Understanding Visual Interfaces for the Next Generation of Dance-Based Rhythm Video Games

Emiko Charbonneau[*] Andrew Miller[†] Chadwick Wingrave[‡] Joseph J. LaViola Jr.[§]
University of Central Florida

Abstract

We present an experimental study exploring how to best guide users when playing RealDance, a next generation dancing game prototype. It uses four Nintendo Wii remotes, attached to the wrists and ankles, to create a 3D spatial interface utilizing the entire body to more closely mimic real dancing. Since RealDance requires a player to use both arms and legs, the player needs 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. To understand the best way to present this information, we implemented three visual interface methods: Timeline, Motion Lines, and Beat Circles, that are based on existing rhythm video games but extended to support RealDance's 3D interaction requirements.

Our study explores each visual interface's effectiveness in conveying dance sequence information and assisting the player in providing a rewarding experience. Our evaluation is based on points scored in the game, and post-questionnaires used to solicit reactions about each visual interface including which was preferred and why. The results of the study show that players had significantly higher scores when using Motion Lines and Beat Circles than with the Timeline. The results also indicate that players found Motion Lines and Beat Circles significantly easier to follow than Timeline and icon position significantly less confusing than the Timeline interface. From these results, we believe that Motion Lines and Beat Circles are more appropriate visual interfaces than the traditional Timeline interface for full body, rhythm dance games.

CR Categories: K.8.0 [Personal Computing]: General—Games; H.5.2 [Information Interfaces and Presentation]: User Interfaces—Evaluation/methodology

Keywords: dance-based rhythm games, dance gaming, 3D spatial interaction, visual interfaces, user evaluation, games

1 Introduction

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 and in rhythm. 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. This is likely attributable to the novelty of increased physical exertion in the case of *Dance Dance Revolution* (DDR) and a greater sense of making music in the case of band games such as *Guitar Hero* and *Rock Band*.

[*]e-mail: miko@eecs.ucf.edu
[†]e-mail:amiller@eecs.ucf.edu
[‡]e-mail:cwingrav@eecs.ucf.edu
[§]e-mail:jjl@eecs.ucf.edu

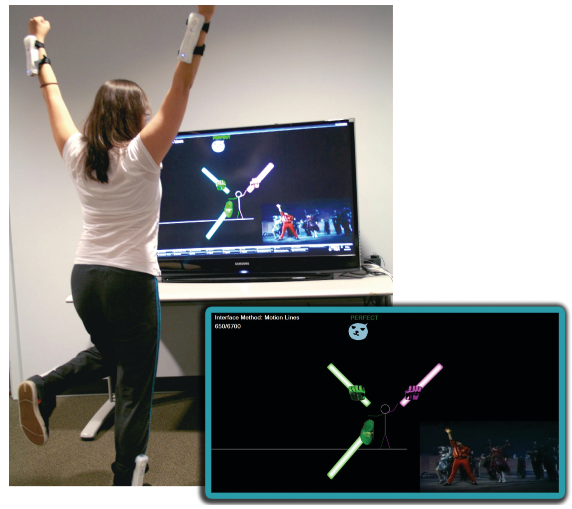

Figure 1: *The RealDance system in action. The Motion Lines interface is pictured.*

The advent of the Nintendo Wii remote (Wiimote) has brought 3D spatial interfaces [Bowman et al. 2004] to the consumer market and the forefront of gaming [LaViola 2008]. However, only a few rhythm music games have made effective use of 3D spatial interaction. For example, DDR 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 then pressing a button.

We postulate that taking advantage of the Wiimote's potential for full body gestures, differentiating between body parts and more refined detection of limb pose, direction and acceleration will lead to a new generation of dance-based rhythm gaming. To explore how to move dance-based rhythm games to the next level, we have developed RealDance [Charbonneau et al. 2009], a dancing game prototype that uses four Wiimotes, attached to the wrists and ankles (see Figure 1). Since RealDance requires a player to use both arms and legs, the player needs 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 is important not only to detect these full body gestures, but to also understand how to best convey the visual cues needed during gameplay. These visual interfaces will have to evolve to adapt to the nuances and greater information requirements of these games, while at the same time remaining easy and fun.

