Physical Activity Enjoyment on an Immersive VR Exergaming Platform

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***Abstract*—Virtual reality (VR) can be combined with exergames technology to provide highly immersive physical activity experiences. The design of VR exergames, so they are enjoyable and engaging, for different age groups, is currently under-investigated. In this paper, we study enjoyment of physical activity on VR-Rides, a virtual exergaming platform with a recumbent trike controller. In our experiment, we assigned participants to one of the two conditions; a static *user interface* (UI) or an *Open World* VR environment which allowed participants to explore a virtual location using Google's Street View 360 panorama images. In both conditions, participants could track their activity data in real-time. The results suggest higher enjoyment and more activity time in an *Open World* condition, where participants are encouraged to explore a virtual location. Almost half of participants in the UI condition showed disinterest after a short interaction time, due to the static environment.**

I. Introduction

Exergames – games that engage players in exercise or other levels of physical activity, use bodily movements as a means of interaction. The interactivity in the game engages players making physical activity more fun and enjoyable. Current exergame literature reports application in diverse demographics such as healthy young [1] and older adult [2], rehabilitation groups [3] and those with cognitive issues [4].

Exergames can be grouped into commercial and noncommercial. Since engagement is driver for sales, the first generally puts higher emphasis on entertainment. Commercial games have also been evaluated [5, 6]. For example, *Nintendo Wii* and *Microsoft Kinect* are commercial platforms with widely studied exergames. The commercial imperative means they are often designed broadly for healthy young adults, although other groups often appropriate them and find them engaging [5].

Noncommercial exergames includes those specifically designed for research purposes to investigate different game variables in relation to aspects of physical activity, such as motivation or enjoyment. However, there is a disconnect between academic and commercial games, predominantly due to limited resources available to academics for developing new high quality exergames. Additionally, licensing issues prevent academics from making changes to the content in commercial exergames, for research purposes.

Exergames use controllers such as *Dance pads*, *Nintendo Wii*, *Microsoft Kinect* as well as regular *bicycle* or *gym cycles* [7] (natural pedal interaction). Most recently Virtual Reality (VR) headsets and controllers have created opportunities for experiences beyond those possible in 2D environments. A study that compared Oculus Rift VR headset with the desktop setup suggests that participants experience higher degree of engagement and deeper immersion (i.e. perception of being present in the game environment) in the virtual environment [8].

But few studies to date have evaluated exergaming setups with head mounted displays. In an early attempt at combining exergames with virtual reality, Bolton et al. [9] developed *PaperDude*, as VR environment where participants engaged in natural pedaling movements on a bicycle whilst wearing a VR headset. The researchers claimed a high level of immersion due to natural pedal movements and a use of avatar to represent player. However, this platform was not formally evaluated against a (non-)VR environment. In a similar attempt, Shaw and colleagues demonstrated immersive virtual reality as a promising media to motivate and engage sedentary users to perform better in their exergaming sessions when compared to a monitor interface and bike only. This study however was evaluated with small sample size and reported major concern of motion sickness [10].

Our *VR-Rides* project [11, 12] is a virtual reality exergaming platform that supports physical activity of moderate intensity. In our previous study we found that VR-Rides was well perceived by both young and older adult players. In this paper, we report our findings about enjoyment and engagement associated with two VR-Rides exergaming experience in a controlled environment. We examine one main question: *Is it more enjoyable for a player to be able to freely navigate the virtual environment compared to a static image with real-time activity data?* Following an experiment where participants were assigned to one of the two design conditions, we report in this paper the differences in activity enjoyment experienced by the two groups. Physical activity enjoyment is studied using three measures: 1) Physical Activity Enjoyment Scale (PACES) [13]; 2) the actual activity time, which is the time spent playing the game, compared to a time-goal set by the participant prior to game play, and 3) intension for future play. We also report participants verbal feedback during their activity on VR-Rides platform, which was collected using think-aloud technique. This study presented in the paper is part of a larger research program that aims to investigate motivational determinants of immersive VR exergames and their contribution to the player's engagement with the game.

