Rift Racers - Effect of Balancing and Competition on Exertion, Enjoyment, and Motivation in an Immersive Exergame

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***Abstract*—By immersing themselves in a game users may exert themselves more than they would in every day life. One important driving factor in games and many forms of exercise is competition, at once engaging socially in the activity and trying to outdo an opponent or oneself. Large differences in fitness levels make competition infeasible between some opponents, but exergaming can remedy this with the use of balancing via exertion.**

We developed a fully immersive virtual cycling race and balanced the competition between opponents by scaling their speed according to how close they were to their target heart rate. Incorporating a virtual reality headset and a vibrant 3D world, users were exhilarated and pushed themselves to high levels of exertion. Our results suggest that balanced games can reduce the performance gap between opponents, and might increase motivation and enjoyment for users with lower fitness level. However, heart-rate balancing might be demotivating for very fit users.

***Index Terms*—exercise game, exergame, exertion, game balancing, competition, immersion, virtual reality**

I. Introduction

Over the past decade an increasing number of exergames (exercise video games) have been developed as they can offer different intensity exercise, and significantly increased heart rate and energy expenditure of users in the same way as traditional exercise [16], [22]. Increasing the intrinsic motivational factors of exercise can be seen as one of the primary roles of exergames and competition has been shown to be a compelling drive for exercising [8].

Competition and intrinsic motivation have been already investigated in exergames, showing that competition increases the motivation of competitive individuals, who have a positive experience and show an improved performance but has a detrimental effect on the experience of non-competitive individuals [20].

The challenge is to create an exergame exhibiting the right level of competition to increase enjoyment and adherence. One important consideration is the variation of participants' skills and abilities. If they are closely matched, participants will be able to motivate and challenge each other. When the difference is too large, participants may feel too advanced and hence bored, or too far below the other individuals' level to develop engagement. In this case the activity may be experienced as less enjoyable. This is particularly true in competition, where the closer opponents' abilities are the greater their competitive drive and the strive to win.

Several authors have investigated techniques to enable players with different fitness levels to compete in exergames [5], [15], [21]. The key idea is to use heart-rate based formulas such that players making an equal effort (exertion defined by players' heart rate relative to their resting heart rate) have a roughly equal performance in the game.

To the best of our knowledge, there is no study investigating the effect of such balancing on the experience and exertion

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level of participants with different fitness partnered in a fully immersive environment. The concern is that heart-rate balancing might work for very simple games, but that for complex VR games the effect of game play, the game environment, and immersion masks the effect of game-balancing. We hence investigate the following research question:

> RQ: *Does heart rate balancing (implemented using Stach et al.'s formula [21]) improve players' performance and experience in a fully immersive and feature-rich exergame?*

We developed an immersive exergame called Rift Racers to examine the difference in participants performance, enjoyment, and motivation while playing an exergame using normal (unbalanced) competition and balanced competition.

II. Literature Review

A. Competition In Exergames

Player motivation is influenced by many factors [6]. Competition is a fundamental concept in gaming to motivate players. Competitive game play can elicit more caloric expenditure than cooperative game play [18]. Effectiveness of competitive game play depends on the structure of the competition and players' psychological traits. Song et al. have shown that competitive exergames do improve physical activity, but had detrimental effects on the exercise experience of non-competitive players [20].

In contrast, cooperative exergames have been shown to increase motivation, promote continued play, enhance self-efficacy, and increase pro-social behaviors [13]. Competing against other players also has practical limitations, e.g. that another player has to be present at the same time.

An alternative to competing against other players, is to compete against virtual players, e.g. program controlled characters or recordings of a players' previous attempt (ghost). Shaw et al. showed that competing against a ghost was more enjoyable than playing on one's own or with a virtual trainer [18].

Michael and Lutteroth recorded all of a player's previous attempts and a projected future performance, enabling players to race against a crowd of "ghost" avatars representing their individual fitness journey [14]. The authors report that this strategy improves physical performance, intrinsic motivation, and flow compared to a non-competitive exergame.

Barathi et al. investigated the use of feedforward-learning in exergames, by enabling players to compete against self models with previously not-obtained performance levels [4]. The authors report that this strategy resulted in improved performance, while maintaining intrinsic motivation, and was superior to competing against a virtual competitor.

