Design of a Virtual Trainer for Exergaming

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ABSTRACT

Exergames are becoming increasingly popular as a way of motivating people to exercise. However, merely adding exercise elements to a game may not achieve the desired level of motivation and long term adherence. By designing an exergame which takes into account the user's personality profile, the user's level of motivation to play the game and thus exercise may be increased.

In this paper, we present an exergame using a virtual trainer system which can be customized for the personality of the user. The trainer system supports two modes: a competitive mode for players who are motivated by pushing themselves to beat an opponent, and a cooperative mode for players who enjoy working with another player to perform well.

We conduct a brief pilot study to evaluate our virtual trainers in which participants' personalities are evaluated using the Sport Orientation Questionnaire. They then play three short sessions of the exergame: a control condition without a trainer system, and one for each of the two trainer system. Our initial results indicate that the training systems are highly motivating when matching the personality of the user, particularly for competitive individuals.

CCS Concepts

•**Human-centered computing** → **Human computer interaction (HCI);**

Keywords

Exergame, Immersion, Head-Mounted Display, Motivation, Trainer system

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1. INTRODUCTION

Different people have different sources of intrinsic and extrinsic motivation. What is motivating for one person may not be motivating, or may even be demotivating for another. For some people, exercise activities are intrinsically motivating, or have intrinsically motivating factors [12]. For some people, gaming is intrinsically motivating. Exergames are increasingly popular as a way to combine exercise and gaming, so that motivation to play a game can encourage someone not otherwise encouraged to exercise to do so.

While plenty of past research indicates that exergames can be effective at motivating people to exercise [13, 19], this past research has applied a catch all approach where the psychological profile of the player is not considered. The variation in factors which different people find motivating means that an exergame with personalized motivational strategies is likely to be more successful at achieving a long term game adherence and increase in activity levels.

Much as how a coach or personal trainer can increase motivation in traditional sporting activities [8], so too might a virtual trainer increase motivation to spend time playing an exergame. There are two main motivations with which players approach exergames: to relax and to achieve [10]. A successful virtual training should be able to provide assistance for both of those motivations. For a player who wants to relax, a trainer system which helps them to play and increases the usability of the exergame is beneficial in order to prevent gameplay induced stress. For a player who wants to achieve, a trainer system that spurs them on to perform at a higher level when playing is ideal.

In this paper, we design a customizeable trainer system that can use information about the player's psychological profile to select a suitable trainer and gameplay profile to provide the player with a maximally motivating experience. Our focus is on designing a trainer system that can target either competitive or cooperative personalities, and that can assist with relaxing or achieving motivations.

In section 2, we identify and discuss some relevant research. In section 3, we discuss the design of our exergame and the various aspects of our virtual trainer system. In section 4, we talk about the implementation details of this system. Section 5 contains a brief summary of the pilot study we conducted to determine if our current approach shows promise. In section 6 we summarise and conclude the paper.

2. BACKGROUND

Exergames have been the subject of a fair quantity of research. While most of the research on exergames focuses purely on the ways in which exercise may be applied as an input to gaming, there has been some research on the way different psychological factors affect a player's motivation to use an exergame. We are particularly interested in research on social factors such as competition and in research on in game feedback cues.

Competitive factors have been shown to increase motivation in exergames. Peng and Crouse [11] look at three conditions of multi-player in exergames: single player versus a pretest score, cooperation in the same physical space, and parallel competition in separate physical space. Their results indicate that parallel competition in separate physical space is the optimal condition as it provides high enjoyment, physical activity, and motivation for future play.

Competitive factors can also influence exercise performance. Song et al. [15] look at the effect of competitive exergame gameplay on peformance and motivation in individuals with competitive and non-competitive personalities. While competition appears to cause increased exercise performance in both types of player, non competitive players did not enjoy the experience and showed a significant reduction in voluntary additional play. The fact that competition increased performance but could decrease motivation is of significant interest for the design of exergames, as increased performance may offer short term benefits, but the potential long term drawbacks of decreased motivation (for example, reduced adherence to an exercise program) likely outweigh these benefits.

