Proceedings of the 57th Hawaii International Conference on System Sciences | 2024

Examining Continuance Intention to Exercise in a Virtual Reality Environment

Akon Obu Ekpezu
Dept of Information Processing Science, University of Oulu
akon.ekpezu@oulu.fi

Isaac Wiafe
Dept of Computer Science, University of Ghana
iwiafe@ug.edu.gh

Charles Nutrokpor
Dept of Computer Science, University of Ghana
cnutropkor@st.ug.edu.gh

Harri Oinas-Kukkonen
Dept of Information Processing Science, University of Oulu
harri.oinas-kukkonen@oulu.fi

Abstract

The use of virtual reality (VR) as a persuasive technology has gained research attention. However, few empirical research has been conducted to explain how persuasive systems design (PSD) features and user experience features affect users' continuance intention to use VR to exercise. This study aimed to examine the factors that influence continuance intention to use VR to exercise. A VR exercise environment was developed, and quantitative data was collected from 118 users post-exercise. Results of the partial least squares structural equation modeling analysis showed that perceived- enjoyment, effectiveness, and persuasiveness significantly influenced continuance intention. However, perceived effectiveness had the strongest impact. The exogenous driver constructs (primary task support, dialogue support, credibility support, and perceived immersion) also significantly influenced continuance intention. These findings highlight how the association between user experience and PSD features may be considered in the development of VR exercise systems to improve adoption and compliance.

Keywords: Persuasive technology, physical activity virtual reality, continuance intention, compliance.

1. Introduction

Despite the increased purchase rate of persuasive technologies/systems, including commercial health and fitness equipment and apps (Wadhwani & Loomba, 2022), more than 25% of the world's adult population is physically inactive (Guthold et al., 2018). Individuals' continuous use of these technologies/systems after adoption often lasts for an average of three months (Cho, 2016). This lack of long-term use affects the effectiveness of these technologies. Particularly, in terms of improved positive health outcomes, health behavior change, and discontinued development and improvement of these technologies/systems (Higgins, 2016). Thus, the success of these technologies/systems relies on the user's continuous use. It is imperative to examine the factors that influence the continuance use intention of these technologies. Recent studies on persuasive technologies/systems have focused mostly on the continuance use intention of health and fitness apps. Perhaps, this is because health and fitness apps are the predominant and cost-effective implementations of persuasive technologies/systems that change human health behavior and outcomes (Wiafe & Nakata, 2012). Virtual reality (VR) as a form of persuasive technology is beginning to arouse extensive research interest among researchers and practitioners (Chow et al., 2017; Wang et al., 2023). It offers a promising environment for promoting physical activity and behavior change while reducing the chances of sustaining injuries in the physical world (Chow et al., 2017). Compared to non-VR systems such as peloton bikes and conventional persuasive systems such as health and fitness apps, a persuasive VR environment stimulates a sense of presence and immersion that has a positive impact on the user's physiological, psychological, and rehabilitative outcomes (Qian et al., 2020). Yet, the continuance intention to use a persuasive VR enviornment to exercise has been less explored.

Prior studies have applied different technology-related models and frameworks such as perceived value theory (Yang & Han, 2021), sports commitment model and theory of planned behavior (Jeng et al., 2020), self-awareness theory and presence (Hooi & Cho, 2017), and hedonic-motivation system acceptance model (Kari & Kosa, 2023) to examine users' continuance intention of VR. However, these studies have not considered VR as a form of persuasive technology/system. Also, research that explores how the fusion of persuasive features with immersive technologies affects users' continuance intention to use VR to exercise is inadequate. User experience (UX) refers to individual's perceptions and

URI: https://hdl.handle.net/10125/106810
978-0-9981331-7-1

responses resulting from how they use an interactive product, system, or service: the way it feels (e.g., immersion), their understanding of how it works, how they feel about it while using it (affective response), how well it serves their purpose(s) (e.g. perceived effectiveness), and how well it fits into the entire context of use (Law et al., 2008). Specifically, this study examines how three of the persuasive systems design principles (i.e., primary task support, dialogue support, and credibility support) of the persuasive systems design (PSD) model proposed by Oinas-Kukkonen and Harjumaa (2009) influence perceived; immersion, persuasiveness, effectiveness, enjoyment, and continuance intention to use VR to exercise. The PSD model has been used by previous studies (Sengupta & Williams, 2021; Wiafe et al., 2022) as a theoretical framework to understand continuance intention to use various forms of persuasive systems. The empirically tested features of this model therefore offer the possibility for an immersive VR environment to leverage.

The rest of the paper is structured as follows. First, the theoretical foundations for the development of the hypotheses are presented, followed by a description of the VR environment, the survey instruments, and data analysis. Then a discussion of the results, limitations of the study, and the conclusions.

2. Theoretical background and research model

The artifact under study is a persuasive VR environment for exercising. Although the nature of VR is different from that of traditional persuasive systems, VR is considered a form of information system (Verhagen et al., 2009). Although there are several models for designing and evaluating persuasive technology/systems (Wiafe et al., 2014), this study adopts the PSD model by Oinas-Kukkonen and Harjumaa (2009). The PSD model comprises 4 principles namely, primary task support, dialogue support, credibility support, and social support. In this study, these principles apart from social support will form the basis for the model development. Social support was not measured because the environment was not developed to facilitate it. Other constructs to be examined will include constructs related to UX and immersive virtual technologies.

