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Player Experience of Needs Satisfaction (PENS) in an Immersive Virtual Reality Exercise Platform Describes Motivation and Enjoyment

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Player Experience of Needs Satisfaction (PENS) in an Immersive Virtual Reality Exercise Platform Describes Motivation and Enjoyment

Recent research suggests that VR games can engage players in physical activity with high levels of enjoyment. Understanding users' motivation to engage and enjoy immersive VR exercise platforms is thus important to designers. We designed a VR exercise platform and conducted an experiment with two conditions, one with a static User Interface (UI) and the other with an Open World environment. Across participants there was significantly ($p= .03^*$) greater enjoyment reported in an Open World compared to static UI. Enjoyment in both static UI and Open World conditions was positively correlated with user's psychological needs and experience; autonomy and immersion. Participants' future play intention was also predicted by autonomy and immersion, but only within the open world condition. Our findings also suggest players can be classified into entertainment-focused and exercise-focused with different expectations and therefore different engagement behaviours with each VR exercise environment. The study highlights the value of informing VR design with measures of psychological need satisfaction.

Keywords: immersive virtual reality; VR exergames; self-determination theory; motivation; enjoyment

1 Introduction

The recent prevalence of consumer level immersive Virtual Reality (VR) products provides highly engaging experiences and opens doors for academic research. As commercial headsets are becoming increasingly affordable and accessible to the general public, one emerging area of VR application is to support active life style or physical activity. A range of studies have explored this technology, even before the arrival of new generation VR Head Mounted Devices (HMDs). For instance, VR motion training systems were found effective to transfer knowledge from a ghost trainer to the trainee (Kim, 1999). Other examples include a VR track cycling platform developed by Yap and colleagues to simulate real track conditions for training purpose (Yap et al., 2018) and a virtual exercise assistant designed by Rabbi and colleagues to provide immersive and interactive gym experience to users (Rabbi, Park, Fang, Zhang, & Lee, 2018).

Our goal is to explore factors associated with the user's experience of using an exercise platform with a VR component, which in turn can influence their motivation for engaging with physical activity. Motivation is the driver that determines a person's level of engagement with an activity, their adherence to it and their behaviour as the result (Reis, Gable, & Ryan, 1995; Ryan & Deci, 2000). Moreover, the user's background influences the technology acceptance in terms of perceived usefulness, ease of use, perception of controls and enjoyment (Sun & Zhang, 2006; Venkatesh, 2000). To study motivational drivers, we built a VR exercise platform which can be manipulated for various experimental set ups, from a simple simulated open world to a gamified environment. Studies on immersive VR exercise platforms are still evolving as an emerging field of research. Therefore, to establish an understanding of user motivation linked to this type of technology, we refer to research on exergames – games that encourage physical activity. Those are increasingly investigated in both Human-Computer Interaction (HCI) as well as health literature, whereby exergames are also sometimes referred to as active video games (Biddiss & Irwin, 2010) or serious games (Wiemeyer & Kliem, 2012). A platform (such as the one we use in our research) can be distinguished from an exergame, in that a platform is a combination of technologies that provides a basis for designing various applications, such as an immersive VR exercise application.

A software framework for developing custom games (Wang, Ijaz, & Calvo, 2017) can be used to test design hypothesis around different motivations. This approach can contribute to the growing body of research on motivation and its determinants (Ryan & Deci, 2017), as discussed in section 2.2. The existing literature suggests that engagement in video games and the cognitive, motivational, emotional and social aspects of use (Granic, Lobel, & Engels, 2014; Rigby & Ryan, 2011) is a function of experiencing psychological need satisfaction (Peters, Calvo, & Ryan, 2018). In an ongoing research, we study the degree to which those needs are satisfied as the result of users' engagement with various design elements of an immersive VR platform and how they impact user enjoyment. As psychological needs are highly subjective phenomena, we engage users with diverse demographics to also examine differences in their motivation needs which may have implications for future design strategies of such platforms.

This paper examines the impact of immersion and availability of physiological exercise data on user psychological need satisfaction, enjoyment, and motivation. In future studies, we aim to add explicit game elements to the platform. Exploring user motivation and experiences as they emerge in the design process can contribute to our ongoing research on immersive exergames and inform the future design guidelines of these environments.

