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Exploration Games played on a DDR Pad can Constitute Beneficial Physical Exercise

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***Abstract*— The addition of an exercise component to computer games is a method that attempts to increase exercise compliance among the population. Various attempts at such games have been made, both commercially and as research projects, but the set of studied game mechanics that are both entertaining and provide beneficial exercise are relatively small. In our work, a game mechanic was designed for a floor-based input controller (DDR Pad). Rather than the standard mechanic usually employed for this device, our approach allows the player to explore a virtual world, requiring exertive movements on the input device in order to progress. The exercise is motivated implicitly through the game goals and a mechanism exists to control the pace of the game by monitoring the player's heart rate. In our trials, we have found that the game is engaging for the participants. The game also provides a beneficial level of exercise, with the player's heart rate, on average, rising to a level that constitutes moderate exercise after three minutes and forty seconds, and increasing from thereon.**

Keywords - exergaming; game design, exercise, DDR

I. Introduction

Physical activity has many health benefits, with exercise being one of the essential components of good health [1]. Regular exercise has been shown to prevent a range of diseases, including cancer, diabetes, and osteoporosis [2]. The ACSM recommends exercise at intensity of 55% or greater of a person's maximal heart rate in bouts of minimum 10 minutes [3]. Despite this, many people do not undertake an adequate amount of physical exercise, with lack of time and motivation being the dominant barriers reported [4] [5].

One avenue to change people's behavior and include more physical exercise in their daily life is to add an exercise component to something that they already routinely undertake. This, in theory, can counteract both the time and motivation barriers to undertaking exercise. One area where this is being explored is the addition of exercise to computer and video games, with the resulting product commonly called an exergame. Exergaming is an area of interest for promoting physical exercise due to the current popularity of computer games. For example, in the USA 72% of the households play video games [6].

Research has shown that exergaming can be compelling and beneficial for players. For example, Warbuton et al. [7] compared interactive video games combined with the use of an exercise bike versus the exercise bike alone, finding greater adherence and health benefits for the combination of game and exercise. However, the suitability of an exergame as exercise depends on its design. For example, video game consoles, such as the Nintendo Wii, and Microsoft Xbox 360 with the Kinect input controller, enable player input through gestures and physical movement of large muscle groups. Many games for these platforms are however tuned more towards entertainment than exercise. In a study of a game, Wii Sports, Graves et al. [8] found that, although players use more energy than when playing a traditional game not requiring exercise, the intensity of the exercise fell below recommended levels.

In this paper, we focus on the use of the floor-based dance pad (commonly called a DDR pad, after the game Dance Dance Revolution) to build a game that is both fun and an effective form of exercise. Typically, games built for the DDR pad platform implement a mechanic of having the player press certain switches on the pad in a specific sequence and time, as explicitly dictated by prompts within the game. These kinds of games are known as rhythm games. Whilst this makes it easier to control the amount of exercise provided (less allowed time between switch presses forces the player to move faster) the gameplay can become repetitive. The novelty in our approach is that our game involves exploration of a world and collecting items. As this does not provide explicit guidance to how hard the player should be exercising, the mapping of the game to the DDR pad needs to be carefully devised so as to implicitly motivate the player to move at a pace that will give them a required amount of exercise.

The rest of this paper is organized as follows: Section II gives an overview of the DDR pad as an exercise device. Section III reviews design guidelines for exergames in general, followed by Section IV which details the design of our game. In Section V we give a description of our experiment and present results from the small trial of the game in Section VI, followed by discussion and conclusion in Section VII.

II. Previous Work

The game Dance Dance Revolution, widely known by its acronym, DDR, was released in 1998. The game used an input device, known as a dance pad, through which the player interacts with the game. Several dance pads with a similar layout have been produced, an example of a pad produced by Cobalt Flux (as used in our work) is shown in Figure 1. The dance pad consists of a square pad that rests on the floor and which the player stands on. The pad is divided into several square areas that the player activates (usually with the feet), each area has a printed symbol (typically an arrow). The DDR game shows a series of 'dance steps' – in time to music, with each step represented using the symbols on the DDR pad. The aim of the game is to activate the areas on the pad in the right sequence at the right time. Since the original DDR game, a number of similar games have been produced using the same rhythm game concept of following 'dance steps'. Novel takes on the dance game mechanic include Sequence, a game from Iridium Studios [9] which ties the mechanic to a Role Playing Game, directing the player to follow sequences of steps to cast spells and fight in battles.

