Designing a Personalized VR Exergame

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ABSTRACT

Exercise is essential for health and well-being. However, it can be difficult for people to meet the recommended amount of daily exercise simply due to the lack of motivation. It has recently become apparent that virtual reality games, even though they were not explicitly designed for exercise, have the potential to provide enough exercise to achieve recommended levels of activity for a day, while keeping people motivated. However, as these games have not generally not been designed for exercise, there is a risk that people may either under- or over-exert themselves. Therefore, in this paper we present and discuss our design for a virtual reality exergame that utilizes a user model and dynamic difficulty adjustment to deliver personalized activity levels and experiences.

KEYWORDS

Personalization; Exergames; Virtual Reality

1 INTRODUCTION

Exergames are fun and can be a convenient way to gain exercise. Popular examples are based on the Nintendo Wii[2], Dance Dance Revolution (DDR)[11] and Microsoft Kinect[8] these have been demonstrated to deliver adequate amounts of exertion to meet recommended levels of activity. Despite this, they are not fully-immersive and are limited in terms of the types of exercises that can be performed as the player needs to follow the directions on the screen.

Virtual reality (VR) is beginning show considerable potential to go beyond previous exergames. As VR games can be fully-immersive, they have the potential to be very engaging and motivating [16]. As we see dramatic drops in the cost for high performance headsets, such as the HTC Vive[1], we can expect even cheaper and very high quality hardware to make VR technology very accessible. By using the HTC Vive's room-scale tracking, the player can gain exercise by naturally moving around, therefore specialized and limited function exercise devices, such as exer-cycles or rowing machines, are not needed [1]. In addition, recent work suggests that playing VR games even for ten-minutes can provide high levels of *actual exertion*, while, at the same time, reducing the perceived exertion and showing the potential to motivate people to exercise[14].

However, while VR exergames are effective at delivering exertion and motivating people to exercise, they have the potential to over-exert people as they lack detailed information about the player's level of exertion[5]. Personalization has an important role to overcome this, making the VR exercise experience tailored for individuals, potentially leading to safer sessions, higher engagement, and guided progression towards set goals. Detecting fitness levels is also feasible through heart-rate and step sensors, which can be used to feed that data in real-time into the games that support it[15].

In this paper, we present and discuss the consideration of designing a personalized VR exergame that changes game characteristics throughout a play through, based on the player's exertion levels and game play performance. We designed this exergame by analyzing the data that we collected from 18 participants which related to their enjoyment, exercise (exertion), interaction and the design recommendations on four existing VR games. The aim of this research is to take the first initial step into VR exergame personalization through both dynamic difficulty adjustment and a user model and discuss what needs to be done in the future.

2 RELATED WORK

It has been identified from previous work on exergames that personalization is required to deliver appropriate exercises to individuals and to also engage people by making the game progressively more challenging [3]. The difficulty and exercise intensity can be personalized based on aspects such as how attractive the player found the game, their calendar, and psychological state [4, 12].

Personalization methods such as user modeling [7] and dynamic difficulty adjustment (DDA) [13] are also used in video games and could be applied to virtual reality experiences, particularly exergames. Recent work of a non-exergame personalized an infinite Mario game's level in segments based on the player's performance and in-game behavior [9]. However, in the case of exergames, an individual's characteristics or properties could also be used, such as their age, gender, height, weight, and heart rate. Work by Kang [6] proposed a model for personalization that utilized the information from the human body to prescribe appropriate exercises, which users could perform while wearing a head mounted display (HMD). Other work by Shaw [10], implemented a virtual reality exergame with the Oculus Rift and an exercycle. It was personalized based on heart-rate, where the virtual trainer would slow down if the exercise became too intense or if the player slowed down. The virtual trainer would send motivating messages to the player during the exercise to encourage them to work harder.

In our work, we extend previous work in the area of VR exergames by exploring how to design a personalized exergame that takes into account the player's current and previous fitness and

[1] https://www.vive.com

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game play performance and adjusts accordingly. In the next section we describe the game in more detail.

3 OVERVIEW OF PERSONALIZED EXERGAME

The design of our personalized exergame, *Snowballz*, is informed by a foundation study [14] that we conducted with 18 participants who played four existing VR games from Steam VR[2] through the HTC Vive head mounted display (HMD). We now describe that study and how it influenced the design of our game.