Exergaming literature (Li & Lwin, 2016; Peng, Lin, Pfeiffer, & Winn, 2012; Song, Kim, Tenzek, & Lee, 2013) parallels motivational design with game elements such as points, challenges, choices, avatars etc. However, immersive VR exergames are complex and layered systems where many features such as active physical interaction with the virtual environment, immersion in the virtual environment, and game mechanics can contribute to user's need satisfaction. We postulate that the very immersive nature of VR environments, similar to desktop virtual environments (Shin, 2017) without any sophisticated game elements, can potentially influence user's need satisfaction. Therefore, we use a bottom up approach to develop an understanding of immersive VR exercise platform and its impact on user's motivation and enjoyment, measured through self-reported Player Experience of Need Satisfaction (PENS) model (Ryan, Rigby, & Przybylski, 2006). The model has been used to study video games and is based on the Self-Determination Theory (SDT) (Ryan & Deci, 2017), a theory that has been used extensively to research motivation for exercise. The suitability of PENS for a platform combining VR and exercise is unique. Through our study we aim to explore a number of research questions such as: can PENS model describe motivation of immersive VR exercise platform users? To what extend do elementary immersive VR environments without any game elements contribute towards user's need satisfaction? Will more immersion be motivating for exercise?

Since immersive VR exergames are still in their infancy, we believe using a psychological model to investigate a VR platform for exergames will help to explain motivation and provide useful design insights. In an experimental set-up, we use self-reported measures of PENS with recordings of physiological signals, acting as proxy for physical exertion, to study motivation, enjoyment, and affect and their link to participants background. To explore the role of immersion, we compare a static User Interface (UI) condition to an Open World (OW) condition, both on a VR platform. In the next section, we provide a brief overview of PENS and exergames, followed by details of our experimental set-up using VR-Rides, our immersive VR exercise platform. The study method and results follow, before a general discussion and conclusion.

2 Background

2.1 Player Experience of Need Satisfaction (PENS)

SDT provides an explanatory framework for why individuals participate, exert effort and persist in a given activity. Cognitive Evaluation Theory (CET), a sub-theory within SDT links motivation to three basic psychological needs namely autonomy (a sense of volition), competence (a sense of mastery over tasks) and, in relevant contexts, social relatedness (feeling related to significant others). According to CET, the extent to which those needs are satisfied would determine the level of motivation a person has for a given activity (Ryan & Deci, 2002). SDT has been widely applied to exercise, highlighting the importance of autonomous self-regulation to motivate physical activity (Teixeira, Carraça, Markland, Silva, & Ryan, 2012). Player Experience of Need Satisfaction (PENS) model was subsequently derived from SDT framework to investigate video games.

Ryan, Rigby and Przybylski applied the CET motivational model to video games in four different studies to develop the PENS model (Ryan et al., 2006). In predicting game enjoyment and persistence; Ryan et al. (2006) developed measures of in-game need satisfaction for autonomy, competence, intuitive controls and players' sense of presence during the game play. They assessed presence in terms of the players' emotional, physical, and narrative immersion in the game. Consistent with the PENS model, their research showed that games were more engaging and motivating when they afforded greater experiences of autonomy, competence, and presence. This SDT-based model for video games (see also (Przybylski, Rigby, & Ryan, 2010)) has been further extended to investigate need satisfaction in video games and short-term wellbeing. PENS model was also applied to other related areas such as rehabilitation, David, Herrlich, & Malaka (2015) studied post-test perceived competence, autonomy, enjoyment, presence and their impact on individual's involvement in a rehabilitation session. In the present work, we use the above-mentioned PENS measures of autonomy, competence, intuitive controls, and presence to predict enjoyment and future play intentions across the two different VR Exercise platform conditions, with the expectation that UI and OW design feature will engender different psychological experiences. If PENS is then found relevant, it will provide a good theoretical basis to further research motivation and enjoyment in VR exergames in the future.

2.2 Player Motivation in Exergames

Exergames are interesting to research in at least two ways. First, using exergames to perform more physical activity can potentially result in improved physical and cognitive health in both young and older adults (Larsen, Schou, Lund, & Langberg, 2013; Staiano & Calvert, 2011; Sween et al., 2014). Existing work provides evidence on efficacy of exergames in light to moderate physical activity (Cibrian, Tentori, & Martínez-García, 2016; Lin, 2015; Pasco, Roure, Kermarrec, Pope, & Gao, 2017). There are various strategies for increasing motivation in exergames, for instance by adding an element of competition to the game (Ijaz, Wang, Milne, & Calvo, 2016). Second, beyond the goal of increasing physical activity level, exergames can be used as a platform for design research. The latter characterizes our research and the platform we have created to specifically understand the role of immersive VR components on the user's experience and motivation for engaging with physical activity.