Cooperative gameplay has also shown benefits in exergaming. Staiano et al. [16] conducted an experiment in which participants played the Nintendo Wii Active game, either cooperatively or competitively against a partner selected from the other participants in their condition. Participants assigned to the cooperative condition lost significantly more weight than the control and competitive participants. The authors attribute the greater effectiveness of the cooperative condition to the social factors involved: as participants worked together to earn points they provided increased support and motivation for one another. The lack of effectiveness of the competitive gameplay is potentially attributable to the participants not being competitively inclined. This matches the findings of the aforementioned study by Song et al. [15] where the non-competitive participants suffered from decreased motivation during competitive gameplay.

The fitness of the user is an important consideration when designing exergames. Göbel et al. [5] describe a series of exergames that track and use the user's heart rate in order to customize the game for their specific fitness level. The games use an exercise bike with a heart rate monitor to track the user's heart rate during play. The games use the heart rate as a tool for adjusting the difficulty of the game and as an input channel, such that the player's success is based on maintaining a target heart rate. The results of their study indicate that these games are enjoyable and motivating, and that the concept of using heart rate in games is well received by players. However, the paper does not give an indication of the level of exercise these games may elecit.

Past work has examined the idea of developing a virtual trainer system. For example Ijsselsteijn et al. [7], where the virtual coach appeared every minute and provided the user with feedback regarding his heart-rate. The trainer was a virtual human female character that was just displayed in the corner of the screen. The feedback provided was prerecorded voice cues that were matched with textual information displayed in a speech bubble above the coach. The example provided in the paper displayed the text: "Your heart rate is too low. Cycle faster." The results from this study highlighted that greater immersion in the game was linked with increased motivation. The trainer also lowered tension surrounding performance and player control while not affecting the enjoyment.

The direct instructions used in the above paper have potential downsides. Hepler et al. [6] report that the effectiveness of these cues may be reliant on the personality and past behavior of the target individual. For example, a user with a history of sedentary behavior may ignore an instruction such as "cycle faster". Furthermore the presentation and interpretation of feedback can have a significant effect on how it motivates an individual. If the feedback is interpreted as controlling, the individual will not be motivated to respond to it [2]. Thus for the design of an exergame, it is necessary that the cues to exercise harder when the current level of exertion is insufficient are presented in a way that lead to increased motivation for the user.

Li et al. [9] also examine the use of a virtual training system for active video games. In their system, the user's bodily motion is detected using a Kinect 3D sensor, and the user must mimic the motions shown on screen by the trainer in order to gain points. While this system has limited gamification, the research indicates that training in an immersive virtual environment is motivating.

Wilson and Brooks [20] compare training with a virtual trainer in an exergame to training with a certified human trainer in a traditional exercise program. Their results show no significant difference in exercise adherence between the two trainer types. However, higher levels of exertion (as measured by heart rate and rate of perceived exertion) are higher when training with a human trainer.

3. DESIGN

There are two core requirements for our exergame:

- The exergame must feel like a game, that is it must be fun to play.
- The exergame must elicit moderate to high intensity exercise from the player.

We base our design on the design of an existing exergame which suitably fulfilled these requirements [13]. In this game, the player moves along a procedurally generated track in a virtual environment at a speed dictated by the rate at which they pedal on an exercise bike. The track contains obstacles which the user may avoid by moving from side to side or by ducking underneath. These motions are achieved by leaning the upper body slightly to the desired side or by ducking on the exercycle respectively. The track also contains bonuses which the user may collect by passing through them. Periodically the track will branch; one one branch there will be few obstacles, and thus neither much risk nor rewards, and on the other branch there will be many obstacles and bonuses, and thus both risk and reward are high.

The objective of this game is to achieve the maximum score in the allotted time. The player gains points by successfully avoiding obstacles on the track, and loses a small amount of points when they fail to avoid them. Certain bonuses also give points.

Our trainer system has several core requirements:

- The trainer must be customizable to different personality types.
- Following the trainer's cues must be intrinsically motivating.
- It must be able to effectively motivate people of different fitness levels.
- The trainer must encourage the user to exercise at an optimal level.
- The trainer's behavior in the game should be human-like.

To fulfill the first requirement, we developed two different trainer systems: a competitive trainer, which races against the player, and a cooperative trainer. While there is likely to be a lot of variation in the personalities of people who play an exergame, these two profiles reflect a significant and interesting division.