Each user study ran up to one hour, as we asked participants to play the four different VR games, for a maximum of ten minutes each, with participants having been briefed to stop at any time in case they wished to, particularly if they felt too tired. Between each game there was a 2 to 10 minute break and during this time we ran a survey about the exertion experienced from the previous game. In the very last session, participants rated their enjoyment (fun) as well as the perceived exercise and interaction of the each game on a Likert scale, giving a score from 1 to 7.

Table 1 shows that the two most enjoyable games to play were *Holopoint* (6.2 out of 7) and *Fruit Ninja* (5.5 out of 7). Both *Hot squat* and *Portal Stories* were considered the least enjoyable of the 4 VR games with fun ratings of 3.3 and 3.9 respectively. Qualitative feedback also match these results with one participant stating that *Holopoint* was *"fun and good exercise because you need to use your whole body"* and another stating *"This game was really fun, levels getting harder but it makes me play longer"*. However from the data, *Hot Squat* was considered to give the most exercise, with an average score of 6.6. *Holopoint* followed next behind with a score of 4.7. It had several good and valued aspects but it was too simple, dull and involved a single physical action, squats. Importantly, some participants noted that *Hot Squat* was good at guiding players into the right posture, with one participant stating *"guide the posture, let me do proper squats inside the game without causing a back injury"*. But it was seen by several participants as being too much like just doing dull exercise which resulted it being less fun and a higher perceived exertion score. This was the consistent picture across participants, with comments like: *"Good exercise but you can feel you're tired, there is no game element and it is really boring and only uses 180 degrees"*, *"I get little bored doing the same things"*, and *"Good for exercise but it's not fun"*.

Game	**Likert scale (1-7)**		
	Fun(SD)	Exercise (SD)	Interaction (SD)
Holopoint	6.2 (0.8)	4.7 (1.5)	4.2 (1.3)
Fruit Ninja	5.5 (1.2)	3 (0.9)	1.6 (0.9)
Hot Squat	3.3 (1.9)	6.6 (0.7)	2 (1.3)
Portal Stories: VR	3.9 (2.2)	1.1 (0.3)	4.6 (2.1)

Table 1: Col 1: *Fun* - 1 very boring ... 7 high enjoyment; Col 2: *Exercise* - 1 low level ... 7 high intense fitness level; Col 3: *Interaction* - 1 is really easy ... 7 is hard to play

For interaction, the last column in the table, we see that Holpoint and *"Portal Stories: VR"* were the hardest to play. with *Fruit Ninja* and *Hot Squat* being much easier. Some participants found that the shooting in *Holopoint* was difficult to learn to do properly and it lacked a proper tutorial, *"shooting was little bit hard to me"* and *"require better tutorial otherwise can't even start a game"*. In addition, participants were also frustrated by the lack of information in *Holopoint*, such as a display of lives left and the current round, *"I was wondering how many lives I had"* and *"poor design, I don't know how many lives I had"*.

Fruit Ninja was considered fun, but got boring over time and did not require much effort to swing the swords. In addition, it was considered difficult due to the large number of objects the player needed to slash at once, with many outside the player's field of view.

Based on the study of 18 people (female: 5, male: 13), aged between 18 and 36 (mean: 27), we learnt the following design recommendations:

(1) The ideal game should be designed so that it does not seem like an exercise. It should be engaging, fun, and the game-play itself should mean that the user moves around to play in a mixture of actions, such as dodging, ducking, and performing arm movements.
(2) Present necessary information about the game, such as their heart-rate and number of lives, in a heads up display (HUD), so the player can keep track of how they are progressing and it can also serve as a motivator. The design of such elements needs care since players should still be able to focus on their game, but also to refer to this information just when they need it.
(3) VR games should not cause the player to over-exert themselves. To prevent this, VR games should take into account what goals the player wants to achieve, their fitness level, and skill at playing the game. All these factors should be taken into consideration to appropriately adapt the game to individual's.

Our VR game, that we present in this paper, is designed to meet these recommendations and is personalized according to the player's fitness and skill level and automatically adjusts the in-game elements. In the next section we describe the design of this game.

3.1 Gameplay Features

We designed *snowballz* (Figure 1) around the fun and light-hearted theme of snowball fighting. We now describe all of the game's mechanics.