Previous research in persuasive systems research has established these constructs (i.e., primary task support, dialogue support, credibility support, perceived effectiveness, and perceived persuasiveness) as determinants of continuance intention (Lehto & Oinas-Kukkonen, 2015; Wiafe et al., 2022). In immersive VR, perceived enjoyment and perceived immersion have been found to play key roles in continuance intention (Hooi & Cho, 2017; Wienrich et al., 2021). Yet, they have not been examined as determinants of a user's continuance intention to exercise in a VR environment in a specific context. The proposed research model is presented in Figure 1. The relationships between the constructs are assumed to be positive. They are mainly developed on the assumption that interactions and human behavior in VR environments tend to imitate real-world situations (Menck et al., 2023).

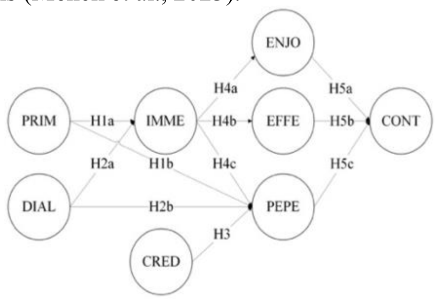

Figure 1. Proposed structural model (PRIM = primary task support, DIAL = dialogue support, CRED = credibility support, IMME = perceived immersion, ENJO = perceived enjoyment, EFFE = perceived effectiveness, PEPE = perceived persuasiveness, CONT = continuance intention).

Primary task support features assist the individual in completing the primary task by reducing the cognitive load associated with the usage of the system or the activity of interest. The presence of primary task support features in a persuasive VR environment has the potential to produce emotions that can cognitively engage the users and draw them into a state of mental absorption (Flavián et al., 2019). VR provides an environment where the users feel engaged and immersed in the activity of interest. By reducing the effort required to complete a task or navigate the persuasive system/environment, users should find it easier to experience immersion and cognitive absorption (Shevchuk et al., 2019). Extant literature posits that the cognitive motivation from primary task support influences the immersive experience in augmented reality technologies for learning (Georgiou & Kyza, 2018). Since augmented reality is an extension of VR (Flavián et al., 2019), it is logical to hypothesize that a similar relationship will hold in VR. Hence, it is hypothesized that:

H1a: Primary task support will influence perceived immersion in a persuasive VR environment for exercising.

Prior studies (Shevchuk et al., 2019; Wiafe et al., 2022) on different application domains of persuasive systems including persuasive games and social networking sites have established that the perceived persuasiveness of a system or an environment is positively influenced by the perceived presence of primary task support. Hence, it is hypothesized that:

H1b: Primary task support will influence perceived persuasiveness in a persuasive VR environment for exercising.

Dialogue support features (e.g., social role, praise, rewards) reinforce interactions between users and the systems by providing feedback and motivation (Oinas-Kukkonen & Harjumaa, 2009). VR enhances these features as it provides increased levels of visual and auditory feedback (Qian et al., 2020). For instance, the use of virtual avatars in VR is more influential in improving motivation, enjoyment, and engagement during exercise (Mouatt et al., 2020). Virtual avatars/agents and immersion are the most prominent VR strategies (Mouatt et al., 2020). The higher the similarity between the embodiment of the virtual avatar and the users' exercise performance, the higher the levels of engagement and immersion (Wienrich et al., 2021). Thus, it is hypothesized that:

H2a: Dialogue support will influence perceived immersion in a persuasive VR environment for exercising.

Similar to primary task support, prior studies on different application domains of persuasive systems have established that the perceived persuasiveness of a system or an environment is positively influenced by the perceived presence of dialogue support (Shevchuk et al., 2019; Wiafe et al., 2022). Dialogue support has also been shown to influence the perceived persuasiveness of a persuasive virtual health coaching system (Lehto et al., 2012). Since the working mechanisms of these systems are similar to the VR environment under study in terms of persuasive features, this study hypothesizes that:

H2b: Dialogue support will influence perceived persuasiveness in a persuasive VR environment for exercising.

Users' favorable impression of a persuasive system is dependent on the degree to which they believe that the information provided by the system is trustworthy and reliable. Credibility support has been shown to positively influence perceived persuasiveness in a persuasive virtual health coaching system (Lehto et al., 2012). Hence, it is hypothesized that:

H3: Credibility support will influence perceived persuasiveness in a persuasive VR environment for exercising.

Perceived immersion is the extent to which individuals feel engaged in relation to the sensory stimulations within the VR environment (Wienrich et al., 2021). It represents the subjective experience of users who perceive themselves to be completely present in a virtual world, thereby losing their consciousness of the real world as well as their sense of time (Shin, 2018). In a VR environment, immersion has been shown to influence enjoyment (Leveau & Camus, 2023), particularly during exercise (Mouatt et al., 2020). Similarly, the psychological immersion resulting from the virtual experience positively influences the users' behavioral intention (Leveau & Camus, 2023). In a virtual health coaching system, the user's behavioral intention was shown to be influenced by the perceived persuasiveness of the system (Lehto et al., 2012). If perceived immersion and perceived persuasiveness influence behavioral intention, then it is logical to posit that the immersive experience will lead to favorable impressions of the environment.

The relationship between perceived immersion and perceived effectiveness has not been largely explored in persuasive systems. However, Spence Laschinger et al.'s (2009) study found a relationship between engagement, one of the three levels of psychological immersion (alongside absorption, and total immersion) and perceived effectiveness. It is envisaged that users of a VR environment may experience any of the three levels of immersion and this may influence their perception regarding the efficacy of the environment to improve their exercise behavior (perceived effectiveness). Hence, this study hypothesizes the following:

H4a: Perceived immersion will influence perceived enjoyment in a persuasive VR environment for exercising.

