would be difficult for a person to add up their scores on two different machines. We also didn't have reliable wireless in the lab for the Xbox 360 systems. After experimentation, we ordered USB drives for each participant. These drives held the game data and the Xbox profile, which could be used on either Xbox. It was also useful for Home participants that already had an Xbox, providing

an easy way for us to collect data in the lab and in the home.

Home

One of the most ambitious investigations during this study was the differences between Home participants and Lab participants. Unlike Lab participants, who would make scheduled appointments to play in the lab space, Home participants were given the equipment necessary to play and allowed to do sessions at their own pace in their own homes. Home-based therapy has been explored in the past as cheaper alternative for patients with serious health conditions, with positive results [3, 67].

Based on performance during the pilot study phase and the cost of equipment, the Home participants were scaled back to another preliminary pilot to favor Lab participant data. Still, there was value in the exploration because it is the natural environment that the game is played in and could allow people to exercise more around their schedule. The Home participants extended to both ends of the spectrum in regards to compliance and performance. While some excelled greatly, exercising more than the Lab participants and engaging constantly with the website, other participants barely engaged. Participation seemed to improve between the pilot studies and the actual study because of the email reminders. Future studies might do well to have phone checkups or regular in-person meetings to discuss any issues, as Home participants were more reluctant to ask questions.

Individual Impact

Games like *Dance Central 2* have the ability to powerfully affect players in unexpected ways. One lost an incredible amount of weight in the time period of the study (over nine pounds) and claimed that the game had changed her water consumption habits. She routinely takes the stairs instead of the elevator after doing the study, and never is out of breath when she reaches her office on

the third floor. Another touching story from a participant regarded the emotional impact of the game. During the user study, she experienced a break up with her boyfriend that was difficult for her. In her final survey and exit interview, she stated how playing this game helped her get through her sadness and gave her something to look forward to every day. We were also surprised by a participant who was so interested in the user study that he watched hours of video online for *Dance Central 3*, both before and during the study, in order to prepare. With common expressions of feeling better, happier and healthier afterwards, as well as renewed interest in exercise and sometimes new interest in learning to dance, this experience had more than a physical impact on the people who participated. Many investigations into the emotional impact of games are taking place across all styles and genres, but fitness and dance games have received little attention in this area beyond their exercise qualities [5, 8, 59, 96]. In the future, more exploration into this area might uncover these unexpected benefits of full-body games.

Limitations

Participant Drop Off

In previous studies, we compensated participants monetarily to reward them for participation. But for Dance Enhanced, we were concerned with additional motivation sources affecting the results. Financial gain has been shown to affect fitness behavior (although not always results) [83]. The participants in this study volunteered out of pure interest in playing a dance game for fitness, but it did reduce the potential interest in this study. While our signups for orientation initially look impressive, they were the result of an email sent to the entire student body (over sixty thousand students). Future studies should take care to recruit much more than required. Also, with a college student population, holiday breaks in semesters need to be noted. In a four week study we took care to avoid these breaks, but they can be overcome for longer studies.

