Dancing in the Streets: The design and evaluation of a wearable health game

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Abstract

Obesity is a worldwide epidemic, with childhood obesity currently ranking as one of the biggest health challenges facing the United States today. In this project we introduce a mobile and wearable health video game, Dancing in the Streets (DITS). DITS uses two wireless, 3-axis accelerometers as input to a social, mobile, phone-based dancing game played by groups of collocated users. DITS was evaluated by 50 American high school students from two different inner-city public high schools. Each student was trained how to use the system and had the opportunity to play through two different songs. We collected usability and demographic data from the participants. In this paper, we present the design of the system and the results of our evaluation.

1 Introduction

The World Health Organization has declared that obesity has become a global epidemic with over than 1 billion overweight adults–at least 300 million of whom are considered clinically obese. Globally, childhood obesity is already an epidemic in some areas. For example, more than 23 million U.S. children and adolescents–nearly one in three young people–are either overweight or obese [7]. Social and environmental changes over the past few decades have resulted in less physical activity as children are spending more sedentary time using electronic media, such as television, computer games, and the Internet [2].

One approach to addressing this epidemic is to encourage physical activity through the use of technology. There are numerous projects in research and industry that have explored the design of technology to support fitness and physical activity [1, 4, 5, 6]. While fitness games are not novel, Dancing in the Streets (DITS) is one of the first to support collaborative play that does not require the use of fixed infrastructure limiting where and how the game is played.

Specifically targeting childhood obesity, we designed, deployed and evaluated a mobile and wearable health video game: Dancing in the Streets. Over the course of two days at two different inner city high schools, 50 teenagers were introduced to DITS with very positive results. In this paper, we introduce the Dancing in the Streets game, describe the technological system, explore the successes and failures of the game in our user evaluation, describe the results of the evaluation, and conclude with suggestions for how to improve the wearable gaming experience.

2 Dancing in the Streets: A Mobile and Wearable Health Video Game

Dancing in the Streets (DITS) is a mobile phone version of the popular arcade game *Dance, Dance, Revolution*™(DDR). When it launched in 1998, DDR pioneered a new genre of rhythm and dance video games. The gameplay of Dance Dance Revolution involves a user moving his or her feet in a set pattern, stepping in time to the general rhythm or beat of a song. Each step is recorded by a dance pad that is built into the machine. The dance pad has four arrows that point in cardinal directions. Each arrow has a pressure sensor underneath it which enables the game to translate the users' movement into input for the game.

DITS is based on this general premise but instead of using a dance pad, DITS uses wireless 3-axis accelerometers that are worn around the players' ankles. DITS uses a mobile phone instead of a console system to control the game and to display graphics. It is worth noting that though there has been research in the use of a dance pad to control desktop interfaces [3], we are unaware of research into replacing a dance pad with wearable sensors which we consider to be one of the contributions of our work.

The prototype DITS system is comprised of a mobile phone (an Openmoko Neo FreeRunner) that is connected over Bluetooth to two 3-axis accelerometers of our own manufacture (see Figure 1(b)). The game can be played using headphones or relying on the speakers built into the phone.

To play the game, a user straps a sensor onto each ankle

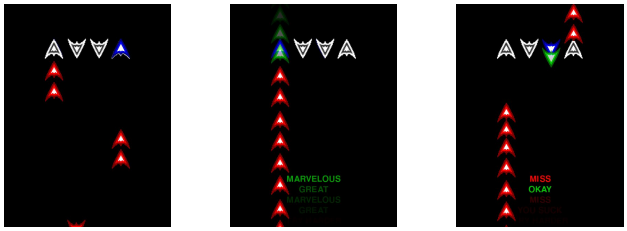
(a) (b)

Figure 1. Two individuals training DITS to recognize the "right foot forwards" pose while wearing the wearable sensors 1(b).

and launches the game from the home screen of the phone. On startup, the user is asked to train the sensors to recognize her movements. To do this, the user is taken through a series of screens that prompt her to assume specific postures and then to touch the screen. A progress bar indicates to the user that the system is learning the user's posture and mapping it onto game controls. During this time, the system collects samples and takes the mean of the samples to create the canonical vector which will represent the specific posture. Given that the user is relatively motionless in each pose (hence learning a pose and not an action), the values in the vectors are the effect of gravity on that particular axis. As the game is played, the average of the values in a windowed sample is compared using Euclidean distance to each canonical vector generated. The closest is chosen as the user's current posture.