H4b: Perceived immersion will influence perceived effectiveness in a persuasive VR environment for exercising.

H4c: Perceived immersion will influence perceived persuasiveness in a persuasive VR environment for exercising.

Extant literature posits that VR provides hedonic user experiences that generate affective responses and affects such as enjoyment (Marasco et al., 2018). The affective response generated by the environment positively influences users' behavioral intentions (Leveau & Camus, 2023). Studies have shown that perceived enjoyment has a positive influence on the continuance use of VR (Mäntymäki & Islam, 2014). Hence, it is hypothesized that:

H5a: Perceived enjoyment will influence continuance intention to exercise in a persuasive VR environment.

Perceived effectiveness and perceived persuasiveness are established determinants of continuance intention to use different forms of persuasive systems/technologies and academic social networking sites (Lehto & Oinas-Kukkonen, 2015; Wiafe et al., 2022). Perceived effectiveness is the extent to which users perceive the VR environment to be useful to them in performing their primary task (e.g., exercise). While perceived persuasiveness refers to an individual's favorable impression of the VR environment. Since VR is an imitation of the real world, it is logical to posit that the established relationships found in prior studies on persuasive systems conducted in the real world will hold in a virtual world. Hence, it is hypothesized that:

H5b: Perceived effectiveness will influence continuance intention to exercise in a persuasive VR environment.

H5c: Perceived persuasiveness will influence continuance intention to exercise in a persuasive VR environment.

3. Methods and materials

3.1. Study context

An immersive VR environment was developed using Blender and Unity3D software. PSD and UX features were incorporated into the environment to enhance the presence and(or) perceptions of the constructs to be measured. Table 1 provides example implementations of these features.

Table 1:Example implementation of system features in the VR environment

Constructs	Features: Example Implementation
Primary task support	Self-monitoring: Participants could see their performance and elapsed time of exercise.
Dialogue support	Praise: automated short phrases complimenting the participant for reaching certain points along the walkway. Similarity: Metaphors that represented real-world scenarios and a familiar sidewalk within the University campus from which the study participants were drawn.
Credibility support	Surface credibility: A visually aesthetic environment with realistic elements.
Perceived immersion	Realistic interactions, visually aesthetic textures, and realistic elements such as vehicle horns, wind effects, and sound frictions from trees were encapsulated within the environment to enhance perceptions of immersion.
Perceived enjoyment	Realistic interactions such as avatars and passers-by comments were implanted within the environment to enhance perceptions of enjoyment.
Perceived effectiveness	Visual indicators that showed participants the effect of the fast or slow arm swinging using the controllers were intended to enhance the participant's perception of the usefulness of the environment in relation to the primary task.
Perceived persuasivenes s	Incorporating several persuasive features into the persuasive VR environment was intended to enhance the participant's favorable impression of the environment.
Continuance intention	In addition to the implemented features, the environment was user-friendly and easy to navigate.

The environment replicated a sidewalk structure within the University campus from which the study participants were drawn. It covered a walking distance of 1.5km to 2km (see Figure 2). Surrounding buildings, landmarks, roadways, trees, and other embodiments of the sidewalk in the real world were replicated in the VR environment to create a sense of familiarity. The environment was purposely built to afford three PSD system principles. This may not be present in existing VR games. Also, to ensure that participants are not affected by confounding variables of the hypothetical environments used in VR games, we developed an environment that is familiar to them. Realistic elements such as vehicle horns, wind effects, and sound frictions from trees were encapsulated within the environment to enhance the immersive experience in addition to the head-mounted Oculus Quest 2 headset. A visually aesthetic environment with realistic elements that replicated a frequently used sidewalk by the study participants in the real world was also implemented to increase perceptions of surface credibility. Visual aesthetics influences users' evaluation of the credibility of persuasive systems (Ramírez-Correa et al., 2018).

Figure 2: A snippet of the sidewalk in VR

The primary task was a gamified exercise that required participants to complete the specified side-walk in less than 20 minutes. Virtual locomotion was achieved by using a pair of headset controllers. That is, by applying a firm grip on the left and right controllers, participants will find themselves moving in the VR environment as they swing their entire arm in a back-and-forth motion following an arm rotation like a pendulum. While participants were not restricted from moving their legs, most of them naturally moved their legs in sync with their arm swings. Subtle obstacles in the form of realistic interactions were implanted within the game as avatars and passers-by comments. The avatars had a rigid-body feature attached to them which stopped the walking participants in their tracks. Thus, allowing participants to physically maneuver through them using natural gestures and movements. The passerby comments were intended to make the participants pause in their tracks to identify who made the comments. The environment facilitated self-monitoring, displaying time-elapsed as well as remaining distance, and enabling participants to monitor their progress. Participants could see the elapsed time of activity and the walking distance yet to be covered. Encouraging phrases such as “You are doing great!” and “You are almost there!” were directed toward participants when they reached checkpoints along the sidewalk.

The arm swinging using the hand controllers was calibrated such that, the faster a participant swings the arm, their virtual locomotion switched from walking to jogging. And the slower they swing their physical arm; their virtual locomotion replicates slow walking. The physical arm swinging using the controllers served as a form of exercise within the virtual setup. An exercise session was completed when the participant finished walking down the stretch of the road.