In this paper, we present a formal user study comparing three different visual interfaces, Timeline, Motion Lines, and Beat Circles for playing RealDance. Section 2 examines work related to full body motion games and surveys the visual interfaces used in rhythm-based games. Section 3 introduces the RealDance prototype. Section 4 discusses the three visual interfaces we developed for RealDance, based on a review of existing rhythm-based games. Sections 5 and 6 present the user study and results while Sections 7 and 8 discuss future work and conclusions.

2 Related Work

2.1 Brief Rhythm Gaming Survey

Seventy-six rhythm-based video games from the last decade were surveyed to identify trends and categories of interface design. Early on, icons streaming across the screen in a timeline fashion were used to indicate the time of a joystick tilt or a button press. This interface made up 61% of the surveyed games with little variation among them, including *Rock Band*, *Guitar Hero*, and *Dance Dance Revolution*. A similar interface style, which accounted for an additional 18% of the games, arranged the icons radially around the screen. In this interface, icons often emerge from the middle of the screen and project out in eight directions, splitting the player's focus to multiple screen positions for increased difficulty. Gameplay sometimes involves an analog thumb stick. Notable examples in this category are *Gitaroo Man* and *EyeToy: Groove*.

The latest generation of gaming devices has introduced new interaction. While some games continue the icon scrolling interfaces, a new form of rhythm gameplay evolved incorporating the absolute positioning of the Nintendo DS touch screen. In the Japanese game *Osu! Tatakae! Ouendan*, players must tap circles in the correct order and in the correct rhythm, as well as trace lines on the screen. This was well received and allowed iNIS to create the sequels *Elite Beat Agents* and *Ouendan 2*. However, only three other games were found to use a similar interface since its release in 2005. In total, these games account for 5% of the surveyed games.

Tracing lines has been used in other control schemes as well. In *We Cheer*, the player holds a Wiimote in each hand, similar to pompoms. Using color to differentiate left and 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 in three dimensions and presents a clear distinction between large and small movements. This interface also has few descendants: a Nintendo DS game (*Princess Debut*) and an upcoming pop star game for the Nintendo Wii, making their contribution account for 4%.

The remaining 12% of the games are not relevant to full body gaming. This includes the Simon gameplay found in *Space Channel 5* and some *WarioWare, Inc* minigames. In these cases, the player watches the game perform several actions and then must mimic them successfully. Another game, *Unison*, expects the player to determine from the on-screen avatar's movements how to shift the controller's joystick. These interfaces are not explored in this work.

2.2 Rhythm Game Components

The ability to track the body has enabled many related applications in non-games and preceded the development of the Wiimote. Motion capture, or mocap, [Moeslund and Granum 2001] 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 [Chua et al. 2003] and Martial Arts [Hämäläinen et al. 2005]. The Body Music system [Khoo et al. 2008] 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 Sensemble system [Aylward and Paradiso 2006] is used to track dance movements using accelerometers and gyroscopes attached to the ankles and wrists.

Labanotation has become the most standardly used iconic representation and of dance movements. However with many different shapes, positions, coloring methods, and staffs for placement, Labanotation literacy entails a large learning curve [Bureau 2007], since it was created for choreography and archival purposes, stressing precision and accuracy over readability.

The study of rhythm games in academics has received little attention until recently. One survey compared music game peripheral controllers [Blaine 2004]. Another conducted an international survey of the *Dance Dance Revoluton* community using an online questionnaire which included questions related to physical motivations, social structure, and priorities in game experience [Hoysniemi 2006]. Other academic research has investigated the heuristics of game design [Desurvire et al. 2004]. One promising approach to understanding rhythm gaming is the GameFlow model [Sweetser and Wyeth 2005], which investigates enjoyment in gameplay. To the best of our knowledge, our study is one of the first to explore different methods of expressing visual information in rhythm games.