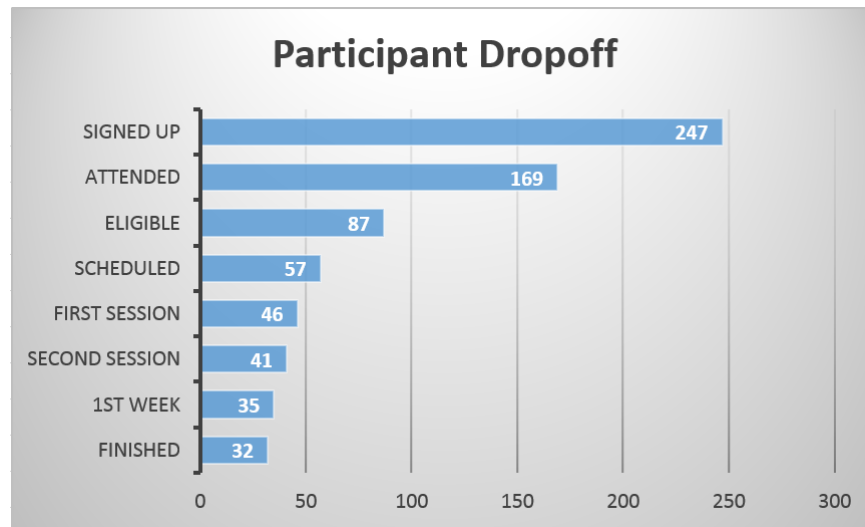


Figure 8.1: Recruiting well over the needed participant amount is necessary to ensure a decent amount finishes the study, but also requires many resources.

It should also be mentioned, however, that almost all of our dropouts occurred because of illness or scheduling issues. Only one participant left because of disinterest. This reflects positively on the interest level for dance games and the quality of *Dance Central 2*, as it is very difficult to maintain participants over time without compensation.

Diversity

Our participant pool was recruited through volunteer interest, and as a result the demographics were dictated by who signed up for orientation and if they were eligible. While we had a diverse group in terms of ethnicity, almost every participant was female. Even of the entire group which came to volunteer, only about ten males showed up compared to almost three hundred females. Future studies should strive for equal amounts of each gender in every condition group, but doing so may be a struggle given that this type of game study seems more popular with females.

Technical and Scheduling Issues

The low sample of this size was partially caused by a number of technical issues. Missed appointments were sometimes caused by food sickness, transportation, and tests. Parking passes were required at our university, making it difficult for non-students to come frequently, and some students had to decline because they lived far away and only visited campus twice a week. We also faced equipment breakdowns with both the metabolic cart and the DXA scanner. These issues took time to fix, and even a delay of a couple days caused a loss of data. In the future, running studies over multiple semesters would result in a better chance to overcome these unpredictable situations.

The purchasing of necessary game equipment was also a challenge. We chose to provide an Xbox, Kinect, and *Dance Central 2* to our Home participants, but some of them did not have televisions and could not participate. It was difficult to gauge how much to purchase, as some participants might already have some of the equipment. On the positive side, we expected some loss with equipment not being returned, but thankfully that did not happen. Still, it is a possibility that needs to be accounted for in studies with similar protocols. The financial burden can be lessened in the future by extending the length of the overall study period so that the same equipment can be loaned multiple times, but this will necessitate more hours for the moderators and researchers.

Scheduling problems hampered the execution of this study for many participants. The nature of this multidisciplinary study required the moderation of a computer scientist and an exercise scientist for sessions which gathered physical data. Including the participant, three different schedules had to align for a successful testing session, and there were four testing sessions per participant. We only allowed a five-day window past the end of the study for participants to run their post-tests. Sometimes, it was impossible for the participants to come back in that time period. When a participant could only come back for one post-test, we prioritized the Post-Experiment Session so that we could utilize the most fitness data as possible. As a result, the Day 28 Session was only

finished by eight Lab None participants and five Lab Content participants. We were unable to run a comparison between the Day 1 and Day 28 data as a result. Future studies should have multiple moderators of every necessary job, in order to cover all days of the week.

Research Questions Revisited

We close with a re-evaluation of our main questions.

Can a body-controlled dance game be considered adequate cardiovascular fitness? Dance games such as *Dance Central 2* do have the potential to be adequate cardiovascular fitness. In the Day 1 session where we evaluated exertion, the results indicated there was some exertion potential to playing the game, similar to dance cardio classes and ballroom dancing. While no significance was found overall in body composition or oxygen consumption, outside factors such as a low pool of participants, holidays, and no dietary instruction likely played a part. Further investigation into this area is still worthwhile, especially now that a framework for running a study of this length and complexity has been established.

Does the environment where the dance game is played have an effect on the participant's motivation to exert themselves? While the study was scaled back in order to feasibly execute it, we can still make some statements about the difference between Lab and Home participants. Logically, the Home participants should be able to perform better; they were not restricted to the Lab schedule, and had a more convenient setup in their own houses. The reality was much different. Lab participants adhered to the exercise program much better than Home participants on average. But a couple standout performances from the Home groups proved that for some people, this opportunity was enough to trigger significant effort. Future investigations within a home setting might uncover more through personality tests or more rigorous analysis of participant groups with

a wider sample size.