The types of feedback each of the trainer systems gives can be customized for the user. The trainers can give textual and verbal feedback on the user's in game performance and level of exercise.

The trainers are designed to encourage following of their cues by helping the user maximize their score. The trainers avoid obstacles and choose paths that will be easier for avoiding obstacles in the distance (for example, if there is an obstacle in the center of the track, and beyond that is one on the left side, the trainer will choose to go right when avoiding the central obstacle). The trainers also attempt to acquire as many of the bonuses as possible, including when doing so would take them through a sandpit, as the potential points from the bonus exceed the points lost for failing to avoid the obstacle. It should be noted that the trainer only looks a certain distance ahead when determining an optimal path, and what appears to be the ideal choice at that distance may turn out to be inferior overall. The distance the trainer looks ahead is approximately the same distance that the user can reasonably discern obstacles and bonuses on the track, in order to avoid giving the trainer the appearance of omniscience, and instead have it demonstrate human-like behavior.

The trainers provide feedback to the user about their heart rate, both in their behavior (detailed later), and in their visual representation. The game determines the target heart rate for the user, based on the American College of Sports Medicine (ACSM) recommendation of 64-90% of the user's maximum heart rate for high intensity exercise [3]. The user's maximum heart rate is calculated based on their age [17], using equation 1. When the user is in the target heart rate zone, the trainer is colored yellow. When the user's heart rate is below this zone, it is colored blue, and when above it is colored red. These colors are chosen for the natural association with temperature: when a player has a low heart rate, the temperature of the body is lower and they do not sweat from exertion, whereas when a player has a high heart rate the body is hot from the exertion.

Figure 1: Screenshot of the game showing the relative positions of the player (blue) and trainer (red) on the radar.

In all cases, the trainer is partially transparent, so as not to interfere with the user's ability to see objects on the track. Our early testing indicated that an opaque trainer occasionally blocked the view of important parts of the track such as upcoming obstacles and bonuses. We hence decided to make the trainer translucent, as a trainer system that was detrimental to the user's ability to perform well in the game could be seen as a source of frustration and lower the user's overall motivation.

$$208 - 0.7 * age \tag{1}$$

3.1 Competitive trainer

In many cases, athletes will prefer to play against another person rather than to play alone or with a cooperative trainer. Furthermore, the gender of the player is linked to their sporting competitiveness. For example non-athlete females are less competitive than athlete females whereas non-athlete males are nearly as competitive as athlete males [14]. That is why we designed a competitive trainer. The trainer in this mode acts like an opponent. The goal is to encourage the user to achieve a high level of exertion, i.e. to train at a level towards the higher end of the recommended maximum heart rate. We hence design the trainer such that if the player has a low heart rate, the trainer will beat them , if the player has an average heart rate, the trainer can be beaten but just for a short time, and if the player has a high heart rate, the trainer can be completely beaten.

In order to achieve this goal the trainer's speed in the virtual environment depends on the player's speed. When the player's heart rate is below the target zone, the trainer's speed will increase up to 1.3 times that of the player. When in the target heart rate zone, the trainer's speed will approximately match that of the player. When the player is above the target heart rate zone, the trainer's speed will drop down to 0.7 times that of the player (see figure 2).

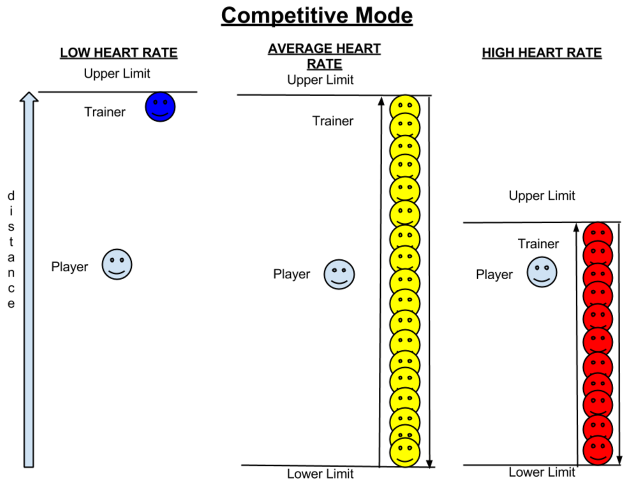

Figure 2: Trainer's behaviour according to the player's heart rate in the competitive mode