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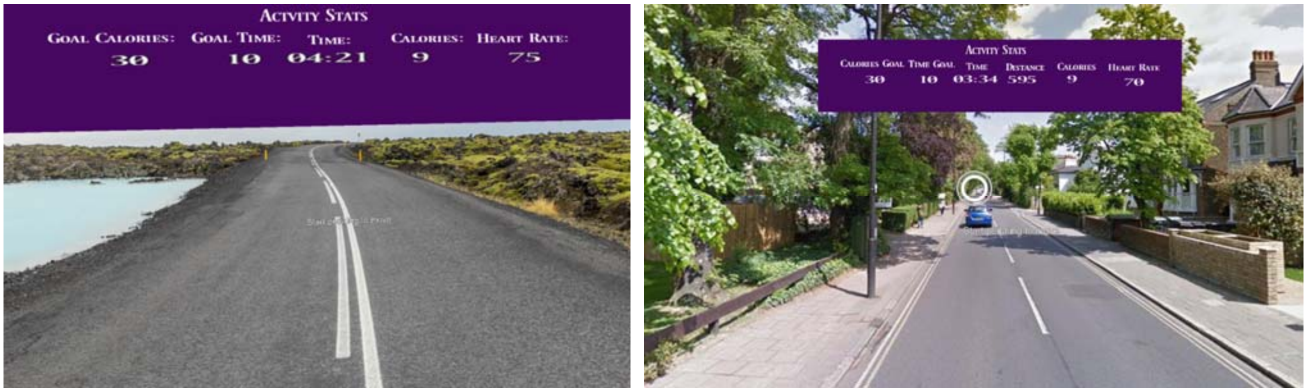

Fig. 1. (a) Condition I – UI (b) Condition II – Open World

II. Study: VR-Rides

VR-Rides is an immersive VR exergaming platform that uses a stationary recumbent trike. A sensor attached to the rear wheel tracks the speed that is sent through an android App to the laptop. The trike acts as a game controller and allows the player to interact with the environment. The VR environment is Google's Street View 360 panorama images of real world locations fetched through a web service. The virtual experience is built using the Unity game engine and combines the visual content, trike movement and participant's physiological data. The participant can experience this immersive environment using an HTC virtual reality headset, where one HTC controller, attached to trike's handle bar, tracks the direction. This study was approved by the Human Research Ethics Committee [Protocol No 2016/996] at the University of Sydney.

A. Setting

Two virtual environments were created with VR-Rides (screenshots shown in Figure 1):

- Condition I: *User Interface* (UI) consists of a static image of a scenic road combined with real-time activity data on time, current heart rate, and calories spent. In-game audio and visual instructions guide the participants to keep pedaling.
- Condition II: *Open World* depicts visual content from Google Street View imagery, specifying distance traveled, activity data (time, heart rate and calories spent). The participants first explore an Australian city to learn about the controls and environment. Then, the participant lands in another city where they can pedal around and explore the neighborhood. The starting and landing location was the same for all participants.

B. Participants

N = 46 participants aged 17 to 28 (M = 21.48 SD = 2.53, Male = 37) took part in the study. They were recruited in the campus of an Australian university. All participants gave informed consent. Two participants were excluded in this experiment due to technical issues. All participants were randomly allocated to one of the two VR-Rides conditions; UI = 20 and Open World = 26. Due to recruitment logistics, we do not have equal number of participants in both conditions.

C. Method

Participants completed a pre-test questionnaire including demographics (age, gender, weight, and height), physical activity routine (weekly frequency), prior experience with wearable activity monitoring devices, video game play routine (weekly frequency) and exergames routine (frequency of use and monitoring of activity data), VR experience and past participation in any VR-Rides study. Participants then advised their likelihood of motion sickness. A Microsoft wristband version 2 [14] was fitted on the participant's to monitor their physiological data (heart rate and calories spent).

The novelty of the VR environment has a strong impact on participants' perception about the games. To minimize this effect each participant experienced a 3-minute VR tutorial. While sitting on the recumbent trike, with the headset, they stated the length of time they wished to engage with the VR-Rides. Next, each participant used the VR-Rides in a pre-assigned condition I or II. Participants reported their experience during the activity (think-aloud method).

After completing the session, they provided feedback about the VR-Rides experience using a post-test questionnaire including PACES [13], Player Experience of Need Satisfaction (PENS) [15] , future play intension and any motion sickness experienced during the activity. This paper only reports on PACES, activity time and future play intension to evaluate participant enjoyment. PACES evaluate enjoyment and vitality of physical activity using 18 items. In this study, we used 9 questions that specifically address activity engagement. Those includes 7-point Likert questions: Q1 (I enjoy it), Q2 (I feel bored), Q4 (I find it pleasurable), Q5 (I am very absorbed in this activity), Q6 (It's no fun at all), Q7 (I find it energizing), Q10 (I feel good physically while doing it), Q16 (It gives me a strong sense of accomplishment) and Q18 (I felt as though I would rather be doing something else). Few items were reverse coded as per original PACES guidelines before any further analysis.

D. Results

In total, 33 (70%) of participants had previously played an exergame and 24 (50%) participants had tried VR in the past. However, only 10 (21%) participants were users of a wearable physiology tracking device. 14 (30%) played video games regularly with frequency (1 - 3 times weekly). Only 8 (17%) of participants indicated likelihood of motion sickness on a moving vehicle.