Does the addition of extra narrative content usually found in other engaging game genres increase motivation and adherence? Yes, there is evidence suggesting that adding other game mechanics improves experience, and has an impact on adherence. Our players were most motivated by the Leaderboard, which inspired them to stay longer and work harder. While not as universally popular, the Story and My Dance Club were still enjoyed a lot from certain participants, inspiring them to become interested in characters and storylines. Even when the website content was critiqued, it represented a genuine desire for more narrative elements in a game like this, and the Lab None participants, with no knowledge of the extra content, wished that the game had more as well. However, the extra content would have had little impact if not for the quality of the game itself. Among almost all participants, simply enjoying to dance and listen to the music was one of the most powerful motivating factors.

CHAPTER 9: FUTURE WORK

There are still many unknown areas regarding full-body dance games. We believe there are many opportunities for this research to be continued and extended. This chapter offers suggestions on how to develop this work further over the next five to ten years.

Multiplayer



Figure 9.1: *Dance Central 2* focuses on multiplayer battle and crew challenges, making it a natural choice for multiplayer gameplay.

One comment often made by participants throughout the study was the desire to play the game with others. Some of the Home participants even broke protocol to do so. The desire is understandable, though the fitness benefit is questionable; some work has suggested exercising alone gives better results, while some suggests group exercise is more motivating[80, 98]. Other exertion gaming studies have done multiplayer studies, both to encourage group behavior and for feasibility of running the sessions [66]. In our case, we wanted to explore the experience of one person who

purchases this game and plays it alone. We also wanted to minimize unknown variables that would come from different personalities interacting [81]. Still, a natural direction for future exploration is to expand this design to group play. *Dance Central 2* was designed for two people to play at a time, encouraging research into participants signing up as pairs.

But this would also introduce more difficulty in recruitment, which should be taken into consideration. And with the addition of multi-person sessions, privacy must also be taken into account. Even small details like the presence of a mirror can change self-efficacy and adherence [53]. Many participants were shy about dancing with other people in the room, even if the moderators were hidden behind curtains or working on something else. Dancing is still an activity that makes people self-conscious, and the clash of different personality types in the group may lead to undesirable outcomes.

Ethnicity



Figure 9.2: The *Dance Central* series features characters of various age, ethnicity and gender, allowing a broader range of players to identify with them easily.

One of the unexpected outcomes of our participation pool was the diversity of ethnicities that

were interested in the study. While gender was almost exclusively female, more than half of our potential participants were not Caucasian. In the end, only eight of our finished participants identified as Caucasian, with the rest being a variety of Hispanic, African-American, Asian, and mixed backgrounds. This is notable in part because many user studies, including our previous work, resulted in mostly Caucasian male participants. Some reasoning for this might be simply that the BMI and age range excluded many Caucasian females that were interested in participating, but it is also likely that the subject of this study appealed to a different demographic. Previous studies in exertion games have identified African-Americans as a population that could benefit from more titles like this [98, 115]. In particular, the *Dance Central* game series is a good subject for investigating this further, because it is one of the few game series that has a variety of characters with different backgrounds, as shown in Figure 9.2.

Personality and Psychology

One element we did not account for in Dance Enhanced was how different personality types influenced preference. Incorporating a personality model into a dance game study would help us understand what type of person is most likely to engage with them. There are already many personality frameworks being examined with exercise, especially with regards to self-regulation theory [13, 22, 45, 61, 87]. There's also work in coping with embarrassment and self-efficacy, two experiences that our participants faced in several studies [53, 85, 96]. An interesting experiment could be conducted on how traditional gamer roles, such as those defined in MMOs by Bartle, translate to full-body games and if they correspond with how different personalities respond to exercise [6].