3 The RealDance System

RealDance seeks to push the limits of the Wiimote hardware and to produce a full-body dancing experience. The goal is for players to feel like they are dancing naturally and improving their performance. Using readily available commodity hardware they receive feedback directly tied to how well they complete each movement. RealDance does not rely on button pressing, a staple of video game controls which contradicts the feeling of dancing. The player is not spatially tethered to a specific location either. Movements which are recognizable as gestures are scored for acting within a certain time window, closer to a realistic dancing experience.

Four Wiimotes, attached to the user's wrists and ankles, supply the data for RealDance. 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 is implemented in C#, using the Bespoke XNA 3DUI Framework [Varcholik 2009] in a Windows environment.

3.1 Gesture Scoring

The gesture scoring in RealDance has three major concerns. First, a range of movements needs to be detectable to match the variety in dance. Second, these movements need to be reliably distinguished from one another. Third, "cheating" needs to be eliminated. In 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 limits the fun and fitness of the gameplay.

For each gesture in the choreography, we consider an interval T based on the expected duration of the movement. This segmentation is completely independent of the input. Each gesture in the choreography is scored independently, so spurious motions in between expected gestures are not penalized. The only inputs to the system are the acceleration vectors $\mathbf{A}$ from the Wiimotes. We will 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.

3.1.1 Impulse motions

An impulse motion, such as a punch, is 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 score 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 select 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,

$$t_k = \arg\max_T -\mathbf{A}_{t,y}. \tag{1}$$

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

$$S_T = 1 - |t_k - t_0|\,. \tag{2}$$

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

3.1.2 Impact motions

An impact motion, such as a stomp, is distinguished from an impulse motion by the presence of a sudden shock when two surfaces collide. This produces an easily identifiable change in acceleration values (jerk) over all three dimensions.

In order to score an impact motion for one Wiimote, we first compute the change in acceleration vectors for each pair of adjacent time samples. We then select the time sample t_k corresponding to the largest magnitude of jerk,

$$t_k = \arg\max_T |\mathbf{A}_t - \mathbf{A}_{t-1}|. \tag{3}$$

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

4 Visual Information

The visual interface presents the dance sequence the player is expected to perform. This includes 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.

4.1 Common Screen Elements

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

The informative screen elements were kept constant as much as possible. The icons used to indicate the body part(s) to move are similar across all three visual interfaces (see Figure 2). Hands and feet icons are 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 performs the dance sequence along with the player. Almost all dance-based rhythm games have characters moving in the background during gameplay. In some games, such as *Dance Dance Revolution*, this is purely aesthetic with little bearing on the step pattern. In games such as *Unison* and *We Cheer*, the character itself guides the player.

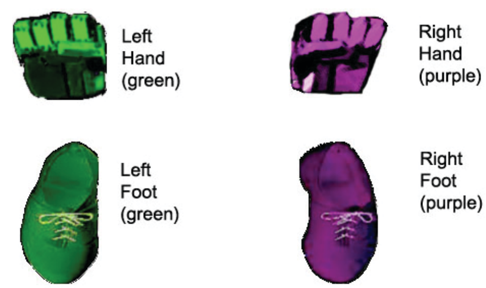

Figure 2: *Icons representing each limb.*

4.2 Timeline

The Timeline interface, as shown in Figure 3 (left), is inspired by games like *Dance Dance Revolution* and *All Star Cheer Squad*. The player knows which limb to move by the icon, where to move them by directional arrows and when to move them by their streaming 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 tiny 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.

4.3 Motion Lines

The Motion Lines interface, as shown in Figure 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.

4.4 Beat Circles

The Beat Circles interface, as shown in Figure 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.