Objective of the game. The player needs to survive as many rounds as they can, or until the system tells them to stop to prevent over-exertion. Their game is over if the player loses all their lives.

Interaction. The primary game mechanic is picking up snowballs from the ground and throwing them at oncoming enemies. Snowballs melt after a certain amount of time to prevent the player from hoarding them.

Enemies. Currently, there are two types of enemies in this game, snowmen and cannon snowmen. The snowmen move towards the player and if they reach the player they take away a life and then disappear. Cannon snowmen shoot large snowballs from a distance at the player. The player can either dodge that snowball or destroy it by hitting it with their own snowball. When the snowmen are

[2] http://store.steampowered.com

ID	Model Component Name	Description (illustrative examples)
		Game performance Model
G1	Player ID	Player's username
G2	Accuracy	Tuple representing *snowmenHit* and *snowmenMissed*
G3	Restarts	Number of restarts (*numRestarts*)
G4	Snowballs Created	Tuple representing the number of snowballs that have been created (*snowballsCreated*) to the proportion of snowmen (*numSnowmen*) in the current round
		Fitness Model
Fit1	Game stop Heart-rate	(220-age * 0.8) for 2 minute
Fit2	Goal Intensity Percentage	The percentage of the maximum heart-rate as defined by the player (70% is recommended)
Fit4	Goal Intensity Time	The amount of time the player's heart-rate needs to be over Fit2 before the game stops

Table 2: User model for Snowballz. Top block is the game session model. Next is the fitness model. Remainder is the model for user preferences.

hit by snowballs they fall to pieces. Cannons cannot be destroyed but the enemy controlling it can, which stops it shooting until the next round.

Rounds. The number of rounds played depends on the player's fitness and skill level. Each round is different depending on the player's current fitness level and gameplay performance. A round is over when all the snowmen have been defeated; after 10 seconds the next round starts again.

Figure 1: In-game screenshot of Snowballz. The player can use both hands to throw snowballs at oncoming enemies (snowmen).

Exercise. This game requires the player to physically move around the play area to avoid snowballs and destroy oncoming enemies using snowballs. These snowballs can only be gathered by squatting and reaching on the ground to create a snowball. Once the snowball is created the player can throw it at enemies in any direction, where the distance the snowball travels is dictated by the force of the throw. Therefore, we created this game to capture elements from both HotSquat and Holopoint, where the player needs to physically move around to avoid projectiles and squat to pick up snowballs. These gameplay mechanics will allow players to gain a varied exercise, while distracting them with oncoming enemies. The personalization enables this game to be accessible to all fitness levels, therefore not being too easy or difficult, thus keeping the player engaged.

3.2 Personalization

Our prototype exergame's difficulty is dynamically adjusted based on gameplay performance. The difficulty level of the game affects the amount and speed of the enemies. It is dictated by an adapted version of the adapted dynamic difficulty adjustment (DDA) model [13]. In the adapted version of the model, we implement the tactical layer of the model as our game is single-player. The tactical layer describes how the game adapts according to the actions of the player. Therefore, this layer allows the game to track the player's performance over the play-through.

Figure 2 shows a flow chart of our adapted DDA system. Based on actions performed by the player during the round the *experience points (XP)* variable increases or decreases, which also affects the *levelIntensity* variable. For instance, when XP reaches 10, *levelIntensity* increases by 1. Conversely, when XP reaches -10, *levelIntensity* decreases by 1. The green boxes represent three different mechanics that affect the XP:

- *Accuracy* consists of two variables, *snowmenHit* (which increases XP by 1) and *snowmenMissed* (which decreases XP by 1).
- *Create snowball* tracks how many snowballs have been created to the proportion of snowmen in the current round. The pseudo code for this is as follows:

  if *snowballsCreated*>numSnowmen **then**
      while i <(*numSnowmen*−snowballsCreated) **do**
          $i \Leftarrow i + 1$
          $XP \Leftarrow XP - 1$
  else
      while j <(*numSnowmen*−snowballsCreated) **do**
          $j \Leftarrow j + 1$
          $XP \Leftarrow XP + 1$
- *Restarts* tracks the amount of times the player has died and needed to restart the game. The amount in *numRestarts* gets removed from XP.