A large number of literature on exergames to-date are based on research on third party commercial setups such as Nintendo Wii (Keogh, Power, Wooller, Lucas, & Whatman, 2014; Lwin & Malik, 2014), Microsoft Kinect (Kamel Boulos, 2012) and dance pads (Tan, Aziz, Chua, & Teh, 2002; Unnithan, Houser, & Fernhall, 2006). Apart from these, use of non-traditional game controllers such as stationary cycle and gym bike have also been recorded (Göbel, Hardy, Wendel, Mehm, & Steinmetz, 2010; Pasco et al., 2017; Yim & Graham, 2007). These have been used to navigate and play the interactive environments/games by both young and older adults alike. One of the challenges for using commercial exergames or similar platforms in research is the difficulty and cost of configuring multiple variations (due to licencing of commercial products) for experimental setups. A considerable number of academic studies have used commercial exergaming setups to study enjoyment (Kamel Boulos, 2012; Konstantinidis et al., 2016; Lin, 2015). A consequence of using fully formed and readily made platforms is therefore the limited knowledge produced in relation to designing for enjoyment in exercise platforms and exergames. The issue is visible in the limited evidence-based design guidelines for immersive VR exergames (Shaw, Wünsche, Lutteroth, Marks, & Callies, 2015). Moreover, research on exergames that have used fully immersive displays is limited. In our study, we address those limitation by exploring the possibility of using the PENS model for understanding enjoyment and motivation on immersive VR exergame platforms, which may then be used to improve design.

Advancements in VR technologies in recent years have opened new avenues for developing fully immersive interactive systems. For example, Yoo and Kay used Google cardboard and a phone's accelerometer that allows the player to exercise in form of jogging as they move through the virtual world (Yoo & Kay, 2016). Currently, only a few immersive exergames use an exercise cycle to translate pedalling into an interactive game play (Bolton, Lirette, Lambert, & Unsworth, 2014; Shaw, Wunsche, et al., 2015; Tuveri, Macis, Sorrentino, Spano, & Scateni, 2016). A related study has explored affiliative (connecting with others) versus competitive (competing with others) immersive exergame designs using VR-Rides, a VR exercise platform that allows users to ride in a virtual world using a recumbent trike connected to a HMD (Ijaz et al., 2016). The results indicated the significance of design set up for player's engagement with exercise as participants assigned to a competitive set up enjoyed their experience better and were more motivated. The flexible platform in that study included controllers (e.g., exercise bike, recumbent trike, phone accelerometer) that accommodated physical movement and interaction with the VR environment. Using a similar platform, we continue to inform our understanding on the factors associated with player motivation for exercise in the study presented in this paper.

In recent studies, several design elements of video games and their link to motivation have been investigated; results suggest better performance outcomes and enjoyment when basic psychological needs were fulfilled (Francisco-Aparicio, Gutiérrez-Vela, Isla-Montes, & Sanchez, 2013; Mekler, Brühlmann, Tuch, & Opwis, 2017; Pe-Than, Goh, & Lee, 2014; Tamborini, Bowman, Eden, Grizzard, & Organ, 2010; Wang, Schneider, & Valacich, 2015). More specifically, some studies have examined the effect of completing activities to gain rewards (Macvean & Robertson, 2013; Peng et al., 2012), the role of avatars (Birk, Atkins, Bowey, & Mandryk, 2016; Li & Lwin, 2016), competition (Song et al., 2013) and multiplayer mode (Peng & Crouse, 2013) on motivation and need satisfaction. Interface embodiment in exergames also plays an important role on user experience (presence and enjoyment), energy expenditure and intension for future exergame-play (Kim, Prestopnik, & Biocca, 2014). These experiments confirm the relevance of using player's psychological needs (Ryan et al., 2006) for explaining their motivation for using commercial video games. However, a holistic investigation of the significance of players need satisfaction for describing the enjoyment and motivation to engage with an immersive VR exercise platform is still missing from the literature. We aim to address this gap in our experiment, discussed next.

3 Experimental Setup

We used VR-Rides exercise platform (Wang et al., 2017) to design several VR environments with different elements that afford different levels of immersion and interaction. We then use those conditions to examine the enjoyment, engagement and motivations of participants while considering the user's background in exercise, gaming and familiarity with technology. We recorded the length of use and intention for future use as an indicator of user engagement with the VR exergame. The study was approved by The University of Sydney's Human Research Ethics Committee (protocol 2016/996).

[Figure 1 near here]

Two conditions were contrasted, namely a 'User Interface (UI)' condition and an 'Open World (OW)' condition, with the latter being intended to be more immersive than the former. The conditions were created using the VR-Rides exercise platform combined with several components including a recumbent trike that acts like a game controller, Google Street View 360 panorama server to fetch real world locations, an Android App to record speed and direction of the trike through a sensor attached to it and an HTC virtual reality headset. Additionally, the participants wore a physical activity monitoring device (Microsoft wrist band v.2) to record physiological data such as heart rate. The two conditions (in Figure 1) were developed using Unity game engine. Condition specific details are described below.

User Interface (UI): The UI condition was a static image of a road with real-time activity data depicted at the top of the interface. The activity data featured time, heart rate and calories burnt. Visual and audio cues in UI condition guided the participants to pedal during the exergaming session.