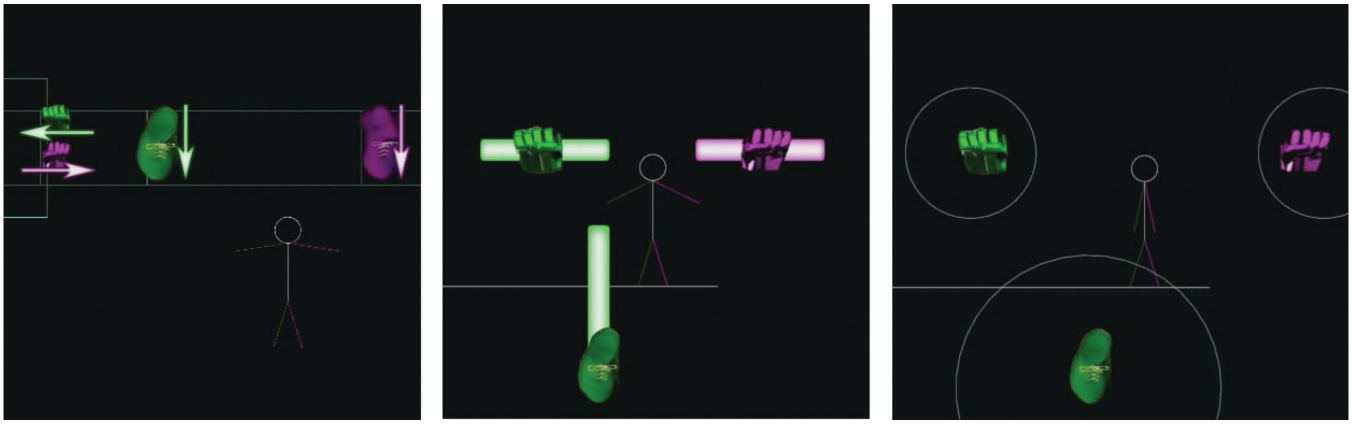

Figure 3: *The three interfaces displaying the same moves. Left: Timeline. Middle: Motion Lines. Right: Beat Circles.*

5 Usability Study

We conducted a user 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 hypothesize 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.

5.1 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.

5.2 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 Ghostbusters^{TM} theme song was used because of its slow, catchy tempo. For the actual experimental task, we chose Thriller^{TM} 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 participants had to perform (see Table 1).

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)

Table 1: *The individual moves in the dance game*

5.3 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. Details on the scoring mechanism can be found in Section 3.1. 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 Table 2).

The experiment began when participants entered the enclosed space. Participants were given a standard 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 2) which appeared in all three interfaces: the four icons designating body parts, the cartoon face avatar, and the stick figure. Once

	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 2: *Post-Technique Questionnaire and Post-Questionnaire*

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.

6 Results

6.1 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 counter-balancing was sufficient for removing any order bias.

	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)

Table 3: *Mean scores broken into move type for each visual interface. Standard deviations are in parentheses.*

6.2 Overall Score Analysis

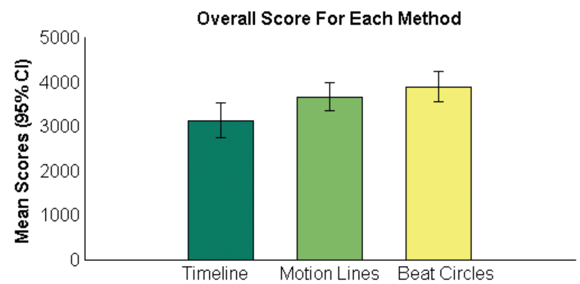

Figure 4: *Overall Score Means*

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 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 [Holm 1979] 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 Lines and Beat Circles ($t_{23} = -1.20, p = 0.243$). This result implies 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.

6.3 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 are 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 shows the means and standard deviations of each move type for each visual interface.

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

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

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 [Holm 1979] 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 provide an interface to RealDance that makes it easier to understand the required dance movements over the traditional Timeline interface.