Dietary Changes

For this study, we asked participants to keep their diet the same as usual. This was important in order for us to isolate the fitness potential of the game, which was one of our goals. But there were some changes in diet noted in Section 7. Many participants noted a change in their water intake, with much more water being consumed not only during game sessions but throughout their daily lives. Diet impact was mostly the same, though participants often mentioned being hungrier. They often admittedly (sometimes guiltily) to indulging in snacks, especially if a holiday occurred during the study. But some participants also found themselves more aware of food, cutting out extra snacks and in one case, continuing to drink soda as we instructed but feeling quite bad about it. In a future study which does not intend to evaluate the fitness impact of the game, incorporating more rigid dietary restrictions, or even working healthy eating choices into the gameplay mechanics, would be an interesting direction to take this research.

Expanding RealDance

Many paths remain open for investigating visual displays in a dance rhythm game. Understanding which screen elements command visual attention would be useful in future interface design. Participants indicate in questionnaires that they focus on the human avatar or the icons if they are available, but using eye or head tracking would give more accurate insight. Another area worth studying in more detail is preparation time. To our knowledge, there is no scientific investigation into how long before a dance move the instruction should be shown, with the standard being between one to four beats. The time prior to execution was chosen by play testing as we developed the RealDance prototype, but a formal user study would give insight into what time would give the best performance and usability results.

Expanding Vibraudio Pose

While we explored non-visual techniques as feedback, vibration and audio feedback can also be used as an indicator for certain movements. Previous virtual reality experimentation has led to investigation in ballroom dance and augmented reality [24, 49]. One possible experimental design would be to set up a Wizard of Oz study, where a hidden moderator would send targeted vibration signals to different body parts before a move needed to be executed.

We did not have precise control of the vibration feedback using the Wiimotes, so building or using a different type of hardware is another way to expand knowledge in this area. The duration or intensity of the vibration could be altered. For audio, many options are possible, as different sounds can denote a positive or negative connotation. One suggestion made by participants that we use a different sound for each limb is a direction worth exploring. And the use of memory retention psychology would be a helpful direction, given that most participants expressed low self-confidence in their ability to remember positions.

Expanding Teach Me to Dance

While we were able to explore perceptions in dance games as teaching aides, there were some clear areas for improvement. First, our game prototype lacked the professional quality of a commercial title. As noted in [48], fun and polish are important factors that in player experience. With the hardware we had available, we created a prototype that displays all the necessary information, but with little finesse. Now that there are dance games available with greater avatar detail and unencumbered interfaces, it would be interesting to expand a teaching study in collaboration with a dance instructor. In our write-in questionnaire data, many participants claimed that the human video was superior because of the nuances to his performance that are lost in the recreated digital

version [16]. This may be a problem even with the more detailed 3D avatars, as some comments during the Dance Enhanced study noted that the character movement still looks jarring compared to real human movement. Running a comparison between having a real person teach dance and a dance game version would be an interesting follow-up to the question of its capability as a teaching aid.

Teach Me to Dance would be improved by extending a new study on the concept over a longer period of time. With only an hour per participant, we could only detect short-term results on simpler moves. Having the same users experience choreography over several sessions would allow us to chart their progress. With the lessons learned from running Dance Enhanced, a multiple-session study would be easier to design.

Expanding Dance Enhanced

Our study faced significant challenges given that there was no baseline study just exploring the game itself without any other elements. We wanted to make sure we explored the effects of Dance Central 2 by itself, and yet were also interested in the multitude of other potential content. Because of the reactions during the pilot study, we chose to keep all three content types for the user study and do a broad exploration of the base game and a variety of other content. But from this point forward, isolating each of these content types and exploring them deeper would be a more valuable way to proceed.

While our results uncovered the power of the Leaderboard, we also saw different personality types leaning towards all three types of content. A future study could delve deeper into just one of these module types and explore more nuance and variety. For the Leaderboard, we could combine the concept of multiplayer and see if there are changes between when participants know and speak to

other players, bring their own friends in, or play in isolation. For the Story content, there are many areas in which this could expand, as the length, type of story, and presentation. For the My Dance Club style of customization, expanding to include avatar creation and more options of interactivity would help in investigating the appeal and potential of simulation content.