Several studies of the DDR pad with games that use rhythm game mechanics point to its potential as an effective form of exercise. Lanningham-Foster et al. [11] have reported from experiments with 25 children that playing the Dance Dance Revolution game increases energy expenditure on average by 172% above resting values, compared to a 138% increase when walking on a treadmill at 1.5 miles per hour. Comparing the exercise outcomes of the Dance Dance Revolution game with the guidelines for exercise set by the American College of Sports Medicine [12], Tan et al. [13] found the game met the minimum recommendation for intensity (at least 60% of maximum heart rate), but did not meet the recommendation for exercise duration.

There are a limited number of games that use the dance pad with non-rhythm game mechanics. The Winds of Orbis is an action-adventure game prototype played with a combination of DDR pad and Nintendo Wii input controllers [9], however no data has been reported to date as to its effectiveness as an exercise. The Nintendo Power Pad, a commercially unsuccessful predecessor of the DDR pad, had games with various types of mechanics, including simulating sporting events, like running, on the pad and using the buttons on the pad to choose appropriate actions for a game character. We have however been unable to find any evaluation of these games is the literature. One game that uses a DDR pad without rhythm game mechanics and has also been evaluated for exercise effectiveness is iAthlete [14]. The game featured a variety of athletics events, with a character running along a fixed path. To make the character progress along the path, the player alternated between pressing the left and right arrow buttons on the pad. Obstacles, like hurdles, were overcome by the player pressing the pad buttons in a specific sequence (but not at specific times), as shown on the screen. Evaluation on fifteen subjects found that the game met the ACSM guidelines for exercise intensity, constituting moderate to hard exercise.

Figure 1: A dance pad produced by Cobalt Flux. The pad rests on the floor and is divided into a number of areas (9 in the shown pad), each area acting as a switch.

III. EXERGAME DESIGN

Our aim was to produce a dance pad game that does not employ the rhythm game mechanic, but rather employs another well known game type where the player explores a virtual world and collect items. Through this game type the player has more control over the game and a greater choice of actions. We now examine the implications of this on providing both a compelling experience for the player and giving them an appropriate level of exercise.

The advantage of rhythm game mechanics, and even the mechanics found in iAthlete [14] where the character follows a fixed path, is that the game limits player choice to a minimum. This makes it easier to give the player a good gaming experience. Csikszentmihalyi [15] identified four characteristics of an activity that give the participant an optimal, compelling experience, called 'flow':

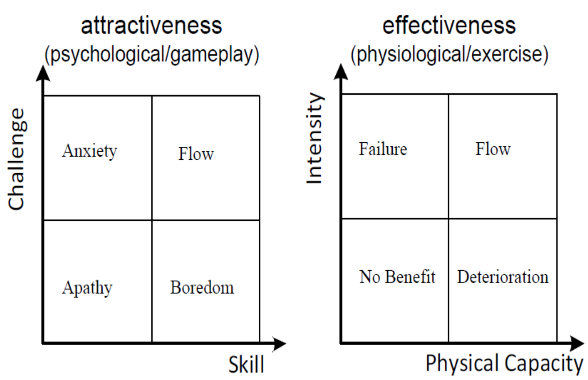
- Give a clear understanding of what the participant must do.
- Give immediate feedback for correct and incorrect actions.
- Allow the participant to focus.
- Match the challenge of the activity to the skill of the participant.