TABLE I. PARTICIPANTS TARGET AND ACTUAL ACTIVITY TIME (MIN:SEC)

	Min	Max	Mean	SD
Condition I: UI				
Activity Goal	2:00	8:00	5:05	1:22
Activity Time	0:44	6:09	3:52	1:31
Condition II: Open World				
Activity Goal	1:00	20:00	5:43	3:59
Activity Time	1:27	10:09	6:02	2:26

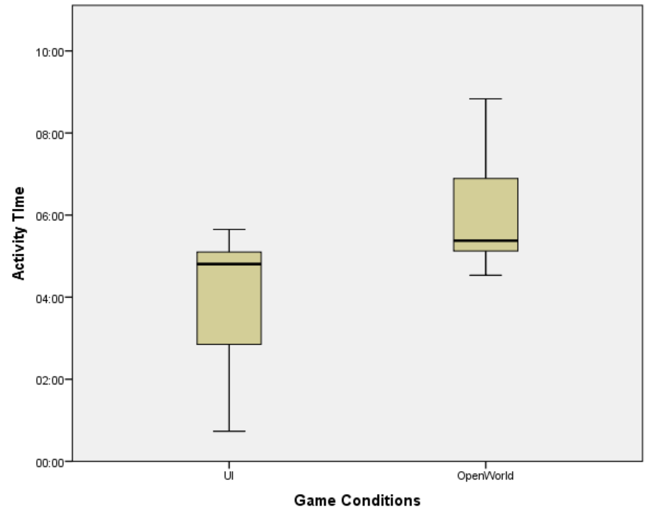

Fig. 2. Activity time on VR-Rides in two conditions

Behavioral Differences – Activity Time:

At the start of the session participants were asked to set a time goal for their activity. Participants were still able to withdraw from the study at any time. The goal set was compared to the actual time spent on VR-Rides. Details are reported in Table I for the two conditions. An independent samples t-test showed a significant difference in actual activity time between *UI* and *Open World* groups; t (44) = -3.46, p = 0.02. Participants in the UI condition spent on average less time (3:52 mins, SD=1:31) than the goal they set (5:05 mins, SD=1:22). Participants in the *Open World* condition spent more time (6:02 mins, SD=2:26) than set goal (5:43 mins, SD=3:59). Higher activity time by *Open World* participants in comparison to the *UI* participants is graphically presented in Fig. 2.

PACES and Two VR-Rides Conditions:

An independent sample t-test on individual items of PACES was used to compare the two conditions, results are outlined in Table II. The results suggest significant difference for *Q1 (I enjoy it)*; *t* (44) = -.463, *P* = .04 between *UI* (M = 4.95 SD = 1.79) and *Open World* (M = 5.15 SD = 1.19). Participants ratings of *Q10 (I find it energizing)* also depicted significant differences for *UI (*M = 5.35 SD = 1.69*)* and *Open World (M = 5.08 SD = 1.16)*; *t* (44) = .648, *P* = .01. It is interesting to note that *UI* participants reported their experience as more physically energizing while *Open World* participants found their experience more enjoyable. All remaining items of PACES did not demonstrate any significant differences in the two conditions. Irrespective of the condition assigned, participants in both conditions reported similar pleasurable experience *Q4* (*UI*: M = 4.65 SD = 1.69, *Open World*: M = 4.46 SD = 1.45) or otherwise boring *Q2* (*UI*: M = 3.90 SD = 1.83, *Open World*: M = 4.23 SD = 1.68) , had similar ratings of being fully absorbed in the activity *Q5* (*UI*: M = 4.05 SD = 1.67, *Open World*: M = 4.62 SD = 1.53), having fun *Q6* (*UI*: M = 4.10 SD = 1.77, *Open World*: M = 4.58 SD = 1.58) and energizing *Q7* (*UI*: M = 4.95 SD = 1.39, *Open World*: M = 4.42 SD =1.33). We learnt from our past experiments that initial habituation of VR environment plays critical role in reducing the novelty effects of this immersive technology. In response to *Q16 (It gives me a strong sense of accomplishment),* the ratings indicated that *UI* group (M = 4.10 SD = 1.89) had a slightly better sense of accomplishment compared to *Open World* group (M = 3.38 SD = 1.50). We expect these slight differences in sense of achievement to be due to the easy controls in *UI* condition where participants just had to pedal during the activity. In contrast, *Open World* participants, had to learn the controls to navigate in a virtual city and turn the trike to steer towards left or right directions. Participants preference of other activity over current session was reported low in both cases *Q18* (*UI*: M = 3.00 SD = 1.41, *Open World*: M = 3.77 SD = 1.03).