Another potential opportunity for further work is the fitness impact on different groups of the population. Ethnicity, age, health conditions, and recent medical operations can all influence the metabolic needs of a human. It may be that this type of game results in low gains in fitness for a college-aged population, but engaging a group with diabetes or in a higher age bracket would result in much different results. Experimentation in different populations would provide valuable information.

CHAPTER 10: CONCLUSION

We have presented an exploration into full-body dance game design using several game prototypes [15, 16, 17]. The research we have done has shown significant user preference in several areas, expanding the knowledge and potential research in this field. Based on the conclusions of our experiments, we can make speculations on some game mechanics that future dance games should include.

In RealDance, we learned that 2D spatial display methods help players can understand what they are expected to do much faster. We have seen results indicating that spatial instructional interfaces positively improve performance in dance games.

In Vibraudio Pose, non-visual feedback performed comparably with visual when used as negative feedback and vibration was preferable to audio. We found that delivering feedback to a specific limb communicated faster than visuals alone. If utilized, wearable devices should incorporate targeted feedback to help players get better. In unencumbered interfaces, the feedback should still be quick and clear.

In Teach Me to Dance, when compared to traditional human video training, dance game interfaces are not a sufficient replacement for dance education in one session. Self-representation should be minimized and positive feedback should be increased. In order to keep player engagement over a long period of time, more interesting visual and audio content should be consistently added.

In Dance Enhanced, different narrative material was shown to impact adherence and experience, especially in terms of competition. The Leaderboard was a popular motivating factor, and participants wanted to have more characters and storylines in their full-body dance games after the study ended.

By stitching this knowledge together, we can begin to picture a dance game that draws upon these strengths as well as techniques found in other popular games. This future dance game might include icons and motion streams that teach a player how to do the movements but can be turned off once a sequence is mastered. Players that want to learn moves better could also use vibrating wrist and ankle bands to quickly indicate errors or upcoming moves.

Right now, most dance games have downloadable songs for purchase, but the options for changing the visual look of the virtual worlds are still limited. By using player-created content or procedurally generated worlds, the look of the game could be constantly updated. The world could even change based on the performance of the player, encouraging a perfect run to create the most interesting looking world. And songs should be earnable in addition to purchasable, a technique found in many free-to-play mobile games. Making something worth money is a great way to encourage people to play in order to get it for free, encouraging more game sessions.

Character creation would help players express themselves through looks and clothing. Earning more outfit pieces can also be a source of motivation for completionist players. Using these virtual avatars, matches can be played online, allowing players to engage without risking embarrassment. Leaderboards which compare calories burned in addition to game scores would encourage people that struggle to do the moves correctly. There's also the possibility for creative competition, as players can compare the style of their characters, the design of their own home or dance club spaces, or even upload their own choreography for other players to perform.

And the roles of non-player characters could be enhanced to make gameplay matter more. Characters could get hurt or have emotional reactions when dance moves are performed wrong, indicating to a player how to improve and giving them an incentive to do so. With the avatar now taking place in the story, more meaningful plot developments that put characters in danger would give the player a greater feeling of accomplishment, boosting self-efficacy. All of these suggestions are

merely speculation, but a combination of these elements would likely make full-body dance games into richer experiences.

Dance games face many difficult problems, both in making the best design choices and proving that significant changes to well-being have occurred. The results of our research present a framework for expanding the exploration of design mechanics and studying their potential impact. By bridging the gap between a fun product and one that improves the life of the player, dance games can promote long-term fun and positive impact.

APPENDIX A: QUESTIONNAIRES

Table A.1: Experiment 1: Post-Technique Questionnaire and Post-Questionnaire.