B. Balancing in Exergames

Video games use balancing to make games more enjoyable and attractive to users. Different balancing strategies exist based on different objectives such as making a game winnable [7]. For competitive games one objective can be to balance user's game play abilities. For example, for racing games "rubber banding" can be used to limit the size of the gap between competitors in order to prevent the weaker competitor from giving up, or the stronger competitor from getting bored [1].

Several types of sports use balancing to achieve a level playing field and make competition more interesting. This is typically achieved using handicapping. For example, in golf net scores are computed from the player's handicap and actual number of strokes. In horse racing better horses may have to carry a higher weight, and in sailing the recorded finish time might be adjusted based on boat capabilities.

Handicapping concepts from sports can be transferred to exergames [3]. Altimira et al. show that adjusting equipment, such as table size and bat size in virtual table tennis, can affect game balancing and player engagement [2]. The authors suggest this can be perceived as unfair by more skilled players and less obvious interventions are preferable.

In order to achieve optimal exercise outcomes it might be more effective to focus on balancing players' physical abilities rather than game play skills. Stach et al. conducted a study in which participants' performance in a cycling exergame was based on how much they exerted themselves, rather than their physical fitness [21]. To do so the authors measured users' heart rate and scaled their game speed according to how close they were to a target heart rate. The authors found that this was effective when participants fitness was largely mismatched, but had a negative effect on competitiveness when participants were of similar fitness levels. The authors also reported that balancing an exergame with heart rate and exertion was natural and did not detract from the game experience. Bayrak et al. proposed an alternative exertion-based balancing formula and report that it results in closer competitive gameplay and a more enjoyable game experience [5].

III. Design

A. Requirements

In order to answer our research question we require a multiplayer game enabling two players to compete. The in-game performance must reflect the players' physical activity. The game must be able to measure players' physical activity and heart rate. It must be possible to balance players' different fitness levels such that an equal effort translates into a (roughly) equal in-game performance. In order to engage users and go beyond the psychological aversion to exercise, we want a visually attractive and fully immersive game to detract the user's attention from the perceived negative aspects of the exercise such as elevated heart rate and fatigue.

B. Platform Design

Our resulting exergaming platform is based on a design proposed by Shaw et al. [19] and is illustrated in figure 1. Players wear an OculusRift head-mounted display (HMD) in order to immerse themselves into the game world. We use upright exerbikes, since most users are familiar with them, they can elicit a high exercise intensity, and they are safe while wearing a HMD. During the entire game players have to hold the bike's handlebars. Players can move left and right in the game world by leaning to the left and right while sitting on the bike. The body motion is detected using a depth camera.

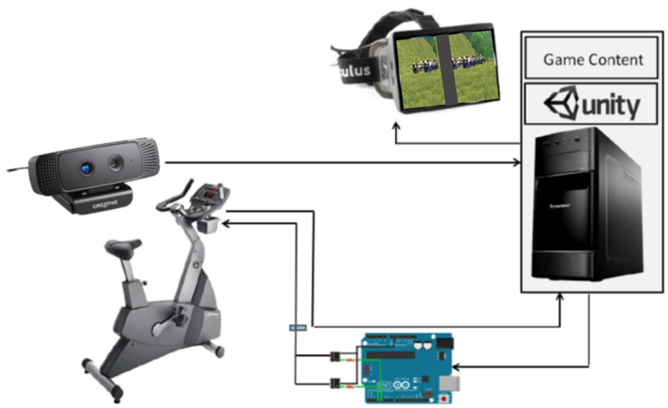


Fig. 1. Immersive multiplayer exergaming platform.

We use two Life Fitness 95Ci Upright Exercise bikes, which are connected to PCs using a serial connection. The CSAFE standard for exercise equipment requires a custom cable - we created one by splicing together several standard cables. The exercycles allow direct reading of data (e.g. speed, calories burned, heart rate), and indirectly adjusting the pedalling resistance on the bikes from the exergame through an Arduino Uno R3 micro-controller.

Players are located in different rooms in order to prevent changes in game play behaviour due to direct communication or seeing another player before the game. The latter might effect performance since, for example, a physically unfit player might give up at the start when realising they will compete against a very fit person.

C. Game Play

We developed an exerbike-based networked multiplayer game called *Rift Racers* using the Unity3D game engine version 5.1 and 5.2, MonoDevelop and C# for scripting, Unity native VR support, and a beta version of Unity's Lobby Asset.