Open World (OW): The OW condition featured visual content from Google Street View, in addition to depicting distance travelled and activity data such as time, heart rate and calories burnt, presented at the top of the interface. To begin, participants explored an Australian city to learn the controls. Participants were then directed to another city (London) for the test. Audio and visual cues provided participants with information about current direction of movement. Both start, and landing positions were kept the same for all participants to avoid any inconsistencies. OW condition presents more choices to explore the surroundings and new landmarks.

Rational for the experiment design: The UI condition presents a single static image in the field of view whereas OW condition encompasses several linked images to give a tour of the surroundings. OW design enables the user to browse the virtual environment autonomously, therefore, we can evaluate the significance of the autonomy through this condition. We hypothesize that autonomous navigation of virtual environment in OW might improve one's immersion, and that may lead to better competence in physical activity in contrast to merely seeing the physical activity data in UI condition. These factors combined are then hypothesized to predict enjoyment of the experience as a whole. Through comparing the two conditions, we explore the following research question: can we create immersion through presenting a frame-by-frame environment in OW? Would that elicit more autonomy and therefore contribute to better competency in OW? The result will inform future designs for motivation in VR exergaming environments. We also wanted to understand the significance of users' background for their experience and therefore explore the extent to which this information should be considered in personalizing the design elements. Can weekly physical activity, video games play frequency, experience of exergames, VR and activity monitoring devices impact user's motivation and enjoyment? As VR-Rides is an exercise platform, we displayed physiological information during the activity in both conditions to help participants make their own implicit goals.

Hypotheses: Using the two conditions in our study, we aimed to explore participants' engagement and motivation with these designs in a VR exercise session. We were particularly interested to investigate the fit of PENS model for explaining user motivation with VR-Rides designs through following initial hypotheses:

(1) H1: Participants in the 'OW' condition will observe higher autonomy than their 'UI' counterparts.
(2) H2: Participants will enjoy the open world more than the static UI.
(3) H3: PENS measures for autonomy, competence and immersion should predict exergame enjoyment.

4 Method

4.1 Participants

Forty-five adults aged 18 – 59 years 62% male (n=28), mean age 26.7 years, SD ±8.6 participated. They were randomly assigned to one of the two conditions: 23 to the UI condition and 22 to the OW condition. There were no significant differences in mean age, gender distribution, weight, or height between groups, nor did the groups report any differences in terms of average weekly physical activity frequency, wearable technology experience, videogames experience, exergames experience or VR Experience (see Table 1). Fisher's Exact test indicated a significant difference between the two groups in the distribution of users who considered themselves likely to suffer motion sickness (%yes: 'UI' = 8.7% (n=2/23); 'OW'= 31.8% (7/22); p = 0.01).

[Table 1 near here]

4.2 Measures

In a pre-test questionnaire, participants provided basic demographic information relating to age, gender, height and weight, weekly exercise frequency and duration, frequency of wearable activity monitoring device use (if used) and data motoring, frequency and duration of weekly video games play, experience of commercial exergames (Yes/No) such as Wii and Kinect and their view of these devices rated via a 7-points Likert Scale (1 – strongly disagree to 7 – strongly agree). Frequency of activities were rated from none to daily. Any prior VR experience and likelihood of motion sickness (Yes/No) on a moving vehicle was also asked.

The post-test questionnaire included The Positive and Negative Affect Schedule PANAS – short form (SF) with 5-points Likert scales (very slightly or not at all –

extremely) where reliability was iteratively tested by (Thompson, 2007). PANAS – SF includes five positive (active, determined, attentive, inspired and alert) and five negative (afraid, nervous, upset, hostile and ashamed) adjectives to report affect. Player Experience of Need Satisfaction (PENS: (Ryan et al., 2006)) measured perceived competence (3 items), autonomy (3 items), immersion (9 items), and intuitive controls, i.e. perception of how seamless or user friendly the interface is (3 items). The internal consistency was tested (Cronbach's alpha = 0.93). Each item in PENS scale collected feedback on a 7-point Likert Scale (1 – strongly disagree to 7 – strongly agree).

In addition, participants completed the Intrinsic Motivation Inventory - IMI (Ryan, 1982) questionnaire to measure motivation and enjoyment (7 items, with 7-point Likert Scales) with Cronbach's alpha = 0.92. To assess the occurrence of motion sickness, participants were asked "Did you experience motion sickness during virtual reality session?" (Yes/No). Participants reported their likelihood of future use of the system via response to a statement: "I am likely to try VR-Rides again in the future" on a 7-point Likert scale (1 – strongly disagree to 7 – strongly agree). This study had seven dependent variables such as perceived competence, autonomy, immersion, intuitive controls, future play intention, positive affect and negative affect. The likelihood of using the VR-Rides again immediately post session was assessed with the following question: "Would you like to try VR-Rides again now? With the follow-up item: If no, why?". Participants verbal feedback on VR-Rides platform was collected through think-aloud technique during the session. To create a frame of reference for the player's competency, we also examined potential differences in physiological signals such as heartrate and RR-intervals of participants in the two VR conditions.