Post-Technique Questionnaire	
PT1	I felt like the images on the screen matched the music well.
PT2	I felt like the moves I was asked to do matched the music well.
PT3	I was able to follow the suggested movements easily.
PT4	This interface made the dance moves easy to understand.
PT5	This interface made the experience more fun.
PT6	The icons were moving too fast and I didn't have time to respond.
PT7	I couldn't understand where to move based on the position of the icons.
PT8	There were too many visual objects on the screen confusing me.
PT9	The stick figure avatar helped me make sense of the dance moves.
PT10	The scores I received matched how well I thought I did.
PT11	When I played this game, I felt like I was dancing.
PT12	This interface made the game play more enjoyable.
PT13	Describe anything you found frustrating about this interface.
PT14	What did you like about this interface?
PT15	What did you dislike about the interface?
PT16	Please provide any additional comments about this interface.
Post-Questionnaire	
PQ1	Which interface do you feel you performed the best in?
PQ2	Which interface felt like the most fun?
PQ3	Which interface did you find the easiest to understand?
PQ4	Which interface made you feel most like you were dancing?
PQ5	Which interface did you find to be most visually pleasing?
PQ6	Which interface seemed to match up with the music the best?
PQ7	Which interface did you like the least?
PQ8	Why did you dislike this interface?
PQ9	Which interface did you like the most?
PQ10	Why did you prefer this interface?

Table A.2: Experiment 2: Post Questionnaire. Questions 1-8 used a 7-point Likert scale where 1 indicated Strongly Disagree and 7 indicated Strongly Agree. Q6 is divided into several similarly worded questions that were different depending on what mode the participant was given. Questions 9-14 were open answer.

Questions 1-5	
Q1	The positive reinforcement helped me know when I was doing the right thing.
Q2	The negative reinforcement helped me know when I was doing the wrong thing.
Q3	The game was difficult because I am not used to using my entire body in a video game.
Q4	I had trouble detecting which body part was giving me vibration feedback.
Q5	I had trouble detecting which body part was giving me audio feedback.
Question 6 Variations	
M1 Pos	I felt the audio feedback helped me get into the correct pose.
M1 Neg	I felt the vibration feedback helped me know what I was doing wrong.
M2 Pos	I felt the vibration feedback helped me get into the correct pose.
M2 Neg	I felt the audio feedback helped me know what I was doing wrong.
M3 Pos	I felt the vibration and audio feedback helped me get into the correct pose.
M4 Neg	I felt the vibration and audio feedback helped me know what I was doing wrong.
Questions 7-14	
Q7	The nonvisual feedback made the game more fun.
Q8	A system with per-limb vibraudio feedback could help you learn difficult body motions.
Q9	Would you rather know when you are right or when you are wrong?
Q10	Did you prefer the Visual Only mode to the other modes?
Q11	Which type of nonvisual feedback did you like most?
Q12	Which type of nonvisual feedback did you like least?
Q13	Have you ever played any games that used vibration or audio as feedback devices.
Q14	Any additional comments about your experience?

Table A.3: Experiment 3: Content of Questionnaires 2 and 3. The * indicates where the question appeared.

Num	Q2	Q3	Question
1	*	*	I feel like I really understood the moves in this dance routine.
2	*	*	I feel like I did a good job performing the dance routine.
3	*		I feel like my performance was accurately detected during the experiment.
4	*		The game was difficult because I am not used to using my entire body in a video game.
5	*		I enjoyed the experiment.
6	*		If I could have picked the music, I would have enjoyed learning the dance more.
7	*		If I could have picked the routine, I would have enjoyed learning the dance more.
8	*		A real human instructor is much better than a digital system like this.
9	*		I could easily tell what I was doing wrong and how I needed to improve.
10	*		I was so engaged in the task that I didn't realize how much I was moving my body.
11	*		If I had a better memory my performance would have improved.
12	*		Did you find yourself focusing more on getting the moves correct or the timing correct?
13	*	*	If you were asked to do this in a week, with no expectation that you would have practiced it, do you think you could perform this dance routine?
14	*	*	Why/Why not?
15	*		What could have made the routine easier to learn?
16	*		Which dance move was hardest? Why?
17	*		Which dance move was easiest? Why?
18	*	*	What part of the screen did you focus on the most during the experiment?
19		*	Which interface did you like the best and why?
20		*	Which interface did you like the least and why?
21		*	Any additional comments about your experience?