Rift Racers was built based on a pre-existing exergame titled Rift Run, in which a player runs through a destroyed city, scaling ramps, jumping off ledges, and crawling under buildings. We maintained the graphical theme of this game and developed it into a long straight race track more appropriate for cycling. Grass and trees were added to the world, animated by simulated wind, as well as explosive fire, tunnels, and ramps.

Animated cheering crowds were placed at the beginning and end of the race to add further motivation to a player, as well as groaning zombies when cycling through a shadowy underpass. All of these graphical effects and game objects add to the immersion in the world, creating a presence in the simulation, and a desire to play the game rather than merely ride an exercycle. The use of a HMD added to the immersion, allowing users to look around in the world and see the position of their opponent. Figure 2 shows several screen shots of the game.

D. Game Balancing

For the basic competitive condition speed is taken directly from the exercycle. This means, if the bike's resistance is constant, the in-game speed is proportional to the players' pedalling speed.

For the balanced version the speed is scaled according to a player's exertion. This is achieved using Stach et al.'s formula [21]. First the maximum heart rate hr_{max} of a player is calculated as [10]

$$hr_{max} = 207 - 0.7 * age \tag{1}$$

The target heart rate hr_{target} is then defined based on the difference between the maximum and resting heart rate $hr_{resting}$, and the desired intensity level. In Stach et al.'s paper the intensity level was 70%, but we found 80% was necessary to get a sufficiently high exercise intensity.

$$hr_{target} = 80\% * (hr_{max} - hr_{resting}) + hr_{resting} \tag{2}$$

The authors then calculate a normalised heart rate factor h, which is zero at rest and one when the maximum heart is reached:

$$h = \frac{hr - hr_{resting}}{hr_{target} - hr_{resting}} \tag{3}$$

Finally a logarithmically scaled factor h' is calculated to take into account that further speed increases are undesired after the maximum heart rate has been reached, and that for fitter players heart rate responds more slowly.

$$h' = log_{10}(9h + 1) \tag{4}$$

In the balanced condition we measured players resting heart rate, recorded their age, and calculated their individual scaling factor h', which was then used to scale the speed recorded by the exercycle.

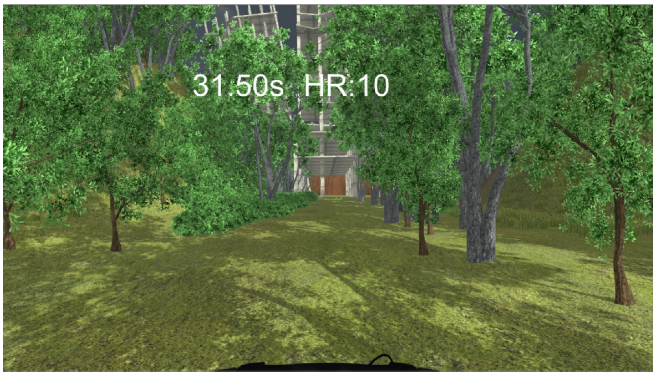
E. Network

For each client, input was processed from the exercycle and the local player's position was updated accordingly. The new position was sent to the server and the opponent's new position was returned, and the scene then rendered to the HMD. The rest of the simulation was local to each client.

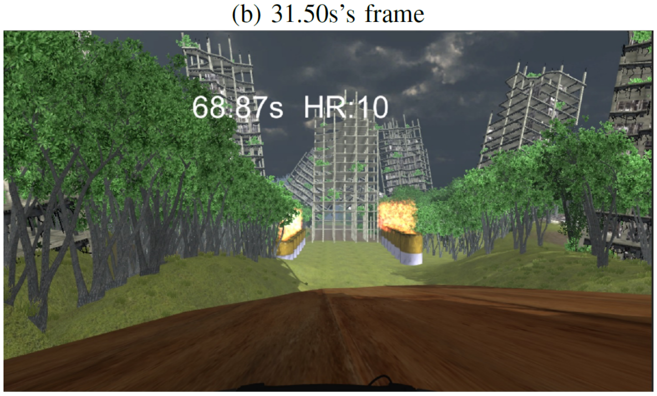
To handle entry into the game we developed a lobby, where a game was created by the host, and the second client joined the game with the local area IP address. Players then entered a waiting area and when both had selected to join the game the game began. The waiting area also allowed us to add parameters for testing condition, age of user, and resting heart rate of the user.

To avoid conflicts in the game all potentially shared components were disabled when the players were spawned into the game, and enabled only on the local player. Examples of these components include the camera and the input component.