Rhythm games are quite clearly a good fit for the first three characteristics: the game tells the player which buttons to press and when, color and sound it typically used to indicate success and failure, and as following the rhythm is the only aim, allowing the player to focus. For a world exploration game, these characteristics are harder to implement as each section of the game world has to be designed with these in mind, so that no matter where the player is, they always have a clear sense of what the goal is, how to achieve it, and that they can gauge their progress.

The fourth characteristic, matching challenge to player skill, is non-trivial for any game, regardless of the gameplay mechanics. This is due to the player's skill level changing as they play. Csikszentmihalyi reported [15] that when challenge and skill are not matched, the activity induces in the participant either anxiety, if the challenge is too high, or boredom, if the challenge is too low. This relationship is shown in **Figure 2**(a). For games, several approaches can be used. A 'reasonable' difficulty level can be determined through playtesting and adjusting gameplay accordingly. Another option is to offer the player the choice of gameplay at various levels of difficulty. A third technique of keeping a player in flow is the dynamic adjustment of game difficulty in response to observations of how they are playing, although this must be done carefully [16] to select what aspects of the player are monitored and how they influence gameplay.

Exergames, in addition to making the player feel compelled to play by providing a good experience; also have the goal of providing an appropriate level of exercise. In response, Sinclair et al. [17] developed the 'dual flow model'. In this model, an exergame needs to maintain the flow of the player along two levels, psychological (termed attractiveness) which corresponds to Csikszentmihalyi's balance of challenge to skill, shown in **Figure 2**(a), and physiological (termed effectiveness), where the physical intensity of the game is matched to the physical capacity of the player, shown in **Figure 2**(b). If the intensity of the game is not suitable, the player will either receive no benefit from the exercise (if the intensity is too low), or will not be able to complete the exercise (if the intensity is too high). In addition, the attractiveness and effectiveness of an exergame interact. If the player is bored or frustrated, they will stop playing and also not receive the required amount of exercise.

Just as player skill increases with playing time, so the physical capacity of the player will increase over time in response to an appropriate level of exercise (although over a longer period). Thus, the appropriate setting and modification of intensity is important to keep a player in flow. A common method to measure the physical intensity of gameplay is to monitor the player's heart rate. If it is too high or too low, gameplay can be adjusted. For games played on a dance pad, effective ways of adjusting intensity include changing the speed at which the buttons on the pad are activated, and the sequence of button activations [14].



(a) (b)

Figure 2: The dual flow model combines Csikszentmihalyi's model of matching challenge to skill for an optimal psychological experience (a) with a model matching intensity of physical exertion to the physical capacity of a subject for an optimal exercise experience (b). (reproduced from [17])

Figure 3: A screenshot from Mr. Balloon. The player's character is shown in the centre, with a gingerbread man in front and to the left. The player has to be larger than the object to pick it up and also has to line the hand up with the basket (bottom left of the image) in order to gain more points. Player size is controlled by performing exercise on the DDR pad, and the hand and basket move in response to the actual and target heart rate respectively.

IV. GAME DESIGN FOR MR. BALOON

Developed for this project, Mr. Baloon is a 3D game played in 3rd person perspective where the player guided the central character so as to 'eat' objects that are present in the world. In order to eat an object, the character needs to be larger than it. To make the character larger, the player has to exercise. The game was made using the Unity 3D Game engine, interfaced to a DDR pad via a standard Windows Game Controller interface. Heart rate was acquired through a Polar wireless chest strap monitor, intended for exercise use. The heart rate monitor was interfaced to the game through a custom-built wireless receiver through the USB port. We now detail the game mechanics and world design for the game and explain how principles of achieving flow have been incorporated.

A. *Game Mechanics*

The central game mechanic is based on the size of the player's character in relation to 'challenge' objects in the game, and, to keep the player in flow in terms of exercise effectiveness, the player's heart rate in relation to a target. The player's character begins at an initial 'small' size, with exertive input required to increase the size of the character and maintain them at the larger size. In our implementation, this exertive input was chosen as the repetition of the left and right input buttons on the DDR pad. The speed at which the player cycled between pressings these switched controlled the size of the player's character.