6.4 Questionnaire Analysis

6.4.1 Post-Technique Results

For each post-technique questionnaire, participants were asked to respond to 12 statements (See Table 2) 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 [Holm 1979] was used at $\alpha = 0.05$ to control for the chance of Type-I errors. Three out of the 12 statements were found to be significant (see Figure 6) and are discussed below.

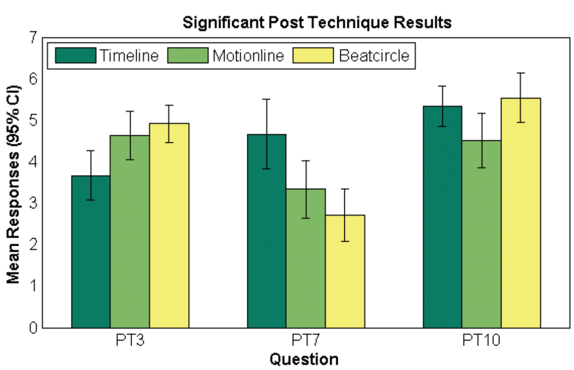

Figure 5: *Post-technique questionnaire results.*

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 correlate with the score data to support that users found it easier with a mirror-like interface that utilizes spatial information.

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

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 2 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 its 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 where 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 which 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.

6.4.2 Post-Questionnaire Results

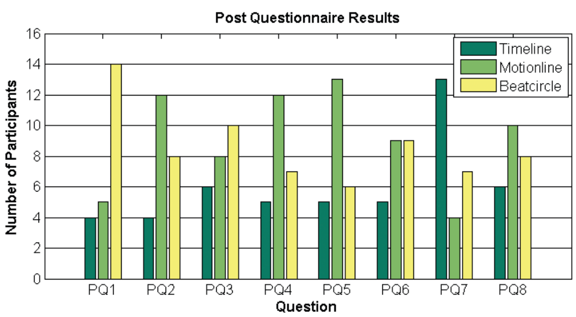

Figure 6: *Post experiment questionnaire results.*

After the experiment, participants were asked to choose one of the three visual interfaces in response to a set of eight questions (see Figure 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 6 shows an interesting trend in that, 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 corroborate 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.

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).”

7 Discussion and Future Work

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 is 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 note that the hands and feet could appear on different lines to address this and that 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 and see if a combination could be best.

Many paths remain open to investigation in the future. Understanding which screen elements command visual attention can be used to improve gameplay. This is especially true regarding the stick figure. Another issue worth studying in more detail is preparation time. The time prior to execution was chosen by instinct as we developed the prototype, but a formal user study would give insight into what time would give the best performance and usability results.

We also plan on using the results of this experiment to design an improved visual interface for the RealDance system. With a better interface, we will be able to create more distinct movements and continue towards the goal of making the game capable of teaching dance. RealDance will also need to be adjusted to allow for more precise scoring. Several of the user suggestions are worth exploration as well, such as changing the color of the icons after execution and audio or tactile feedback.

8 Conclusion

Sight reading rhythm games are a successful genre of video games, and most of them use the Timeline interface well. However, now that all current consoles are exploring 3D user interfaces, a full body dance game is finally possible. This will require a visual interface to tell which body part(s) to move, where to move them and at what time.

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 Timeline 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.

9 Acknowledgements

This work was partially supported by IARPA, SAIC, and NSF (IIP0750551). Additionally, the authors wish to thank Charles Hughes and the anonymous reviewers for valuable feedback.

References

AYLWARD, R., AND PARADISO, J. A. 2006. Sensemble: a wireless, compact, multi-user sensor system for interactive dance. In *NIME '06: Proceedings of the 2006 conference on New interfaces for musical expression*, IRCAM — Centre Pompidou, Paris, France, France, 134–139.

BLAINE, T. 2004. The convergence of alternate controllers and musical interfaces in interactive entertainment. In *NIME '05: Proceedings of the 2005 conference on New interfaces for musical expression*, National University of Singapore, Singapore, Singapore, 27–33.