TABLE II. INDEPENDENT SAMPLE T-TEST - ENJOYMENT SCALE FOR TWO VR-RIDES CONDITIONS

PACES Scale	UI	Open World	T-test Results
Q1	M = 4.95 SD = 1.79	M = 5.15 SD = 1.19	*t* (44) = -.463 *P* = .04*
Q2	M = 3.90 SD = 1.83	M = 4.23 SD = 1.68	*t* (39.10) = -.629 *P* = .80
Q4	M = 4.65 SD = 1.69	M = 4.46 SD = 1.45	*t* (37.39) = .398 *P* = .24
Q5	M = 4.05 SD = 1.67	M = 4.62 SD = 1.53	*t* (39) = -1.18 *P* = .90
Q6	M = 4.10 SD = 1.77	M = 4.58 SD = 1.58	*t* (38.38) = -.95 *P* = .67
Q7	M = 4.95 SD = 1.39	M = 4.42 SD = 1.33	*t* (40.04) = 1.29 *P* = .91
Q10	M = 5.35 SD = 1.69	M = 5.08 SD = 1.16	*t* (44) = .648 *P* = .01*
Q16	M = 4.10 SD = 1.89	M = 3.38 SD = 1.50	*t* (35.63) = .42 *P* = .18
Q18	M = 3.00 SD = 1.41	M = 3.77 SD = 1.03	*t* (33.48) = -2.04 *P* = .28

Relationship between Activity Time, Future Play Intension, Past Experiences and Enjoyment Scale:

Actual Activity Time on VR Rides platform did not demonstrate significant relationship with any other experiences and PACES (median). Also, prior experiences with VR and exergames technology, and frequency of physical activity per week reported in pre-test questionnaire showed no significant relationship with PACES (median). In UI condition, 50% (10) of participants expressed intention to play on VR-Rides for a few more minutes. In comparison, only 34.6% (9) participants wanted to try VR-Rides for few extra minutes after current session (future play intension). We assume this lack of interest to continue after current session was due to longer activity time in *Open World* condition.

Future play intention (FP) for VR-Rides in UI condition was strongly but negatively correlated ($M = 1.50$ $SD = .51$ $r = -.49$ $p = 0.02$) with past video games frequency ($M = 2.85$ $SD = 1.95$) and strongly correlated to VR experience ($M = 1.45$ $SD = .51$ $r = .50$ $p = .02$). However, FP in *Open World* condition does not strongly correlate to any other participants' said technology experiences. Same number of participants in both *UI* (Yes = 2 No = 18) and *Open World* (Yes = 2 No = 24) conditions reported motion sickness. It is worth noting that UI condition has no navigation or movement in virtual space that could cause sickness.

Participants verbal feedback collected using the think-aloud technique, provide us further insight about their experience with two conditions. About half of the *UI* group 45% (9) asked questions such as: "Am I meant to move?", "Is this thing supposed to be moving?", "Is something supposed to be happening?". On researcher's response of this condition being static, participants expressed disappointment or disinterest "Oh that's unfortunate" or "It's incredibly boring". However, we also observed in *UI* condition comments such as "there are 35 seconds left to my set goal" where the participant was motivated to meet their activity goal. In contrast, *Open World* was positively received and had feedback such as "This is the future, O man!", "That was amazing, that was cool", "You can turn with trike, aw pretty cool".

III. Discussion

This study compared enjoyment for moderate physical activity in two VR exergame conditions. For both conditions, participants could track real time activity data (activity time, heart rate, and calories spent) during the session. Participants in both groups found VR-Rides appealing and pleasurable activity. Though, *Open World* group had higher enjoyment that was confirmed by their behavior (time spent) during the activity. In comparison, UI group experienced higher vitality where participants were trying to achieve their activity goal observed through verbal feedback. Post-test ratings of PACES items depicts that *UI* group was engaged in activity as they felt more energized compared to *Open World* group who reported higher enjoyment. Behavioral data suggests that *Open World* (M = 6:02) participants spent more time on VR-Rides in comparison to *UI* (M =3:52) participants. Future play intention for UI condition showed strong and negative correlation with past video games frequency (experienced interactive games players) suggesting preferences for interactive environments than a static interface. Participants in both groups showed similar interest and immersion. Note that setting the initial activity goal prior to game play may have impacted these results, particularly for those participants with frequent weekly physical activity and past exergames experience.

In our future work, we aim to further investigate the activity enjoyment on VR-Rides, eliminating the requirement for the participants to set an activity goal and removing the VR tutorial prior to the experiment. We believe such changes may reveal interesting behavioral patterns. In addition, we aim to gain a better understanding of various design elements of the VR-Rides and links to motion sickness.

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