Each challenge object (a gingerbread man) is of a fixed size. Challenges are completed in two parts – first the challenge object must be 'collected', second it must be 'placed' into a container. In order for the player to 'collect' the challenge object, the player's avatar must be larger than the challenge object when they collide. A screenshot showing player character and 'challenge' objects is shown in **Figure 3.** This motivates the player to use exertive input to increase the character size.

Success of the second step, 'placing' the object, is dependent on the player's heart rate (measured in our case using a chest strap) matching their target heart rate. In the game this is represented as a 2D overlay (shown in **Figure 3**, bottom left). In order for the object to be successfully placed, the hand must be lined up with the basket when the object is collected. Both hand and basket move. The hand is positioned on the x-axis of the screen as a function of the speed at which the player is activating the switches on the DDR pad. The faster the player taps the switches, the further to the right of the screen the hand moves. The basket moves in response to player heart rate. If the player is below their target, the basket moves to the right, requiring faster player input to line the hand up with the basket. If the player has exceeded their target heart rate, the basket moves to the left, forcing the player to slow their speed in order to place collected objects in the basket. The target heart rate was taken as a fraction of maximal. Maximal heart rate was computed using the common formula 220 – Age, as documented in the ACSM guidelines [3]. Age was input into the game by the player (also using the DDR pad) when a new game is started.

The generic game mechanics is to allow the player to explore the game world seeking 'challenges'. In order to limit the controls required for exploration (as the player is also focused on increasing the size of the character), the player is assigned a set forward speed. As an extra motivation to explore the world, this speed is adjusted up with the exercise speed (speed of tapping left and right arrow buttons). Direction of the character's motion is fully controlled by the player, allowing them to turn the player using the forward left and right diagonal arrow switches.

B. World Design

Whilst the exercise effectiveness balance of the dual flow model is maintained by monitoring the heart rate, the attractiveness, or ability to keep the player compelled to play, was established using a compelling world design with extensive feedback from playtesters, employing seven iterations of playtesting and game refinement in response to the playtests.

A clear goal is provided for the player through the construction of a clear path through the game world, with subsequent sections of the game blocked off until all challenges within the current section are completed. In initial play testing, the players found it hard to orient themselves. To help the player's sense of direction and guide them forwards, arrows were included as part of the texture on the terrain of the game world. In addition, challenge objects were positioned in such a manner so as to let the player see them from a distance, thus draw them to unexplored sections of the game.

The game world and characters are represented in 3D using the Unity 3D Game Engine. The world was designed as a series of sub-sections, constrained by 'cliffs' that the player cannot surpass. The world was designed and populated based on the premise that the player is new to the game. Thus, the first challenge is simple, and the challenge objects are smaller than the player. This gives the player an opportunity to focus on the navigation controls and learn about object collection. From this, the player moves to larger challenge objects and learns how to make their character larger. In keeping with the theory of flow, this progression was designed to match the challenge to player skill.

V. EXPERIMENT SETUP

Once the game was completed, seventeen subjects participated in an experiment, playing the game from start to finish. The subjects (16 males and 1 female) were aged between 20 and 47 years, with median age 24. Based on Body Mass Index, 53% of subjects were classified as normal weight, 23.5% classed as overweight, and 23.5% classed as moderately obese. The average daily active time for participants was less than 2 hours. Almost all the participants (except 1) indicated they want to increase the amount of exercise they undertake. The biggest reason for doing that was to improve health and get fitter, followed by the reasons of having fun and improving their appearance. More than 90% of the participants undertook some form of physical exercise at least once a week, and claim to have average health.

Success of the game was gauged on two dimensions, the effectiveness of the game as a form of physical exercise, and the attractiveness of the gameplay to keep the player motivated. To measure effectiveness, the subject's heart rate was recorded, and a post-game survey was used to determine their level of engagement with the game in terms of enjoyment, and perceived exercise benefits. Questions were directed at phenomena that have been related to flow, where Csikszentmihalyi [15] identified that a person in flow may experience:

- An altered sense of time
- A feeling of control
- Lowered self-awareness
- Focus and self-motivation on the task

The survey consisted of questions based around the symptoms of flow with answers on a 5 point Likert scale. Possible answers for each question were: 'strongly disagree', 'disagree', 'neither agree nor disagree', 'agree', or 'strongly agree'.