4.3 Procedure

Participants read a Participant Information Sheet describing the study and provided their informed consent, followed by completing the pre-test questionnaire. Participants were then allocated randomly to one of the two VR-Rides conditions (UI or OW). A Microsoft wrist band (2) was fitted to monitor and record the activity for both groups. This activity monitoring device was adjusted before the VR session to keep record of base values (e.g. heart rate at rest). Participants were assisted to sit on the trike, wear the headset and familiarize themselves with the VR-Rides setup for couple of minutes. They were not given any general VR tutorial prior to sitting on the trike but were instructed to do VR-Rides activity for a few minutes on their own. This choice later led participants making implicit goals for riding few minutes (e.g. 5 minutes) or reaching to specific landmark in OW condition. However, the two VR-Rides conditions had built-in introduction to the environment to enable participants to successfully complete the activity (use VR-Rides exercise platform for a few minutes on free will while interfacing with either UI or OW design). After the activity, participants filled the post-test questionnaire. At this stage, participants were asked about their willingness to continue the activity for a few more minutes and report specific reason for their decision in post-test questionnaire.

5 Results

Activity time: Independent sample t-test shows that there are group differences between UI (N = 23) mean activity time (SD) = 4:40 (3:21) Min = 1:07 Max =12:03 and OW (N = 22) mean activity time (SD) = 9:19 (6:23) Min = 2:11 Max = 27:20 groups $t\ (43) = -3.08$, $p = .004$. Participants in OW group spent significantly more time doing the moderate activity on the trike. A box-plot (Figure 2) graph of play time for two VR-Rides conditions also suggests the findings.

[Figure 2 near here]

Group differences in need satisfaction, enjoyment, positive/negative affect: An independent sample t-test showed significant differences in participants' reported enjoyment ($t(43) = -2.16$, $p = .03$,) affirmed H2, perceived autonomy ($t(43) = -3.0$, $p = .004$) confirmed H1 and immersion ($t(43) = -2.12$, $p = .04$). However, there were no significant differences in ratings of competence, intuitive controls, or aggregated ratings of positive/negative affect. This answers our question about relationship of need satisfaction with basic VR designs. Results confirm that OW condition with multiple frames as a VR tour was successful at creating better immersion than UI. Also, participants in OW condition felt more autonomous with given choices and reported more enjoyment. There is need to balance between choice and distraction. For instance, in OW if participants were presented with too many stimuli (e.g. things to explore), it can undermine competence as they need to be focused on exercise but also enjoy. Comparatively, aggregated ratings of positive affects for both UI and OW shows that participants irrespective of their condition generally felt positive on VR-Rides exercise platform. A detailed description of these results is shown in Table 2.

[Table 2 near here]

Future Play: A Pearson chi-square test was performed to determine participants willingness to play in the future ("I am likely to try VR-Rides again in future"). No significant differences were observed across the two conditions, X2 (6, N = 45) = 1.60, p = .95. Additionally, an independent samples t-test was conducted to compare re-participation for few extra minutes ("Would you like to try VR-Rides again now, if no, why?") in each VR-Rides condition. There were significant differences between participation for in the UI condition (M = 1.57, SD = 0.507) and OW (M = 1.82, SD = 0.395); t (41) = 12.798, p = 0.001. More participants showed willingness to spend few extra minutes in UI condition (Yes = 10 (43%) and No = 13 (57%)) immediately after the session, in comparison to the OW condition (Yes = 4 (18%) and No = 18 (59.1%)). Participants provided a variety of reasons for not wanting to try the VR-Rides exercise platform for extra time. The common themes generated from the post-test questionnaire are reported in Table 3, along with the number of participants who reported the sentiment behind the theme. 'Boredom' and 'other commitments' were cited in both groups as a reason for not extending the session for a few extra minutes. Given that participants in the OW condition spent relatively more time in their sessions, they cited 'tired' (n=3) in addition to 'simplicity of content' (n=3) and 'preference of 3D virtual environment' (n=5) compared to a static street imagery. Participants in the UI condition also reported 'static and none interactive interface' (n=4), as reason for not extending the session. Most notably the lack of a smooth sense of movement within the OW was salient.

[Table 3 near here]

Motion Sickness: In pre-test, nine individuals indicated that they were likely to suffer from motion sickness (UI n=1, OW n=8), while in post-VR session, we found only two of those individuals experienced motion sickness, while two additional individuals reported motion sickness (OW n = 4) post-VR. Less number of motion sickness cases reported in OW can be attributed to design decision of using panorama images instead of a 3D virtual environment. Also, smooth virtual movements and orientation in VR environment were ensured in relation to pedalling speed on VR-Rides Platform.