Table A.4: Experiment 4: The * columns indicate which questions appeared on the Initial Survey, which on the Final Survey, and which on both.

Initial	Final	Question
*	*	I find it difficult to exercise regularly.
*	*	I would exercise more if exercising was more fun for me.
*	*	I think playing a game would make exercising more enjoyable.
*	*	I would enjoy a fitness game that focused on characters and storylines.
*	*	I would enjoy a fitness game that focused on competing with other players.
*	*	I would enjoy a fitness game that focused on unlockable collectibles based on my progress.
*	*	I would enjoy a fitness game that gave me rewards for using it frequently.
*		I think that I will be more fit by the end of this user study.
*		I have trouble exercising consistently over a long period of time.
*		I have trouble working out for more than 30 minutes in an exercise session.
*		What game systems do you own?
*		What kind of games do you like to play, if any? How often do you play them?
*		Do you ever play mobile or Facebook games? Which ones and how often?
*		Have you played a motion controlled game (Wii, Sony Move, Kinect)? Which ones?
	*	I feel more fit now than when I began this user study.
	*	Playing a dance game made me want to exercise longer during a session.
	*	I am interested in buying a dance game and continuing to play it for cardio exercise.

Table A.5: Experiment 4: The * columns indicate which questions were given to the None and Content condition groups at the end of the Final Survey.

None	Content	Question
*	*	What were your favorite parts of the game? Why?
*	*	What were your least favorite parts of the game? Why?
*	*	What features do you wish the game had that would have made it easier to use as an exercise aid?
*	*	Are there any features of other games that you think would have made this game more enjoyable?
	*	What was your favorite part of the website? (My Dance Club, Leaderboard, Story)
	*	What was your least part of the website? (My Dance Club, Leaderboard, Story)
	*	Do you think if this content was in the Xbox game, it would have made playing this game better? Why?
*	*	What level of difficulty did you play on: Easy, Medium or Hard?
*	*	What mode did you usually play: Picking your own song, making your own playlist, Crew Challenge mode?
*	*	Did you finish Crew Challenge mode? What would have made it better?
*	*	Do you think being in this study has changed how you feel about exercise?
*	*	Any additional comments about your experience?

Table A.6: Experiment 4: The * columns indicate which questions were given to the None and Content condition groups during the weekly survey, which was given at the end of each of the four weeks.

None	Content	Question
*	*	I feel good about my progress in the study.
*	*	I am enjoying the game sessions.
*	*	I feel like I am getting a lot of exercise during the sessions.
*	*	I'm finding it difficult to exercise three or more times a week.
*	*	I'm finding it difficult to exercise for thirty minutes or more at a time.
*	*	I exert myself as much as I can while playing the game.
*	*	What part of the game are you enjoying most?
*	*	What part of the game are you enjoying least?
	*	I am enjoying the Story part of the website.
	*	I am enjoying the Leaderboard part of the website.
	*	I am enjoying the My Dance Club part of the website.
	*	What do you like best about the content on the Dance Enhanced website?
	*	What do you could be improved about the content on the Dance Enhanced website?
*	*	Please note any other observations you've had.

APPENDIX B: GAMES CITED

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15. *In the Groove*. Roxor Games (Arcade), 2004.
16. *Just Dance*. UBI Soft (Wii), 2009.
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18. *Ouendan 2*. Nintendo (DS), 2007.
19. *Princess Debut*. Natsume (DS), 2008.

20. *Rock Band*. Harmonix Music Systems (PlayStation), 2007.
21. *Sequence*. Iridium Studios (PC), 2011.
22. *Space Channel 5*. United Game Artists (Dreamcast), 1999.
23. *Tokimeki Memorial 2 Substories: Dancing Summer Vacation*. Konami (PlayStation), 2000.
24. *Unison*. Tecmo (PlayStation 2), 2001.
25. *WarioWare, Inc.: Mega Microgame\$*. Nintendo (GBA), 2003.
26. *We Cheer*. Namco Bandai (Wii), 2008.