(a) First frame



(b) 31.50s's frame



(c) 68.87s's frame

(d) Last frame

Fig. 2. Sample of captured frames from the game..

IV. Evaluation

A. Methodology

We performed a user study investigating the effect of balancing of fitness levels in a competitive visually rich immersive exergame. Our study contained two conditions:

Condition 1: Without heart rate balancing (using speed from the exerbike)

Condition 2: With heart rate balancing (speed from the exerbike is scaled with equation 4)

Apart from this difference the games were exactly the same in both conditions. All user study participants took part in both conditions and the order of the conditions was randomized.

Users were first given a warm-up period where they could play the game without opponent. This enabled users to get familiar with the equipment and virtual environment (e.g. distance to be cycled and obstacles).

The study was conducted in two collocated computer labs and we evaluated two users competing at a time. Races were conducted as participants became available and no matching of fitness levels was performed when pairing opponents. To reduce simulation sickness we avoided rotational movements and steep inclinations in the virtual environment [19].

Participants completed a demographic questionnaire and the Sport Orientation Questionnaire (SOQ) at the beginning of the user study. The SOQ is a list of statements describing reactions to sport situations, in particular competition [11]. The instrument assesses three separate but related subscales of competitiveness, win, and goal orientation using a 7-point Likert-scale.

Participants completed after each condition a questionnaire containing seven questions designed by us for measuring players' experience of different aspects of the competition.

At the end of the user study participants completed as final questionnaire the Intrinsic Motivation Inventory (IMI), an instrument that assesses subscales of intrinsic motivation [8]. Each construct is measured using a 7-point Likert-scale.

B. Participant Demographics

The user study had six participants (5 male, 1 female). The mean age was 24 years (SD=5). All participants were current students of the School of Computer Science at the University of Auckland. According to the SOQ all participants considered themselves as competitive (from slightly competitive to very competitive) and goal driven. The body mass index ranged from 20.75 up to 29, with an average of 24.74. The participants exercised on average 3.83 hours per week.

C. Results

We measured for each race and each participant the time taken to complete the race and the heart rate directly at the end of the race (see table I). The average final heart rate for all participants was 161.15 BPM for condition 1 and 167.17 BPM for condition 2. The average time to complete a race was 125.33 seconds in condition 1 and 129.17 seconds in condition 2. The average time difference between participants was 34

		Condition 1 (no balancing)			Condition 2 (with balancing)		
Participant ID	Resting HR	Final HR	Time (seconds)	Result	Final HR	Time (seconds)	Result
1	65	144	88	win	167	109	win
2	95	173	130	win	176	128	win
3	70	174	115	lose	186	107	win
4	85	170	185	lose	177	144	lose
5	80	140	127	lose	139	160	lose
6	75	167	107	win	156	127	lose

TABLE I

RACE RESULTS FOR ALL SIX PARTICIPANTS IN BOTH CONDITIONS.

I1: The opponent's behaviour fitted my expectations.
I2: The opponent was hard beat.
I3: The opponent helped me to perform well.
I4: I was focused on beating my opponent.
I5: I was focused on achieving a good time.
I6: I found this condition enjoyable.
I7: I found this condition motivating.

	I1	I2	I3	I4	I5	I6	I7
Participant ID	Condition 1 (no balancing)						
1	6	1	1	2	6	6	6
2	3	3	5	5	3	5	5
3	1	1	1	5	5	7	7
4	5	6	5	7	6	4	6
5	1	7	4	5	6	3	4
6	1	4	6	6	4	4	5
Mean values	2.83	3.67	3.67	5.00	5.00	4.83	5.50
Participant ID	Condition 2 (with balancing)						
1	3	1	3	6	6	6	6
2	5	5	6	6	3	5	5
3	7	7	7	7	7	7	7
4	7	3	6	6	6	6	6
5	2	6	5	5	5	2	2
6	2	7	1	1	1	1	1
Mean values	4.33	4.83	4.67	5.17	4.67	4.50	4.50

TABLE II

POST-CONDITION QUESTIONNAIRE 1 WITH RESPONSES ON A 7-POINT LIKERT-SCALE FROM 1 (STRONGLY DISAGREE) TO 7 (STRONGLY AGREE).