DITS requires the player to train five postures: standing still; left foot forwards; left foot backwards; right foot forwards; and right foot backwards (see Figure 1(a) for an example of training right foot forwards). The postures are mapped onto interface elements seen in Figure 2. Left foot forwards is mapped onto the furthest left arrow, left foot backwards is mapped to the second arrow from the left, right foot backwards is mapped onto the third arrow from the left and right foot forwards maps to the rightmost arrow.

Once the user has successfully trained the system to recognize her movements, she is prompted to select a song. The songs are presented on the screen in order of difficulty from easiest to the hardest. Having selected a song, the user now begins playing the game. The gameplay begins as soon as the music starts playing. Red arrows progress up the screen, animating from the bottom to the top. There are four target arrows at the top of the screen (see Figure 2(a)). The object of the game is for the user to hold her foot in the right pose at the moment that a red arrow crosses through a target arrow. The game is designed so that this event occurs in time to the beat of the music. When the user assumes a posture, the corresponding target arrow turns blue (see Figure 2(a)). If the user successfully holds her foot so that the target is illuminated at the same time that the red arrow goes through it, the red arrow turns green and the game registers a hit (see Figure 2(b)). Each time the user fails to do this, the game registers a miss (see Figure 2(c)). Hits are rewarded with the display of encouraging words on the screen in green text while misses result in the display of discouraging words in red text. Hitting or missing targets in succession prompts the text displayed to the user to either become progressively more positive or more negative. For example, in Figure 2(b) the user has successfully hit the target several times in a row resulting in the text displaying the words "okay," then "great," and finally "marvelous."



(a) (b) (c)

Figure 2. Screenshots of DITS.

The goal of the game is to record as many hits as possible while avoiding misses. At the end of the game, the score is displayed to the user revealing the total number of hits and misses registered for that song.

3 Evaluation

In the fall of 2009, we conducted an evaluation of DITS at two inner city public high schools. Our evaluation contained three phases: training the users, gameplay, and a follow-up questionnaire. In the training phase of the evaluation, two researchers introduced DITS to a group of approximately 10 students who were preselected to participate in the DITS evaluation by their teachers. We asked that the students come from a range of financial backgrounds and have varying degrees of physical fitness. We trusted the teachers to select the students and to have them ready to participate when we arrived at the school.

To begin the first phase of the evaluation we collected permission slips from each student that documented parental assent granting the research team permission to interact with the students participating in the study. We then asked the students to complete a demographics questionnaire while the researchers readied the systems for use. Next the students were shown a short video that communicated how the system works and the object of the game. Following the video the researchers demonstrated the system to

the students and answered any and all questions. The training phase of the evaluation took approximately ten minutes.

In the gameplay phase of the evaluation, students either volunteered or were selected to use the system in groups of four. The students each trained the game to recognize the postures that they wanted to use to play the game, and then selected one of the four available songs. Each student played the game twice and danced to different songs each time. Once a student had completed both songs, they were asked to remove the sensors from their legs and return the DITS system to the researchers. The gameplay phase of the evaluation took approximately ten minutes per group.

When all students had successfully completed the gameplay phase of the evaluation, they were then presented with a questionnaire designed to gather feedback on the system. The questionnaire was composed of a combination of Likert scale and short response questions. Upon completion of the final phase of the evaluation, each student was paid $20 for their participation and the evaluation was concluded.

4 Results

We collected data from 50 participants (11 from School 1 and 39 from School 2). Demographic data for our participants is presented in Table 1.

			Average		
School	Students	Males	Age	Height	Weight
School 1	11	6	16	1.65 m	68.9 kg
School 2	39	22	17	1.70 m	71.7 kg
Total	**50**	**28**	**17**	**1.68 m**	**69.9 kg**

Table 1. Demographic data.

4.1 Overall Experience and Impressions

In general, we received an overwhelmingly positive response to DITS. When asked their opinion of their overall DITS experience, 49 of the 50 participants were either "Somewhat Satisfied" or "Satisfied" with "the overall experience of playing the DITS game." The same results were seen as 49 of 50 participants were "somewhat satisfied" or "very satisfied" with the training they received and all but one of the students had "neutral" feelings or were some degree of "satisfied" after dancing through their first song. Additionally, every student agreed that it was "easy for me to learn how to play the game."