APPENDIX C: IRB APPROVAL LETTERS



University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901, 407-882-2012 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Notice of Expedited Initial Review and Approval

From : **UCF Institutional Review Board**
FWA00000351, Exp. 10/8/11, IRB00001138

To : **Joseph J. LaViola II** and Co-PI: **Emiko Charbonneau**

Date : **February 04, 2009**

IRB Number: **SBE-09-06028**

Study Title: **Exploring Visualization Techniques for Learning Dance Moves in Video Games**

Dear Researcher:

Your research protocol noted above was approved by **expedited** review by the UCF IRB Chair on 2/4/2009. **The expiration date is 2/3/2010.** Your study was determined to be minimal risk for human subjects and expeditable per federal regulations, 45 CFR 46.110. The categories for which this study qualifies as expeditable research are as follows:

4. Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed they must be cleared/approved for marketing.
7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

The IRB has approved a **consent procedure which requires participants to sign consent forms.** Use of the approved, stamped consent document(s) is required. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Subjects or their representatives must receive a copy of the consent form(s).

All data, which may include signed consent form documents, must be retained in a locked file cabinet for a minimum of three years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained on a password-protected computer if electronic information is used. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

To continue this research beyond the expiration date, a Continuing Review Form must be submitted 2 – 4 weeks prior to the expiration date. Advise the IRB if you receive a subpoena for the release of this information, or if a breach of confidentiality occurs. Also report any unanticipated problems or serious adverse events (within 5 working days). Do not make changes to the protocol methodology or consent form before obtaining IRB approval. Changes can be submitted for IRB review using the Addendum/Modification Request Form. An Addendum/Modification Request Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at <http://iris.research.ucf.edu>.

Failure to provide a continuing review report could lead to study suspension, a loss of funding and/or publication possibilities, or reporting of noncompliance to sponsors or funding agencies. The IRB maintains the authority under 45 CFR 46.110(e) to observe or have a third party observe the consent process and the research.

On behalf of Tracy Dietz, Ph.D., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 02/04/2009 02:40:27 PM EST

IRB Coordinator



University of Central Florida Institutional Review Board
Office of Research & Commercialization
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Orlando, Florida 32826-3246
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Approval of Human Research

From: **UCF Institutional Review Board #1
FWA00000351, IRB00001138**

To: **Emiko Charbonneau and Co-PI: Joseph J. LaViola II**

Date: **September 29, 2010**

Dear Researcher:

On 9/29/2010, the IRB approved the following human participant research until 9/28/2011 inclusive:

Type of Review: UCF Initial Review Submission Form
Project Title: A Comparison of Traditional Dance Instruction and Game-based Methods
Investigator: Emiko Charbonneau
IRB Number: SBE-10-07065
Funding Agency: University of Central Florida(UCF)
Grant Title: Internal Funding N/A
Research ID: N/A

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

If continuing review approval is not granted before the expiration date of 9/28/2011, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

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

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

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

Signature applied by Joanne Muratori on 09/29/2010 08:53:36 AM EDT

IRB Coordinator



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

Approval of Human Research

From: **UCF Institutional Review Board #1
FWA00000351, IRB00001138**

To: **Emiko Charbonneau and Co-PIs: Joseph J. LaViola II, Theodore Angelopoulos**

Date: **December 17, 2012**

Dear Researcher:

On 12/17/2012, the IRB approved the following human participant research until 12/16/2013 inclusive:

Type of Review: IRB Addendum and Modification Request Form
Modification Type: NOTE: When Addendum/ Modification request was reviewed, IRB realized the study was approved in error. The study has been re-reviewed and now has approval to begin.
Project Title: Investigation on the Cardio Fitness Benefits of Playing a Dance Game for 4 Weeks
Investigator: Emiko Charbonneau
IRB Number: SBE-12-08733
Funding Agency:
Grant Title:
Research ID: N/A

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

If continuing review approval is not granted before the expiration date of 12/16/2013, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

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

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

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 12/17/2012 04:52:42 PM EST

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