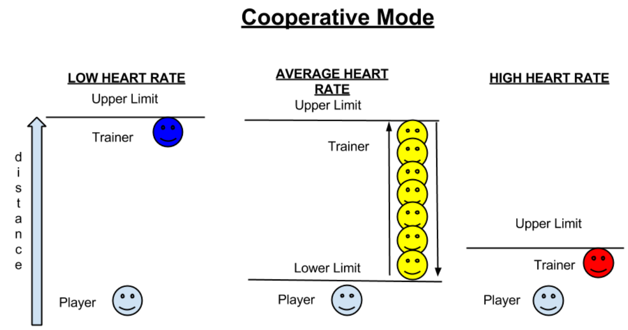

Figure 3: Trainer's behaviour according to the player's heart rate in the cooperative mode

The speed of the trainer also takes into consideration the distance from the player. If the player spends an extended time in the low heart rate zone, it is important that the trainer does not get too far ahead, otherwise it may be demotivating, or at least no longer motivating if the trainer has moved out of the player's view. Similarly, it is important that the trainer does not fall too far behind if the player is spending an extended period of time above the target heart rate zone, otherwise the benefit of the trainer will be lost even if the player's heart rate falls back into the target zone.

While in the target zone, the speed variation means that the trainer behaves as a human player of similar abilities, in that it occasionally pulls slightly ahead and occasionally falls slightly behind. This means that the user is always being made aware of the presence of the trainer and is encouraged to work harder to stay ahead. As the user tends towards the upper end of the target heart rate zone, the trainer spends more time behind the user, while at the lower end of the zone it spends more time ahead of the user.

3.2 Cooperative trainer

The cooperative trainer is designed for cases where the player does not have a competitive personality but would still benefit from the presence of another "player" on the track. In this mode, the trainer is always in front of the player, regardless of their heart rate or speed. The trainer's primary purpose is to give the player something to focus on following, similar to how athletes may use temporary partners for segments of a track, and to indicate an optimal path through the game environment.

Similar to the competitive trainer behavior, the cooperative trainer system varies its distance based on the heart rate of the user (see figure 3). If the user is below the target heart rate, the trainer maintains a position well ahead of the player. Above the target heart rate, and the trainer stays only barely ahead of the player. While the player is within the target heart rate zone, the trainer varies its position in a similar fashion to the competitive trainer, but within the bounds given by its own high and low heart rate positions.

Note that the virtual trainer design reflects two techniques from game design used to make multi-player games more interesting: "Rubberbanding" means that two players don't move too far apart even if their true speed varies significantly. The technique is popular in racing games to make the game play more interesting even if competitors skills vary. "Handicapping" is used in exergames in order to allow players with different physical fitness to compete effectively, and can by making the performance of a player character dependent on the users exertion. I.e. two users with similar exertion perform similarly in the game, even though their actual performance varies significantly due to different levels of fitness.

The heart rate dependence of the virtual trainer can be considered a type of handicapping, whereas the distance dependency is a type of rubberbanding.

3.3 Feedback

The game includes a number of different forms of feedback which can be enabled or disabled according to the profile of the player. These feedback types provide encouragement and information about the player's performance. It is important that the feedback options given can be calibrated to the player, as some past research indicates that such positive feedback may increase the intrinsic motivation for some individuals, but decrease it for others [18].