BOWMAN, D. A., KRUIJFF, E., LAVIOLA JR., J. J., AND POUPYREV, I. 2004. *3D User Interfaces: Theory and Practice*. Addison-Wesley, Boston.

BUREAU, D. N., 2007. Labanotation, September. http://www.dancenotation.org/DNB/index.html.

CHARBONNEAU, E., MILLER, A., WINGRAVE, C. A., AND LAVIOLA, J. J. 2009. Poster: Realdance: An exploration of 3d spatial interfaces for dancing games. IEEE Computer Society, Los Alamitos, CA, USA, vol. 0, 141–142.

CHUA, P. T., CRIVELLA, R., DALY, B., HU, N., SCHAAF, R., VENTURA, D., CAMILL, T., HODGINS, J., AND PAUSCH, R. 2003. Training for physical tasks in virtual environments: Tai chi. In *VR '03: Proceedings of the IEEE Virtual Reality 2003*, IEEE Computer Society, Washington, DC, USA, 87.

DESURVIRE, H., CAPLAN, M., AND TOTH, J. A. 2004. Using heuristics to evaluate the playability of games. In *CHI '04: CHI '04 extended abstracts on Human factors in computing systems*, ACM, New York, NY, USA, 1509–1512.

HÄMÄLÄINEN, P., ILMONEN, T., HÖYSNIEMI, J., LINDHOLM, M., AND NYKÄNEN, A. 2005. Martial arts in artificial reality. In *CHI '05: Proceedings of the SIGCHI conference on Human factors in computing systems*, ACM, New York, NY, USA, 781–790.

HOLM, S. 1979. A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics 6*, 2, 65–70.

HOYSNIEMI, J. 2006. International survey on the dance dance revolution game. *Comput. Entertain. 4*, 2, 8.

KHOO, E. T., MERRITT, T., FEI, V. L., LIU, W., RAHAMAN, H., PRASAD, J., AND MARSH, T. 2008. Body music: physical exploration of music theory. In *Sandbox '08: Proceedings of the 2008 ACM SIGGRAPH symposium on Video games*, ACM, New York, NY, USA, 35–42.

LAVIOLA, J. 2008. Bringing vr and spatial 3d interaction to the masses through video games. *IEEE Computer Graphics and Applications 28*, 5, 10–15.

MOESLUND, T. B., AND GRANUM, E. 2001. A survey of computer vision-based human motion capture. *Comput. Vis. Image Underst. 81*, 3, 231–268.

SWEETSER, P., AND WYETH, P. 2005. Gameflow: a model for evaluating player enjoyment in games. *Comput. Entertain. 3*, 3, 3–3.

VARCHOLIK, P. 2009. The bespoke 3dui xna framework: A low-cost platform for prototyping 3d spatial interfaces in video games. In *Sandbox 2009: ACM SIGGRAPH Video Game Proceedings*.

Games Cited

1. *All Star Cheer Squad.* THQ (Wii, DS), 2008.
2. *Dance Dance Revolution.* Konami (Arcade), 1999.
3. *Dance Dance Revolution Hottest Party.* Konami (Wii), 2007.
4. *Elite Beat Agents.* Nintendo (DS), 2006.
5. *EyeToy: Groove.* SCE (Playstation 2), 2004.
6. *Gitaroo Man.* Koei (Playstation 2), 2002.
7. *Guitar Hero.* Activision (Playstation), 2005.
8. *Osu! Tatakae! Ouendan.* Nintendo (DS), 2005.
9. *Ouendan 2.* Nintendo (DS), 2007.
10. *Princess Debut.* Natsume (DS), 2008.
11. *Rock Band.* Harmonix Music Systems (Playstation), 2007.
12. *Space Channel 5.* Sega (Dreamcast), 2000.
13. *Unison.* Tecmo (Playstation 2), 2001.
14. *WarioWare, Inc.: Mega Microgame$.* Nintendo (GBA), 2003.
15. *We Cheer.* Namco Bandai (Wii), 2008.