The entire experiment took approximately 30 days to complete with each participant experiment’s session taking approximately 40 minutes. Ten minutes were for introduction and familiarization with the headset as well as to identify any phobia related to using the headset, and 20 to 30 minutes was used for the gamified exercise and for responding to the post-experimental questionnaire.

3.2. Data collection and participants

The experiment was set up in a lab located on the premises of the University. Invitations for voluntary participation were distributed to both students and faculty using the university’s mailing list. Upon arrival, participants provided verbal consent to partake in the experiment. Before commencing the experiment, participants completed a pre-experimental questionnaire, which captured their demographics, level of physical activity, and experience with VR. Capturing this information upfront enabled the post-experimental questionnaire to focus solely on their experience within the VR environment. Regardless of their experience with VR, each participant was made to have a 5–10-minute exposure to the virtual space using the Oculus Quest 2 headset. They navigated within a pre-installed roller-coaster game available on the meta-store. Afterward, participants were given some minutes to relax before partaking in the actual experiment. After completing the exercise, participants filled out a post-experimental questionnaire in the lab. Google Forms was used to design the questionnaire and it measured the constructs hypothesized for this study using a 5-point Likert scale. Question items for the constructs were adopted from prior studies and rephrased to suit the context of this study (refer to Table 3).

At the end of 30 days, 118 individuals had participated in the experiment. Over 99% (n = 117) of the study participants were undergraduate students aged between 18 and 34 years old, while 76.27% (n = 90) were males. Only 39.83% of the study participants completed the specified sidewalk in less than 20 minutes. Table 2 provides a summary of the participant's demographics.

Table 2: Demographics of study participants

Demographics	Value	Counts (%)
Sex	Male	90 (76.27)
	Female	28 (23.73)
Age	Below 18	1 (0.85)
	18 to 24	113 (95.76)
	25 to 39	3 (2.54)
	40 to 59	1 (0.85)
Education Status	Undergraduate	117 (99.15)
	Postgraduate	1 (0.85)
Exercise frequency	Everyday	22 (18.64)
	5-6 days/week	5 (4.24)
	3-4 days/week	21 (17.80)
	2 days/week	23 (19.49)
	Once a week	15 (12.71)
	2-3 days/month	6 (5.08)
	Once in a month	13 (11.02)
	None	13 (11.02)
Have you heard of VR before?	Yes	109 (92.37)
	No	9 (7.63)
Have you ever experienced a VR environment?	Yes	90 (76.27)
	No	28 (23.73)
Do you have any medical/health condition associated with the use of a head-mounted display?	Yes	0 (0)
	No	118 (100)
Completed walking distance between 18 to 20 minutes	Yes	47 (39.83)
	No	71 (60.17)

4. Data analysis and results

This study used the partial least squares structural equation modeling (PLS-SEM) to examine the relationships between the constructs in the proposed research model. Both the measurement model and the structural model were assessed using relevant threshold values specified by Fornell and Larcker (1981) and Hair et al. (2022). The SEMinR library in *R* programming language was used.

4.1. Assessment of the measurement model

To verify how much of each indicator’s variance is explained by its construct, the indicator loadings were examined by a threshold value greater than or equal to 0.7. The loadings ranged between 0.746 and 0.926, indicating acceptable indicator loadings (see Table 3).

Table 3. Question items and indicator loadings

Constructs	Question items	Loads

PRIM (Wiafe et al., 2022)	The VRE provides me with the support I need to complete my exercise task.	0.802
	The VRE makes it easier for me to exercise.	0.854
	The VRE provides the space for me to exercise.	0.746
DIAL (Wiafe et al., 2022)	The VRE provides me with motivational support when exercising.	0.820
	The VRE praises me for exercising.	0.894
	The VRE provides me with appropriate feedback when exercising.	0.800
CRED (Wiafe et al., 2022)	I find the VRE to be trustworthy.	0.842
	I find the VRE to be reliable.	0.902
	I find the VRE to be credible.	0.789
IMME (Leveau & Camus, 2023)	I was absorbed in the VRE.	0.800
	Within the VRE, everyday thoughts were still on my mind.	0.801
	While in the VRE, I was unaware of what was happening around me.	0.796
ENJO (Leveau & Camus, 2023)	Exercising within the VRE was fun	0.786
	I completely enjoyed exercising within the VRE	0.858
	Exercising within the VRE was pleasurable	0.719
EFFE (Wiafe et al., 2022)	My chances of exercising improve by using the VRE.	0.917
	The VRE is effective for exercising.	0.916
	In my opinion, I will find exercising within a VRE to be helpful.	0.906
PEPE (Wiafe et al., 2022)	The VRE has an influence on me.	0.862
	I prefer exercising in the VRE to exercising in the real world.	0.872
	The VRE makes me reconsider my exercise habits.	0.926
CONT (Jang & Park, 2023; Yang & Han, 2021)	I would prefer to use a VRE for exercising.	0.903
	I intend to use a VRE to exercise in the future.	0.912
VRE = virtual reality environment		

Internal consistency reliability was assessed using values of Cronbach's alpha (CA) and composite reliability (CR). CR and CA values are above the 0.70 threshold indicating that all constructs are reliable. The convergent validity assessment was based on the average variance extracted (AVE) values, and all values were higher than the specified 0.50, indicating high levels of convergent validity. Refer to Table 4.