3.3.1 Written feedback

Written feedback is a useful tool for motivation. It allows for the giving of explicit feedback about specific aspects of a player's performance, in a relatively non-intrusive manner. The feedback takes the form of 'messages' from the trainer to the player. We have two general categories of written feedback: distance based and multiplier based. The distance based feedback is a selection of messages that are displayed based on the distance between the player and the trainer, offering congratulations if the player is in front, and encouragement if they are behind (see figure 4). Each category has a number of possible messages; the message to be displayed each time is chosen randomly in order to maintain a sense of relevance to the player. This feedback is displayed near

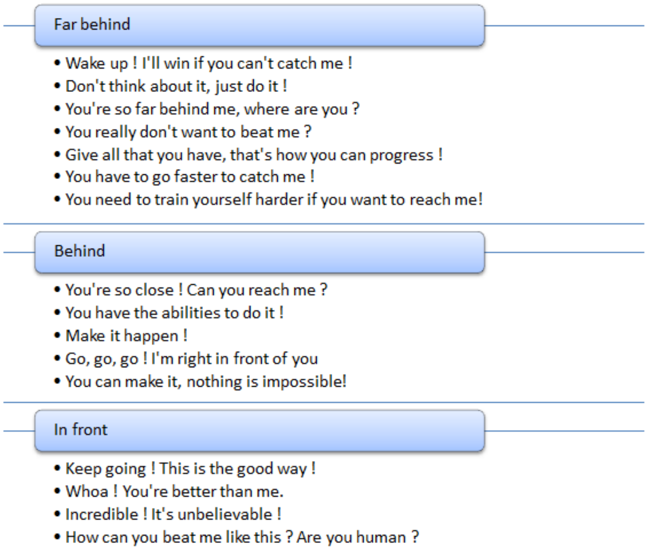

Figure 4: The three groups of positional feedback used by the competitive trainer.

Figure 5: Screenshot of the game showing the feedback when the player is far behind the trainer.

Figure 6: Screenshot of the game showing the feedback when the player is close and behind the trainer.

the top of the screen.

The first category of distance based feedback is used when the player is far behind the trainer; the feedback encourages player to work harder to catch the trainer (see figure 5). The second category is used when the player is close behind the trainer, the feedback encourages the player to push just a little harder to beat the trainer (see figure 6). The third category is selected when the player is in front of the trainer, in this case the feedback congratulates the player and encourages them to continue their efforts (see figure 7).

The multiplier based feedback is a set of messages displayed when the player avoids enough obstacles (see figure 10), displayed underneath the score and multiplier indicator.

3.3.2 Vocal feedback

Written performance feedback that appears periodically may bother the player as it may draw their attention away from the gameplay elements. If this causes them to fail to avoid an obstacle it could be frustrating if they are approaching the game with a competitive or goal oriented, maximum-score mindset.

An alternative form of feedback is vocal feedback. Vocal feedback gives the same information as written feedback, but through audio rather than on-screen messages.

3.3.3 Detailed information

Detailed feedback over multiple exercise sessions about a user's performance and metrics has been linked with greater exercise adherence [1]. The ability to give users direct feedback about their exercise statistics is thus useful. However, we hypothesize that these statistics will be more motivating for those approaching the game with an inclination towards exercise rather than gaming. Detailed information about the user's exercise performance can be shown on the right part of the screen and contains 4 pieces of information : the

Figure 7: Screenshot of the game showing the feedback when the player is in front of the trainer.

Figure 8: Screenshot of the game showing the detailed information (Heart Rate, Speed, Distance traveled and Distance with the trainer).

heart rate, the speed, the distance traveled, and the distance between the trainer and the player (figure 8). These kinds of information are useful to motivate the player and allow them to compare their performance to previous play attempts.

3.3.4 Positive information

The positive information is here to inform/congratulate the player when they achieve certain targets such as reaching a certain distance, avoiding a lot of obstacles or getting a certain percentage of the bonus boxes (see figure 9). The goal of this feature is to show that the player can obtain results thanks to their effort.

3.3.5 Score multiplier

The aim of the score multiplier is the same that the positive information, it rewards the player if they successfully avoid multiple consecutive obstacles (figure 10). The score multiplier increases by 1 for every 7 obstacles the player avoids. The multiplier is displayed to the right of the score (see figure 9).

3.4 Choice of the path

When the track branches, one path is low risk, low reward, containing few obstacles and no bonuses. The other path is high risk, high reward, containing many obstacles and bonuses (see figure 11). As mentioned previously, exergames are approached with two primary motivations, to relax and to achieve [10]. For a player who has an achievement motivation, the high-risk high reward branch is the ideal choice. For a player with the relaxation motivation, the low-risk branch may be more appealing. When following the trainer, the trainer should be selecting paths that align with the user's goals.