Physical Activity and Video Games Experience: Further exploration allowed us to investigate the relationships between the physical activity frequency, BMI, exergames and video games experience and use of activity monitoring devices for two groups. We were mainly interested to observe impact of these experiences on participants enjoyment, autonomy, competence and immersion. Frequency of physical activity (exercises-focused) and frequency of video games (entertainment-focused) both exhibited a relationship among all variables of pre-test questionnaire. Linear regression model of weekly physical activity frequency reported in the pre-test questionnaire showed a significant negative impact on autonomy ($r = -.40$, $p = .028$) and enjoyment ($r = -.50$, $p = .008$) of UI participants.

Video games frequency was also negatively related to enjoyment ($r = -.66$, $p = .009$) and Immersion ($r = -.63$, $p = .015$) of OW participants. It seems the more experienced the gamer, the less these platforms-in-design impressed them.

[Table 4 near here]

Relationship between need satisfaction, enjoyment, positive affect and future play: Correlations in Table 4 show that autonomy (UI: r= .74** OW: r =.82**) and immersion (UI: r = .60** OW: r = .86**) significantly correlate with enjoyment in both VR-Rides conditions, as expected. However, these effects are relatively stronger for

OW condition. Participants' ratings of enjoyment in UI (r = .44*) positively correlate positive affect. Comparatively, perceived autonomy (r = .63**), Immersion (r = .70**) and enjoyment (r =.86**) of OW participants significantly correlate with their positive affect. UI participants' intention for future play was strongly correlated to intuitive controls (r = .67**) as shown in Table 4. By contrast, perceived autonomy (r = .58**), Immersion (r = .56**), enjoyment (r = .75**) and positive affect (r = .52*) of OW participants strongly predicted their intention for future play. The finding suggests differences in participants experiences in both conditions and confirm our hypothesis (H3). Moreover, these results illustrate some constructs of PENS model had higher impact on enjoyment such as autonomy and immersion experienced in two designs. Despite the no-game design of OW, participants' future play intension relates to perceived autonomy, immersion, enjoyment and positive effect confirms participant's interest in VR exercise platform. Where simple design of UI condition and intuitive controls apparently were only reason to play in the future.

[Table 5 near here]

In Table 5, PENS variables are simultaneously regressed onto the three outcomes, with results showing the relative importance of experiences of autonomy and immersion in the two conditions.

Heart Rate and RR Intervals in two VR-Rides Groups: Independent sample t-test suggested no significant differences in Body Mass Index (BMI) of participants in the two conditions; t (37) = -.48, p = .64. During the activity there were no significant differences in maximum heart rate in the UI (M = 89.71 SD = 12.45) compared to the OW (M = 88.17 SD = 14.57) participants; t (33.71) = .35, p = .73. When investigated for RR-interval from start to end of the activity, there was no difference in minimum RR-interval in both conditions. However, maximum RR-interval showed significant differences for UI ($M = 1.23$ $SD = 0.20$) in contrast to OW ($M = 1.37$ $SD = 0.24$) participants $t(35.38) = -1.98$, $p = .05$.

Participants Verbal Feedback: Participants' feedback using think-aloud technique provided further insights into their experiences in each condition. Approximately 70% (16/23) of participants in UI conditions asked, "Why it does not move?", "Would it move?", "I would have loved to continue the activity if there was an option to move around. Am I supposed to move?". On researcher's confirmation of being static condition, participants stated, "Can I stop?" and "Can I stop here? I want two more minutes." Comparatively, OW participants responded positively to their experiences and remarked: "I really want to go that way" and "It's fun" and were immersed in the environment "There's a car coming, it can hit me." However, many also indicated a preference for smoother movement in the VR environment saying, "Is this meant to be smooth" and some showed reactions to the discontinuous visuals. Also, they expressed a need for clear objective, "What is the destination" and "It seems this doesn't have any objective, right?".

6 Discussion

The study revealed significant differences in autonomy, immersion, competence and enjoyment between the UI and OW conditions. Moreover, within each condition experiences of autonomy and presence were most predictive of enjoyment. The study thus generally supports the PENS model and show how a design feature can impact user need satisfaction. While autonomy and presence were clearly important, competence did not emerge as a significant predictor of enjoyment, positive affect and future play. This may be due to the implicit goal in our experimental design where participants were simply allowed to explore the VR experience for a few minutes. We used PENS as a model for understanding motivation in a VR exercise platform. This provides a well-tested theory of motivation, namely SDT, for designing and researching future variations of VR exercise environments. Given that VR exergaming is in its infancy, using a theoretical model of motivation assists us to explore what worked or did not go well for users of VR exercise platform, this is particularly important to establish before adding any game elements to the platform.