When asked to elaborate on their initial impressions of playing the game, the feedback was again very positive. For example, one student wrote, "It was awkward at first but as you start to play it was fun and challenging. After a while you forget all about everyone else and focus on the game. Overall it was really fun." Another student wrote, "It was very fun and exciting. It was a way for me to workout with just moving my feet." A third student wrote, "It was kind of unusual to play this game. It was a very appealing game to play. I am not used to play video games so I cannot compare it with other games. I really liked it though. It would be a very exciting and fascinating game for kids as well as adults." And finally, a fourth student wrote, "Playing the game was very fun and exciting. While playing the game I was never bored or wanted to stop. The game was very intense and non-frustrating." Mixed in with the praise we received suggestions for improvements but when asked to "tell us what it was like to play the game" sentiments were universally positive. Opinions were not always this positive for all aspects of DITS. Participants had particularly mixed opinions when it came to technical aspects of the game, especially the use of the sensors.

4.2 The Sensors

We asked for feedback on two specific aspects of the sensors: students' physical interaction with the devices and the sensor performance. The students overwhelmingly found the sensors "easy to attach" (49 of 50 either agree or strongly agree), "light weight" (50 of 50 agree or strongly agree), and "easy to remove" (again 49 of 50 either agree or strongly agree). However, opinions were not as positive when it came to the performance of the sensors. Twelve percent of the students either disagreed or strongly disagreed with the sentiment that the sensors responded correctly on the screen to each of their movements, while 10% reported sensors that did not successfully recognize a kick.

In addition to collecting data on the participants' reaction to the sensors, we also solicited opinions on how we can "... improve the sensors to make the game more fun or easier to play." Several students had trouble training the sensors which gave them the impression that the sensors were either broken or in need of tuning. The importance of training the sensors was not always understood by the users as evidenced by the following quote: "Make the sensors a little more sensitive. Because at times I was kicking hard and it didn't recognize it." Depending on the particular problem experienced by the user, we received feedback that the sensors were too sensitive, were not sensitive enough, were not responding, or were simply uncomfortable to wear. This feedback highlighted the need to better train players on how to use the sensors prior to starting the gameplay.

4.3 Is DITS a game or a workout?

Participants were pretty evenly split on whether the current incarnation of the game made them work hard when playing. All of the participants were interested in expe-

riencing more difficult levels of the game (which has the potential to increase the amount of time a user spends interacting with the system) with the majority of the participants claiming that they "got a good workout" when playing the game. However, playing through only two songs probably did not generate enough activity for our participants to actually receive a healthy workout. When asked how long they would be interested in playing DITS, fifteen participants indicated between 20 and 30 minutes, nineteen indicated 30 minutes to an hour, and nine participants suggested times of greater than an hour. Only eight students indicated that they would only want to play DITS for less than 20 minutes. Ten to twenty minutes of usage could be upwards of six or seven songs depending on the length of the song. With approximately half of the participants breaking a sweat (26) and feeling winded by the end of the game (25) after playing through just two songs, it is conceivable that twenty minutes of usage could constitute a substantial workout for many of our participants. Though the majority of the students did not report that their "muscles felt sore," we do not have any follow-up data to investigate if they were sore the next day. In the future we plan to collect quantitative physiological measures of work (heart-rate, calorie count, etc.) as well as conduct follow-up interviews to better explore the physical benefits of DITS.

4.3.1 Feedback on the social appropriateness of DITS

One potential way to encourage users to play DITS is to encourage the social acceptance or popularity of the game. When asked if they would "enjoy playing this game with others at the same time," all of the participants either "agreed" (11) or "strongly agreed" (39) that they would. Forty seven (47) of the participants indicated that they would "enjoy a multiplayer version of the game." All but five of the participants indicated that they would be "interested in a DITS competition."

5 Conclusion

In this paper we introduced the design and evaluation of a wearable health video game, Dancing in the Streets (DITS). DITS was evaluated with 50 high school students' from two different inner-city public high schools. Each student was trained how to use the system and had the opportunity to play through two different songs. We collected usability and demographic data from the participants, analyzed the data, and presented the results in this paper.

The system received positive reviews from almost every user. While we are excited about the students' reaction to DITS, the evaluation uncovered several usability challenges including the importance of properly training the participants to use the sensors prior to starting the game and the importance of introducing competitive modes that encourage groups of users to continue to use the game. Future work includes iterating on the game design to add collaborative and workout tracking features as well as the collection of quantitative measures such as heart rate and calorie count metrics. Refinements to the gameplay have the potential to improve the user experience as well as to increase the chances of creating a game that not only is fun to play but also encourages children and teenagers to start exercising more and improving their physical fitness by playing Dancing in the Streets.

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