Figure 9: Screenshot of the game showing the player's score with associated positive feedback and multiplier.

4. IMPLEMENTATION

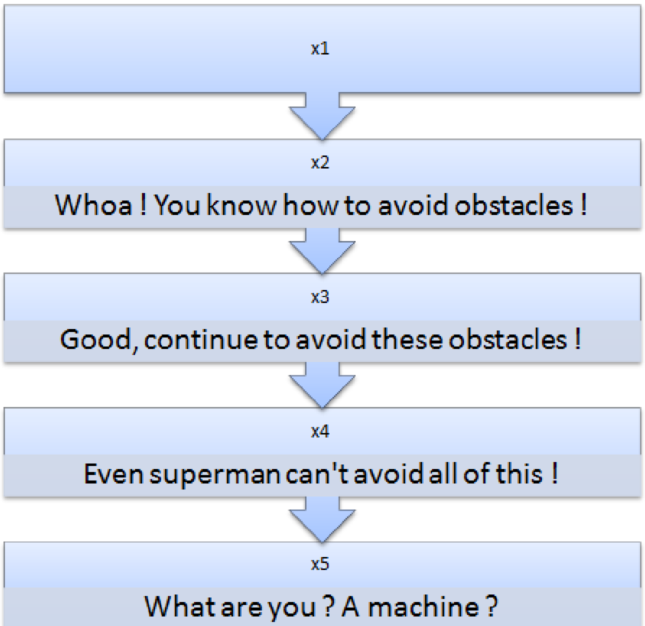

Figure 10: Different positive information according to the multiplier.

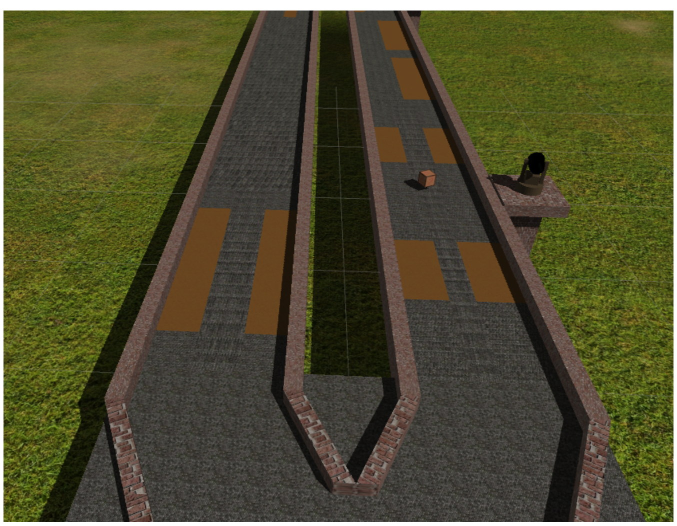

Figure 11: Overhead view of the game showing an easy path (on the left) and a hard path (on the right).

Figure 12: User on the exercise bike, wearing the Oculus Rift and headphones. The depth camera is visible in front of the user.

4.1 Hardware

To control the character, we use a Creative SENZ3D depth camera and a LifeFitness 95CI Upright Exercise Bike (figure 12). When the player leans to the left or right, their in game representation moves left or right respectively. The more the player leans, the greater the rate of lateral movement. To avoid overhead obstacles, the player have to duck and the character responds in moving his head down. To look around, the player needs to move his head and to move forward, the user has to pedal.

The exergame sends and receives data from the bike thanks to the Communications Specification for Fitness Equipment (CSAFE) port of the bike. The resistance of the bike is controlled by an Arduino microcontroller which triggers the bike's inbuilt resistance system.

The game is displayed to the user on an Oculus Rift DK1 head mounted display, and audio is provided via the Logitech G35 headset, chosen for its positional sound features.

4.2 Software

The exergame is written using the Unity game engine, version 4.6, using the standard Unity package provided by Oculus VR to support the Oculus Rift. Motion tracking is handled by a separate application using the Intel Perceptual Computing SDK, which streams data to the game engine.

5. PILOT STUDY

We conducted a small pilot study of six users to test the effectiveness of the different trainer systems and see whether user motivation increased when using a trainer system which matched their level of competitiveness.