Notably in our study, we found some participants who can be characterized as entertainment-focused. Those participants ignored physiological information about their physical activity as they were more engrossed in exploring the immersive environment. For instance, these participants took their time to stop and explore the virtual environment in OW condition rather than focusing on their physical activity, which resulted in lower exertion and therefore lower heart rate. In contrast, we found a typical group of participants whom we might characterize as exercise-focused. Those participants seemed to have an understanding of their physiological data and interpreted it in relation to their physical activity during the session. Exercise-focused participants were engaged differently in physical activity (compared to entertainment-focused ones) as they were more observant of their physical exertion data.

Our investigation also suggested that participants' weekly physical activity level negatively predicted autonomy and enjoyment in the UI condition. We speculate that those who exercise regularly might have higher expectations for the system. They may have a better understanding of their preferences and may not find our VR exercise platform with UI condition more novel than regular gym cycles as both present similar interface with activity information. Another important outcome revealed the significance of participants' prior video games experience which negatively predicted their enjoyment and immersion in the OW condition. Remarks on the simplicity of the OW environment compared to commercial video games that are designed for entertainment indicates the importance of considering personalization of the game experience for more game-savvy participants. This realization to design personalized exergames that match players competencies and interests aligns with mixed findings in studies on long-term adherence (Biddiss & Irwin, 2010) of players in non-immersive exergames. Göbel and colleagues studied the feasibility of their personalized non-immersive exergame and found that personalization influenced players behavior and motivated them to adhere to playful physical activity in long-term (Göbel et al., 2010) . McCallum suggested that providing the player with the agency to personalize design gives them a sense of control (McCallum, 2012). Our study also suggests that fulfilling the need for autonomy (sense of control) in immersive exercise platform contributes towards user's motivation and enjoyment.

Despite the elementary design elements in the two conditions, findings have implications for user's need satisfaction. However, to engage participants in recurring VR exercise session(s) demands careful design decisions. Immersion was experienced in both conditions where OW had higher immersion. The perceived immersion was further related to autonomy, competence and enjoyment in UI where these effects were even stronger in OW condition except competence. This suggests high immersion in future VR exercise platforms should be a key design consideration in order to enhance user motivation. Immersion not only contributes to enjoyment but also to positive affect and future play (OW condition). Our results on immersion in VR exercise platform match findings of Ho, Lwin, Sng, & Yee (2017) for non-VR exergames.

Participants had their own perceptions of a VR exercise platform and revealed expectations with a think-aloud technique. Participants expressed disappointment when they found the UI condition was less interactive than expected. On other hand, an open world environment as a design choice in VR exergames can successfully immerse and engage participants, however preference for sophisticated 3D environment was noticeable. The design choice to use Google Street View as the visual content in our work, instead of a smooth 3D environment, was a trade-off between slight decrease in immersion and control of motion sickness. This requires designers of VR exercise platforms to achieve reasonably good immersion while maintaining less instances of motion sickness with currently available technology. Based on our investigation, we confirm the significance of personalization and catering for user's (entertainment- versus exercise-focused) expectations for need satisfaction and therefore enjoyment and motivation for physical activity in VR exercise platforms. The solution might involve individually tailored design elements to engage different type of users; this would result in better engagement.

Limitations. This study is limited to an Australian sample with relatively small size (N = 45), and to English speakers. A larger and more representative sample would be an important consideration in future studies. In addition, this study contrasted two VR designs. Although the ability to 'navigate' the open virtual world was the most salient difference to static UI; other associated features such as perception of receiving real-time feedback relevant to action (as participants pedaled), and perception of travelling through different regions in immersive OW might have contributed to the results. Neither of the two study conditions entailed complex game mechanics or had complex goals, as our aim was primarily to investigate the fit of PENS model for describing user motivation in VR exercise platforms. However, this work is part of a larger research project and a first step towards understanding user motivation and enjoyment in immersive exergaming environments.

In future studies, we would like to examine immersive exergaming with concrete game design elements and their motivational affordances considering findings of this work. In general, VR vs VR-exergaming experiments are challenging where there are several factors that can affect users' motivation including VR novelty, embodiment in exergaming platform and motion sickness. A potential alternative to our current experiment would be a 'within subject design' for all VR conditions or a longitudinal study.

7 Conclusion

This is, to our knowledge, the first study to investigate motivation and engagement of immersive VR exergames. We evaluate two different VR environments and explore how these contribute towards participants need satisfaction and as the result their motivation and enjoyment. We found the PENS made a suitable theoretical approach to investigate those matters in immersive VR exercise platform. We also examined the relationships between participant's health, prior experiences (video games, exergames, VR and health monitoring devices) and found two typical groups characterized as exercise-focused and entertainment-focused, who experienced the immersive experience differently due to differences in expectations from a VR exercise session. This resulted in variations in their motivation and enjoyment. These findings highlight the importance of personalized environments for motivating users with different needs and expectations.