VI. RESULTS

In terms of game play, most of the participants (>80%) agree or strongly agree that they could use the interface spontaneously and automatically without thinking and knew clearly what they want to do and achieve. All of the participants were aware their performance in the game and 70% of them felt in total control of the game. Participants reported that they were not concerned with what others may have been thinking of their playing performance (82% agree or strongly agree). About 70% of the participants felt the game play time went fast, and more than 90% enjoyed playing experience.

In terms of game design, more than 90% agree the goals of the game are clearly defined and the feedbacks regards to the user's action was adequate and useful. More than 80% of the participants agree their action could contribute to the progression of the game and more than 70% of them feel totally immersed with the game play. The user interface was easy to use (86% agree or strongly agree).

In terms of the exercise effectiveness of the game, the average session time was 11 minutes and 50 seconds, meeting the ACSM minimum recommended exercise bout (at least 10 minutes). More than 90% of subjects agree the game made them work hard and leads to a great work out, 51% were feeling exhausted after the game play. These perceptions were confirmed in the analysis of heart rate response. The heart rate response was calculated as a percentage of the maximal heart rate that was reached (using the formula 220-age to determine maximal heart rate). On average, a player's heart rate reached 60% of their maximal heart rate after 3 minutes and 40 seconds, reaching 70% of maximal after 10 minutes and 40 seconds.

For each player, the average heart rate of the session and the maximum heart rate for the session were compared against ACSM exercise intensity zones [3], results summarized in Figure 4. Examining the maximum heart rate reached in a session, 56% of players reached the level of 'Hard' exercise (heart rate between 70 and 89% of maximal heart rate). The other 44% reached a 'Very Hard' level (heart rate above 90% of maximal). Classifying the average heart rate across a session, it was in the 'Light' exercise zone (35 to 54% of maximal heart rate) for 19% of players, 'Moderate' (55 to 69% of maximal heart rate) for 44%, and 'Hard' for 37 % of players.

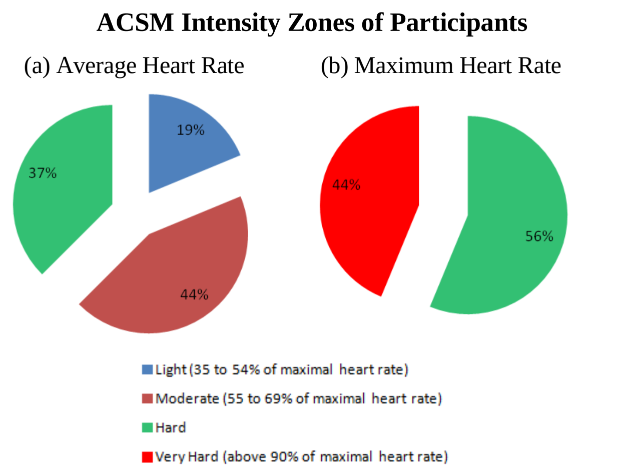


Figure 4: The distribution of player's exercise intensities into ACSM intensity zones, based on (a) average heart rate for the session and (b) the maximum heart rate reached during the session.

VII. CONCLUSION

We have shown that a DDR pad based game designed around exploration rather than a rhythm mechanic can be both entertaining and an effective form of exercise. To be effective, an exergame needs to present an appropriate level of gameplay challenge whilst requiring an appropriate amount of physical exertion. Through careful design of the world and playtesting we were able to create a compelling experience for players, with players experiencing the artifacts of flow (altered sense of time, feeling of control, lowered self-awareness, and focus and self-motivation on the task). By monitoring player heart rate and adjusting gameplay accordingly, the game allowed the players to complete the game at an intensity level that constitutes a beneficial level of exercise. This was confirmed by most players reporting that they received a 'great' workout.

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