Table 4. Properties of latent variable

	PRIM	DIAL	CRED	IMME	ENJO	EFFE	PEPE	CONT
PRIM	**0.802**							
DIAL	0.517	**0.839**						
CRED	0.582	0.342	**0.845**					
IMME	0.427	0.418	0.303	**0.799**				
ENJO	0.464	0.385	0.307	0.577	**0.790**			
EFFE	0.653	0.408	0.723	0.324	**0.344**	**0.913**		
PEPE	0.628	0.532	0.558	0.576	0.501	0.680	**0.887**	
CONT	0.606	0.406	0.569	0.326	0.448	0.804	0.689	**0.908**
CA	0.724	0.788	0.802	0.719	0.703	0.900	0.864	0.786
CR	0.844	0.877	0.882	0.841	0.832	0.938	0.917	0.903
AVE	0.643	0.704	0.715	0.638	0.624	0.834	0.787	0.824

CA = Cronbach's alpha; CR = Composite reliability; AVE = Average Variance Extracted; Bold cells = square root of AVE

The discriminant validity assessment was based on the Fornell and Larcker (1981) criteria. As shown in Table 4, the square root of the AVE of each construct (bolded values in table 4) is higher than the construct's highest correlation with any other constructs in the model.

4.2. Assessment of the structural model

Collinearity issues were examined using the variance inflation factor (VIF) values. It was observed that all VIF values were below the threshold of 3, indicating that collinearity among predictor constructs is not an issue in the structural model. Next, the path coefficients (β) of the exogenous driver constructs were examined. Refer to Figure 3.

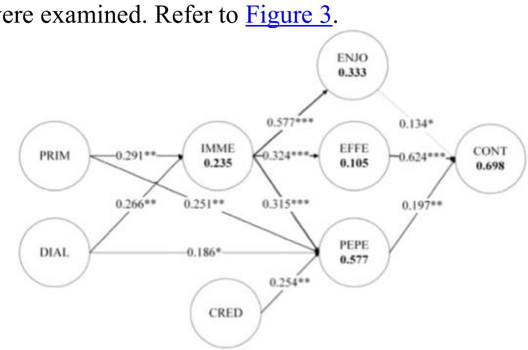

Figure 3. Structural model full path analysis (path significance: *p < 0.05; **p < 0.01; ***p < 0.001).

It was observed that perceived effectiveness has the strongest positive impact on continuance intention (0.624), compared to perceived enjoyment (0.134) and perceived persuasiveness (0.197). Also, perceived immersion had a strong positive impact on perceived enjoyment (0.577) compared to perceived effectiveness (0.324) and perceived persuasiveness (0.312). For the path coefficients between the PSD constructs and perceived immersion and perceived persuasiveness, it was observed that primary task support had a higher impact on perceived immersion compared to dialogue support, while credibility support had a higher impact on perceived persuasiveness.

Most importantly, the results were examined for statistical significance. Assuming a 5% significance level and T statistics exceeding 1.960, it was observed that all relationships were statistically significant. H2b and H5a were supported at a significance level of 0.05, H1a, H1b, H2a, H3, and H5c were supported at a significance level of 0.01, while H4a, H4b, H4c, and H5b were supported at a significance level of 0.001 (see Figure 3).

The effect sizes (f^2) values for all combinations of endogenous and corresponding exogenous constructs is shown in Table 5. Based on Cohen's (1988) criteria, it was observed that perceived effectiveness has a strong effect on continuance intention. This path appeared to be the strongest among all the established paths in the model, with an effect size of 0.67. This result suggests that designers of VR environments should focus more on enhancing the user's perception of effectiveness as it appears to be a primary driver of continuance intention compared to perceived enjoyment and perceived effectiveness.

Table 5: Significance and relevance of path coefficients.

Hypotheses	Path coefficient *(β)*	T- statistics	Effect sizes *(f^2)*
PRIM→IMME	0.291	2.832	0.081
PRIM→PEPE	0.251	2.475	0.078
DIAL→IMME	0.266	2.487	0.067
DIAL→PEPE	0.186	2.279	0.055
CRED→PEPE	0.254	2.889	0.150
IMME→ENJO	0.577	7.893	0.500
IMME→EFFE	0.324	3.327	0.118
IMME→PEPE	0.312	3.744	0.176
ENJO→CONT	0.134	2.014	0.044
EFFE→CONT	0.624	9.107	0.672
PEPE→CONT	0.197	2.665	0.057

Perceived immersion had a strong effect size on perceived enjoyment (0.500), and a moderate effect size on perceived effectiveness (0.118) and perceived persuasiveness (0.176). For the driver constructs, primary task support and dialogue support had a weak effect size (f2≥ 0.02) on perceived immersion and perceived persuasiveness, while credibility support had a moderate effect size on perceived persuasiveness (0.150). With no irrelevant effect sizes (i.e., f2< 0.02), the model is said to have practical relevance. Figure 3 also shows that perceived immersion explained 33.3%, 10.5%, and 57.7% of the variance in perceived- enjoyment, effectiveness, and persuasiveness respectively. Whereas over half of the variance (69.8%) in continuance intention was jointly explained by perceived: enjoyment, effectiveness, and immersion.

To gain an idea of the impact of the exogenous driver constructs (e.g., PRIM, DIAL, and CRED) on the outcome constructs (e.g., CONT), Hair et al. (2022) suggest an examination of the total effects. As shown in Table 6, PRIM has the strongest total effect on CONT (0.149), followed by DIAL (0.127), and CRED (0.050). This indicates that researchers and designers of VR environments for exercising should pay more attention to enhancing primary task support features as they have a positive impact on the user's perception of immersion and continuance intention.