Part. ID	Interest / Enjoyment	Perceived competence	Effort / Importance	Pressure / Tension	Value / Usefulness
1	5.00	7.00	6.80	1.20	1.86
2	4.71	4.50	4.40	3.60	4.86
3	7.00	5.17	4.40	3.00	7.00
4	4.57	2.67	5.40	4.80	6.14
5	4.29	2.50	6.40	4.00	4.43
6	3.71	2.67	5.60	3.80	4.71
Mean	4.88	4.08	5.50	3.40	4.83

TABLE III

RESULTS FOR THE FIVE SUBSCALES OF THE IMI QUESTIONNAIRE. RESPONSES WERE A 7-POINT LIKERT-SCALE FROM 1 (STRONGLY DISAGREE) TO 7 (STRONGLY AGREE).

seconds in condition 1 and 29 seconds in condition 2, i.e. roughly 15% smaller with heart-rate balancing. However, a Wilcoxon signed-rank test showed no significant differences for any of these results ($p > 0.05$).

The results of the post-condition questionnaire are shown in table II. It can be seen that on average participants found the unbalanced condition slightly more motivating and enjoyable. This is surprising since heart-rate balancing was suppose to increase these variables. However, the differences are entirely due to participant 5 and 6. For both participants their final HR was lower in the balanced competition, which indicates a lower motivation. Furthermore, participant six was the most competitive user according to the SOQ survey and won the unbalanced competition, but lost the balanced one, which might have created negative emotions.

For the balanced competition participants had a higher agreement with the statements that the opponent fitted their expectations and was hard to beat, that the opponent helped them to perform well, and that they focused on beating the opponent.

Unfortunately, because of the small sample size none of these differences was significant.

Some individual results are worth noting: Participant one was the fittest user and was the only one who found it easy to beat the opponent in both conditions.

Participant three lost the unbalanced competition, but won the balanced competition, and strongly agreed that this condition was enjoyable and motivating. The table shows one unexplained inconsistency for this user. Participant three lost the unbalanced competition, but strongly disagreed that it was hard to beat the opponent; but then won the balanced competition and strongly agreed that it was hard to beat the opponent. We believe this participant might have misread the question and the answers should be reversed.

Table III shows the results of our post-test IMI questionnaire. All participants found the game interesting and enjoyable, with one user really liking it. Three users did not feel competent playing the game, likely due to losing at least one race. The fittest participant in our study (ID 1) felt very competent, and also recorded the fastest times in the races. All participants felt quite strongly that they had put effort into the task and doing so was important to them, which is reflected in them all achieving high final heart rates.

The perception of pressure and tension was in general close to neutral, but the fittest participant (ID 1) felt virtually no pressure, whereas participants four and five felt slight pressure. On average the game was perceived as valuable / useful and only the fittest participant (ID 1) disagreed with this.

D. Discussion

Our study indicates that our game is enjoyable and motivates users to exert themselves. We believe our (and many other) exergames are not suitable for very fit users, who might prefer to focus on the exercise rather than a game. This corresponds with results from Shaw et al., who report that immersive exergames worked best for sedentary users, but users exercising regularly reacted negatively to it [17].

We believe balanced competition is a promising feature for exergaming in terms of making games closer and more interesting. However, we could not find any evidence that it makes the experience more enjoyable or motivating. We found strong individual differences and that balancing might be demotivating for very fit users.

Our study suffers from a large number of limitations. User study limitations include that we had only six participants and due to the small sample size we did not find any statistically significant differences. Results were influenced by self-selection bias and the fact that all participants were rated as competitive on the SOQ questionnaire. Furthermore, our discussions with students suggest that users competitive in sports are not necessarily competitive in gaming, and vice versa. While we did randomise the order of conditions, the small sample size means that we still had order effects.

Design limitations include that our game did not include a maximum speed cap on the input from the exercycle. This means that for a very fit individual the heart rate balancing might not have worked as intended, as indicated by the fact that after balancing time difference were reduced, but were still very big. We did not fix the resistance level of bikes and let users choose a level they were comfortable with, as long as that resistance was used in both conditions.

V. Conclusion and Future Work

We developed a fully immersive exergame using virtual reality technologies and a vibrant three dimensional game world. We matched users against each other in a high speed cycling race and measured their performance, motivation, and enjoyment with and without heart-rate balancing.

Our results indicate that heart-rate balancing reduces the performance gap, which corresponds with results reported by Stach et al. [21]. We did not find any general effect on enjoyment and motivation of users. However, our results suggest that heart-rate balancing might have a positive effect on users with lower fitness levels, and a negative effect on very fit users.

In future work we would like to investigate the effect of heart-rate balancing on music and rhythm-based exergames [9], [12].

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