ACKNOWLEDGMENTS

The authors would like to acknowledge contribution of Richard M. Ryan for study design and providing access to the PENS questionnaire. Also, M. Johan Alibasa who has developed the Android App used in this work for tracking physiological signals with Microsoft band 2.

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Table 1: Participants' demographics in two conditions

Demographics	**UI (N = 23)**	**OW (N= 22)**
Age: mean (SD)	25.91 (8.03)	27.59 (9.35)
Weight: mean (SD)	67.9 (15.9)	74.1 (21.2)
Height: mean (SD)	169.9 (9.6)	172.1 (9.2)
Gender distribution: % males	52% (n=12/23)	73% (16/22)
Wearable tech: % no	83% (n=19/23)	81.8% (16/22)
Avg. exercise: hr (min)	3.6 (2.7)	2.7 (1.9)
Videogames exp.: % yes	39% (n=9/23)	55% (12/22)
Exergames exp.: % yes	35% (n=8/23)	41% (9/22)
VR experience: % yes	23% (n=6/23)	27% (6/22)
Motion Sickness: % yes	8.7% (n=2/23)	31.8% (7/22)

Table 2. An Independent Sample t-test for UI and OW Conditions

Factor	**UI**	**OW**	**T – test**
Enjoyment	M = 3.30 SD = 1.82	M = 4.45 SD = 1.74	t (43) = -2.16, p = .03*
Autonomy	M = 1.83 SD = 1.15	M = 3.36 SD = 2.15	t (43) = -3.0, p = .004**
Immersion	M = 2.43 SD = 1.78	M = 3.55 SD = 1.74	t (43) = -2.12, p = .04*
Competence	M = 4.13 SD = 1.96	M = 5.14 SD = 1.49	t (43) = -1.93, p = .06
Intuitive Controls	M = 5.57 SD = 1.62	M = 5.77 SD = 1.45	t (43) = -.453, p = .65
Pos. Affect	M = 14.17 SD = 4.06	M = 15.82 SD = 4.51	t (42.1) = -1.28, p = .21
Neg. Affect	M = 5.83 SD = 1.64	M = 5.64 SD = 1.43	t (43) = .412, p = .68

Table 3: Number of participants and their specific reasons for unwillingness to play extra time

UI Condition (N= 23)		**OW Condition (N = 22)**	
Other Commitments/No time	6	Other Commitments/No time	4
Static/non-interactive interface, no movements	4	Tired after current VR-Rides session	3
Boring	3	Game content too simple and have already tried all options	3
		Boring	3
----		Smooth movement or prefer video type VR	5

Table 4: Correlation between PENS variables (autonomy, competence, intuitive controls & immersion) enjoyment, positive affect and future play

	1	**2**	**3**	**4**	**5**	**6**
UI (N = 23)						
1. Autonomy	-					
2. Competence	.31	-				
3. Intuitive controls	-.07	.105	-			
4. Immersion	.61**	.43*	.07	-		
5. Enjoyment	.74**	.38	.08	.60**	-	
6. Positive Affect	.34	.20	.05	.38	.44*	-
7. Future Play	-.02	.05	.67**	.20	.20	.32
OW (N = 22)						
1. Autonomy	-					
2. Competence	.28	-				
3. Intuitive controls	.32	.61**	-			
4. Immersion	.91**	.21	.15	-		
5. Enjoyment	.82**	.32	.35	.86**	-	
6. Positive Affect	.63**	.37	.17	.70**	.86**	-
7. Future Play	.58**	.12	.29	.56**	.75**	.52**

*P < .05, **p < .01, ***p < .001

Table 5: Regression Models of UI and OW Groups Comparing Contributions of Players Experience of Need Satisfactions (PENS) measures

VR-Rides Conditions	**Dependent Variable**	**Independent Variable**	**β**	**Adj. R^2**
UI (N = 23)	Enjoyment	Autonomy	.60**	
		Competence	.11	
		Intuitive Controls	.09	.52
		Immersion	.18	
	Positive Affect	Autonomy	.17	
		Competence	.04	
		Intuitive Controls	.04	-.02
		Immersion	.26	
	Future Play	Autonomy	-.11	
		Competence	-.10	
		Intuitive Controls	.65**	.37
		Immersion	.26	
OW (N = 22)	Enjoyment	Autonomy	-.04	
		Competence	.02	
		Intuitive Controls	.22	.74
		Immersion	.86*	
	Positive Affect	Autonomy	-.11	
		Competence	.30	
		Intuitive Controls	-.09	.45
		Immersion	.75	
	Future Play	Autonomy	.21	
		Competence	-.18	

		Intuitive Controls	.28	.24
		Immersion	.37	

*P < .05, **p < .01, ***p < .001

Figures

Figure 1: UI (left) and OW (right) conditions with activity statistics

Figure 2: Participant's activity time in two conditions

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