Table 6: Total effects of exogenous constructs

Paths	Path coefficient (β)	T- statistics
PRIM→ IMME	0.291	2.832
PRIM→ ENJO	0.168	2.452
PRIM→ EFFE	0.094	1.714
PRIM→ PEPE	0.342	3.722
PRIM→ CONT	0.149	2.897
DIAL→ IMME	0.266	2.487
DIAL→ ENJO	0.153	2.198
DIAL→ EFFE	0.086	1.936
DIAL→ PEPE	0.269	3.462
DIAL→ CONT	0.127	2.892
CRED→ PEPE	0.254	2.889
CRED→ CONT	0.050	2.065
IMME→ ENJO	0.577	7.893
IMME→ EFFE	0.324	3.327
IMME→ PEPE	0.312	3.744
IMME→ CONT	0.341	4.408
ENJO→ CONT	0.134	2.014
EFFE→ CONT	0.624	9.107
PEPE→ CONT	0.197	2.665

5. Discussion and implication of findings

This study developed an immersive and persuasive VR environment and proposed a structural model to examine users' continuance intention to exercise in a VR environment. The model was an integration of selected constructs from the PSD model and UX with immersive technologies. Specifically, this study investigated the relationship among primary task support, dialogue support, credibility support, perceived- immersion, persuasiveness, effectiveness, enjoyment, and continuance intention. The results of the study provided support for all the proposed hypotheses. Thus, providing researchers and practitioners with a better understanding of what factors determine the continuance intention to exercise in a persuasive VR environment. Within the scope of persuasive systems/technologies research, the findings from this study corroborate with prior studies related to other forms of these systems/technologies. This is a point of fact that VR as a form of persuasive technology effectively imitates real-world situations.

The results indicate that primary task support, dialogue support, and credibility had a statistically significant influence on perceived persuasiveness. These findings are similar to prior studies (Ekpezu et al., 2023; Shevchuk et al., 2019; Wiafe et al., 2022) on other forms of persuasive systems. The VR environments' capability to (i) reduce the user's effort of completing the primary task (i.e., exercise), (ii) facilitate computer-human dialog, and (iii) provide a reliable and credible interface creates a favorable impression of the environment.

Whereas the influence of primary task support and dialogue support on perceived immersion has not been largely explored in persuasive systems research, this study established a statistically significant influence of these constructs on the perceived immersive experience of the users. This indicates that the presence of primary task support and dialogue support features in the VR environment effectively assisted the users in accomplishing the primary task (exercising) by providing clear instructions, intuitive environments, visual cues, relevant feedback, and encouragement. Particularly, the provision of dialogue support significantly enhances satisfaction and enjoyment (Alhammad et al., 2021). A well-designed VR environment with a higher degree of primary task support and dialogue support can create a higher degree of absorption, engagement, and immersion for the user. This notion has been confirmed by (Nutrokpor et al., 2021). Regardless, attention must be given to enhancing primary task support features as they tend to have a higher impact on perceived immersion compared to dialogue support (see Table 3).

Similar to prior studies (Leveau & Camus, 2023; Mouatt et al., 2020), findings from this study show that greater levels of immersion can enhance users' enjoyment of the VR environment. As posited in prior studies (e.g., (Kari & Kosa, 2023)), this study affirms that the relationship between immersion and enjoyment may be associated with deep physical and mental involvement in the primary task which causes users to lose track of time and forget unrelated events. Perceived immersion was also observed to have a statistically significant influence on perceived effectiveness and perceived persuasiveness. This shows that when users feel cognitively absorbed and engaged within the VR environment, they are more likely to perceive the environment to be capable of fulfilling their intended goals. Similarly, heightened levels of immersion can also lead to favorable impressions about the environment.

In prior VR studies, continuance intention has been significantly predicted by factors such as perceived usefulness, satisfaction, and enjoyment (Mäntymäki & Islam, 2014); presence and enjoyment (Jang & Park, 2023); and utilitarian and hedonic values (Yang & Han, 2021). In this study, continuance intention was directly predicted by perceived enjoyment, perceived effectiveness, and perceived persuasiveness. While perceived enjoyment may be considered a primary driver of continuance intention due to its commonality among prior studies and this study, findings from this study showed that perceived effectiveness is a stronger predictor of continuance intention, followed by perceived persuasiveness, and then perceived enjoyment. Perhaps, when it has to do with exercising as a primary task within the VR environment, users are more interested in the ability of the environment to enable them to achieve their goals as well as their favorable impression of the influence of the environment on them, and least interested in the pleasure derived from the environment. As observed in the results (see Table 5), perceived enjoyment had a weak effect on continuance intention with an effect size of 0.044 compared to the 0.657 effect size of perceived effectiveness. Perceived effectiveness was predicted by the user's perception of immersion in the environment, and this was predicted by primary task support and dialogue support. In conventional persuasive systems such as web-based systems for weight management (Lehto & Oinas-Kukkonen, 2015), virtual health coaching systems (Lehto et al., 2012), and academic social networking sites (Wiafe et al., 2022), perceived persuasiveness has been predominantly predicted by primary task support, dialogue support, and credibility support. Findings from this study show that in the presence of these three PSD features, perceived immersion is a stronger predictor of perceived persuasiveness in VR environments. As shown in Figure 3, primary task support, dialogue support, credibility support, and perceived immersion conjointly accounted for over 50% of the variance in perceived persuasiveness.