At the end of each round, the system checks each of the mechanics and calculates the amount to increase or decrease the *levelIntensity* and then maps it to a difficulty, as shown in Table 3. Therefore, this system is not constantly adjusting the difficulty; rather it adjusts levels based on the determined difficulty. This is to prevent the possibility of the player's engagement being affected by sudden changes in difficulty, such as the enemy's speed increases, which could potentially impact player engagement.

Information about the player and their session are saved at the end of their session into a user model (Table 2). This user model

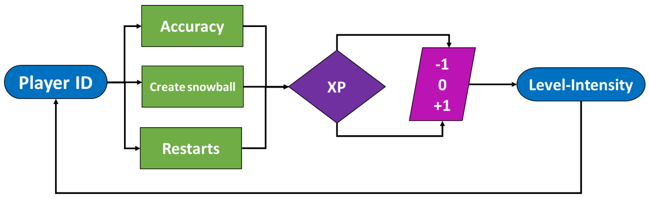

Figure 2: Flow chart describing the Tactical Layer approach used to dynamically adjust the difficulty of the game.

is read and loaded by the game when a new session is started. The information from this user model is then fed into the Tactical Layer, to determine what difficulty the player should start at. The player's fitness information is stored in this model, Fit1 is the player's maximum heart-rate. This is used to calculate when the player is achieving a vigorous amount of exertion (vigorous intensity activity), as set as a percentage (such as 70%) of the player's maximum heart-rate, which is stored in Fit2. If the player has met their goal vigorous exertion time (Fit3), which is the amount of time the player's heart-rate is over the percentage set in Fit2, the game will stop and inform the player that they have exercised enough today.

levelIntensity	**Difficulty**
1	Very easy
2	Easy
3	Medium
4	Hard
5	Very hard

Table 3: The difficulty levels that the game can choose.

Based on the difficulty level and round, the enemy speed and number of enemies spawned will change.

3.3 Future Study Setup

The study will be conducted inside a dedicated VR lab. The interactive space is approximately 3 x 3 meters (Figure3). The equipment required to run *Snowballz* is:

- 1 x HTC Vive HMD
- 2 x HTC Vive Base Stations
- 2 x Controllers
- 1 x Desktop PC running Windows 10 with Intel Core i7 3.4 GHz, 16 GB RAM,and Nvidia Geforce GTX 960 graphic card
- 1 x Speaker System
- 1 x Microsoft Kinect version 2 (for video recording)
- 1 x Heart-rate Chest Strap

Figure 3 shows how to setup the VR space to run the study. Two Lighthouse sensors that track the player's position in the physical space, can either be mounted on tripods or on the wall on opposite sides of the space. For obtaining the player's heart-rate data players can either wear a chest strap or a wrist strap heart-rate monitor, which is sent via Bluetooth to the computer running the game.

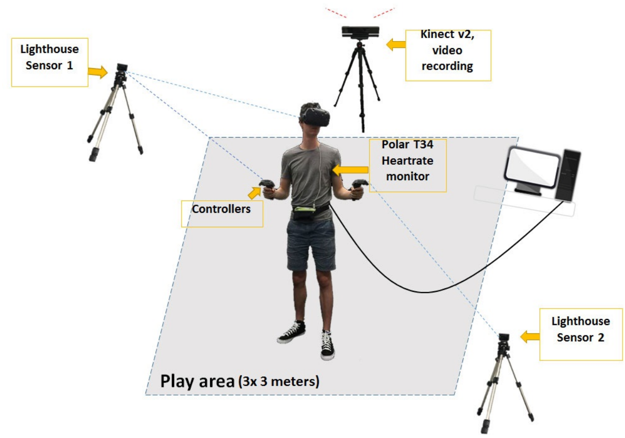

Figure 3: The setup of the HTC Vive in our dedicated VR space.

4 DISCUSSION AND CONCLUSION

In this workshop paper, we have presented and discussed a design of a personalized VR exergame that uses data from two sources, the player's heart-rate and their game performance. We propose that VR exergames should monitor and consider the player's physical fitness to ensure players are not over-exerted, resulting in either injury or the player quitting the game. Future work will test the game presented in this paper in a long-term user study to measure the effectiveness of the personalization at delivering tailored experiences and exercise over time.

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