For this pilot, rather than exercising only with the game customized to their personality, each user tested both of the trainer systems as well as playing the game in the absence of a trainer. This allows us to see if the trainer profile which we would expect to be most motivating for a user is actually so. Participant's competitiveness was measured using the Sport

Table 1: Mean percentage of time spent in each heart rate zone

	Low	Average	High
Default Condition	20%	58%	22%
Competitive Condition	10%	51%	40%
Cooperative Condition	13%	59%	28%

Orientation Questionnaire (SOQ) [4]. This questionnaire evaluates three metrics of the subject: their competitiveness, win, and goal orientations.

The participants completed three ten minute exercise sessions, one for each of the conditions given below. The test conditions were performed in a random order, and separated by five minute breaks to allow the user to recover their stamina. Following each session, the participant completed a short questionnaire in which they answered statements about their enjoyment and motivation on a seven-point Likert scale.

1. Without trainer - Basic Condition.
2. With competitive trainer - Competitive Condition.
3. With cooperative trainer - Cooperative Condition.

In the basic condition, there is no trainer present, and no direct feedback provided to the user about their heart rate or performance (other than the natural changes of points in response to game events). The competitive condition is played with a trainer exhibiting competitive behavior present, and includes textual information about the user's heart rate and speed, and both textual and vocal feedback about their performance. In the cooperative condition, the trainer is again present and demonstrates cooperative behavior. This condition provides vocal feedback about the user's performance.

5.1 Pilot Study Results

The results of the pilot study show promise for the effectiveness of the training system. Most participants rated the game as highly enjoyable and motivating in each of the conditions. Each condition elicited a desirable level of exercise. Table 1 shows the mean time spent in each heart rate zone for each condition. Each condition had a mean time in the moderate or high heart rate zones of least 80% of the session, with the trainer conditions being more demanding.

Competitiveness shows a strong positive correlation with motivation in both the competitive and cooperative conditions, but the correlation is stronger for the competitive (r=0.7) than the cooperative (r=0.54). Similarly, winning orientation shows a strong positive correlation with motivation in the competitive condition (r=0.69), but only a moderate correlation with motivation in the cooperative condition (r=0.38). However, goal orientation shows a weak correlation with motivation in the competitive condition (r=0.15), but a moderate correlation with motivation in the cooperative condition (r=0.44).

Two-tailed Wilcoxon signed-rank tests show that differences in distance travelled and calories burned between each of the trainer conditions and the basic condition are not significant at a p-value threshold of 0.05.

6. CONCLUSION

This paper presents an exergame and associated trainer system which aims to improve the long term motivation of users to exercise by delivering an experience customized to the factors that the user will find motivating. This is achieved through differing trainer behaviors and types of feedback within the game. The use of the player's heart rate as an input allows for the game to provide an experience suited to the particular fitness level of the user.

Results from our pilot study indicate that the game is enjoyable and motivating, particularly when playing with the trainer system most aligned to the personality of the user. In particular, the competitive trainer profile appears much more motivating for competitively inclined individuals, and the cooperative trainer is much more motivating for goal oriented individuals. The game is effective at eliciting moderate to high intensity exercise for the duration of play, fulfilling the core purpose of being effective as a mechanism to increase user exercise levels. While the addition of the trainers does not appear to significantly increase exercise performance beyond that of playing the exergame normally, the overall high intensity of the exercise indicates that this is due to the user performing at a high end in every condition.

Our results suggest that virtual trainers are a valuable addition to exergames and can be used to improve motivation during exercise. This is in particular the case if before usage a personality profile of the user can be obtained, e.g. using a standard questionnaire such as the SOQ, and based on this the competitive or collaborative trainer is chosen.

6.1 Future Work

Future work for this research will involve further evaluation of the existing trainer profiles with an extension of our pilot study. Further, while our exergame system effectively targets the personality factors associated with competitiveness, it will be interesting to see what other motivation factors can be customized for users with different characteristics.

We are also interested in developing the trainer system to automate the selection of the customizable parameters. Rather than requiring a personality test to select a trainer profile, it would be ideal for the game to analyze the user's behavior and modify the trainer's properties accordingly.

7. ADDITIONAL AUTHORS

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