This study contributes to the growing body of research on persuasive systems/technologies by providing a theoretical framework for understanding the determinants of continuance intention to exercise in a VR environment. The findings suggest that designers of VR exercise systems should focus on creating systems that are perceived as enjoyable, effective, and persuasive, with more emphasis on perceived effectiveness. Positive perceptions of the efficacy of the VR environment to improve exercise behavior play a crucial role in boosting user's confidence in their ability to successfully perform and achieve physical activity goals. The study highlights the importance of PSD constructs in creating favorable impressions of the environment. By considering these factors, designers can create VR exercise systems that are more likely to be adopted and used over time, potentially leading to improved physical activity adherence and outcomes.

6. Conclusion and future work

This study shows the relevance of the PSD constructs as base factors that influence the users' perceptions of their experience within the VR environment and how this influences their continuance intention. However, it is important to consider other factors such as the social support principle (of the PSD framework) on user experience and continuance intention to exercise within the VR environment. Attention should also be given to the compliance behavior of users within the VR environment. This is because prior studies (e.g., (Yang et al., 2020)) have used compliance as a measure of continuance intention. Furthermore, the proposed model should be tested on a larger population and explore the impact of individual differences such as age, gender, and fitness levels.

6. Acknowledgement

All the members of the HCI- Lab, Dept of Computer Science, University of Ghana (UG) for developing the VR environment (https://osf.io/g8z6e). This study was supported by BANGA-UG.

7. References

Alben, L. (1996). Quality of Experience. *Interactions*, *3*(3), 11–15. https://doi.org/10.3169/itej.62.190

Alhammad, M. M., Wiafe, I., & Gulliver, S. R. (2021). Exploring the Impact of Persuasive Features on Customer Satisfaction Levels of E-Commerce Websites Based on the Kano Model. In R. Ali, B. Lugrin, & F. Charles (Eds.), *PERSUASIVE 2021. Lecture Notes in Computer Science* (Vol. 12684, pp. 11–13). Springer, Cham. https://doi.org/10.4037/aacnacc2022378

Cho, J. (2016). The impact of post-adoption beliefs on the continued use of health apps. *International Journal of Medical Informatics*, *87*, 75–83. https://doi.org/10.1016/j.ijmedinf.2015.12.016

Chow, Y. W., Susilo, W., Phillips, J. G., Baek, J., & Vlahu-Gjorgievska, E. (2017). Video games and virtual reality as persuasive technologies for health care: An overview. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications*, *8*(3), 18–35. https://doi.org/10.22667/JOWUA.2017.09.30.018

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (N. Hillsdale & Lawrence Erlbaum (eds.); 2nd ed.).

Dabi, J., Wiafe, I., Stibe, A., & Abdulai, J. D. (2018). Can an enterprise system persuade? The role of perceived effectiveness and social influence. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *10809 LNCS*, 45–55. https://doi.org/10.1007/978-3-319-78978-1_4

Ekpezu, A. O., Oinas-Kukkonen, H., & Wiafe, I. (2023). Investigating the Determinants of Compliance Intention in Behavior Change Support Systems. *AMCIS 2023 Proceedings*, *17*, 1–10. https://doi.org/https://aisel.aisnet.org/amcis2023/sig_adit/sig_adit/17

Flavián, C., Ibáñez-Sánchez, S., & Orús, C. (2019). The impact of virtual, augmented, and mixed reality technologies on the customer experience. *Journal of Business Research*, *100*(October 2018), 547–560. https://doi.org/10.1016/j.jbusres.2018.10.050

Fornell, C., & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research, 18*(1), 39–50.

Georgiou, Y., & Kyza, E. A. (2018). Relations between student motivation, immersion, and learning outcomes in location-based augmented reality settings. *Computers in Human Behavior*, *89*, 173–181. https://doi.org/10.1016/j.chb.2018.08.011

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2018). Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1·9 million participants. *The Lancet Global Health*, *6*(10), e1077–e1086. https://doi.org/10.1016/S2214-109X(18)30357-7

Hair, J. F., Hult, G. T., Ringle, C. M., Sarstedt, M., Danks, N. P., & Ray, S. (2022). Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R. In *Handbook of Market Research*. https://doi.org/10.1007/978-3-319-57413-4_15

Higgins, J. P. (2016). Smartphone Applications for Patients' Health and Fitness. *American Journal of Medicine*, *129*(1), 11–19. https://doi.org/10.1016/j.amjmed.2015.05.038

Hooi, R., & Cho, H. (2017). Virtual world continuance intention. *Telematics and Informatics*, *34*(8), 1454–1464. https://doi.org/10.1016/j.tele.2017.06.009

Jang, Y., & Park, E. (2023). An adoption model for virtual reality games : The roles of presence and enjoyment. *Telematics and Informatics*, *42*(May 2019), 101239. https://doi.org/10.1016/j.tele.2019.101239

Jeng, M. Y., Yeh, T. M., & Pai, F. Y. (2020). The continuous intention of older adult in virtual reality leisure activities: Combining sports commitment model and theory of planned behavior. *Applied Sciences (Switzerland)*, *10*(21), 1–14. https://doi.org/10.3390/app10217509

Kari, T., & Kosa, M. (2023). Acceptance and use of virtual reality games: an extension of HMSAM. *Virtual Reality*, *0123456789*. https://doi.org/10.1007/s10055-023-00749-4

Law, E., Roto, V., Vermeeren, A. P. O. S., Kort, J., & Hassenzahl, M. (2008). Towards a shared definition of user experience. *Conference on Human Factors in Computing Systems - Proceedings*, *April*, 2395–2398. https://doi.org/10.1145/1358628.1358693

Lehto, T., & Oinas-Kukkonen, H. (2015). Explaining and predicting perceived effectiveness and use continuance intention of a behavior change support system for weight loss. *Behavior and Information Technology*, *34*(2), 176–189. https://doi.org/10.1080/0144929X.2013.866162

Lehto, T., Oinas-Kukkonen, H., Pätiälä, T., & Saarelma, O. (2012). Consumers' perceptions of a virtual health check: An empirical investigation. *ECIS 2012 - Proceedings of the 20th European Conference on Information Systems*, *January*.

Leveau, P. H., & Camus, et S. (2023). Embodiment, immersion, and enjoyment in virtual reality marketing experiences. *Psychology and Marketing*, *April*, 1–15. https://doi.org/10.1002/mar.21822

Mäntymäki, M., & Islam, A. K. M. N. (2014). Social virtual world continuance among teens: Uncovering the moderating role of perceived aggregate network exposure. *Behavior and Information Technology*, *33*(5), 536–547. https://doi.org/10.1080/0144929X.2013.872190

Marasco, A., Buonincontri, P., van Niekerk, M., Orlowski, M., & Okumus, F. (2018). Exploring the role of next-generation virtual technologies in destination marketing. *Journal of Destination Marketing and Management*, *9*(December 2017), 138–148. https://doi.org/10.1016/j.jdmm.2017.12.002

Menck, J. H. D., Lechte, H., Lembcke, T. B., Brendel, A. B., & Kolbe, L. M. (2023). Towards Design Principles for Experimental Simulations in Virtual Reality - Learning from Driving Simulators. *Proceedings of the Annual Hawaii International Conference on System Sciences*, *2023-Janua*, 1303–1312.

Mouatt, B., Smith, A. E., Mellow, M. L., Parfitt, G., Smith, R. T., & Stanton, T. R. (2020). The Use of Virtual Reality to Influence Motivation, Affect, Enjoyment, and Engagement During Exercise: A Scoping Review. *Frontiers in Virtual Reality*, *1*(December). https://doi.org/10.3389/frvir.2020.564664

Nutrokpor, C., Ekpezu, A. O., Wiafe, A., & Wiafe, I. (2021). Exploring the Impact of Persuasive System Features on User Sentiments in Health and Fitness Apps. In P. Tikka, H. Oinas-Kukkonen, & N. Shevchuk (Eds.), *CEUR Workshop Proceedings*.

Oinas-Kukkonen, H., & Harjumaa, M. (2009). Persuasive systems design: Key issues, process model, and system features. *Communications of the Association for Information Systems*, *24*(1), 485–500. https://doi.org/10.17705/1cais.02428

Qian, J., McDonough, D. J., & Gao, Z. (2020). The effectiveness of virtual reality exercise on individual's physiological, psychological and rehabilitative outcomes: A systematic review. *International Journal of Environmental Research and Public Health*, *17*(11), 1–17. https://doi.org/10.3390/ijerph17114133

Ramírez-Correa, P. E., Rondán-Cataluña, F. J., & Arenas-Gaitán, J. (2018). Student information system satisfaction in higher education: the role of visual aesthetics. *Kybernetes*, *47*(8), 1604–1622. https://doi.org/10.1108/K-08-2017-0297

Sengupta, A., & Williams, S. (2021). Can an Engagement Platform Persuade Students to Stay? Applying Behavioral Models for Retention. *International Journal of Human-Computer Interaction*, *37*(11), 1016–1027. https://doi.org/10.1080/10447318.2020.1861801

Shevchuk, N., Degirmenci, K., & Oinas-Kukkonen, H. (2019). Adoption of gamified persuasive systems to encourage sustainable behaviors: Interplay between perceived persuasiveness and cognitive absorption. *40th International Conference on Information Systems, ICIS 2019*, 1–17.

Shin, D. (2018). Empathy and embodied experience in virtual environment: To what extent can virtual reality stimulate empathy and embodied experience? *Computers in Human Behavior*, *78*, 64–73. https://doi.org/10.1016/j.chb.2017.09.012

Spence Laschinger, H. K., Wilk, P., Cho, J., & Greco, P. (2009). Empowerment, engagement and perceived effectiveness in nursing work environments: Does experience matter? *Journal of Nursing Management*, *17*(5), 636–646. https://doi.org/10.1111/j.1365-2834.2008.00907.x

Verhagen, T., Feldberg, F., Hooff, B. van den, & Meents, S. (2009). Understanding Virtual World Usage : A multipurpose model and empirical testing. *Proceedings of the Seventeenth European Conference on Information Systems*, 1–15.

Wadhwani, P., & Loomba, S. (2022). *Fitness Equipment Market - By Equipment (Cardiovascular, Strength Training [Weightlifting, Weights, Barbells & Ladders, Extension Machines, Power Racks]), By End-Use (Home, Health Clubs, Office, Hotel) & Global Forecast, 2023 - 2032 Report ID: GMI443 Publ.* https://www.gminsights.com/industry-analysis/fitness-equipment-market-report

Wang, R., Bush-Evans, R., Arden-Close, E., Bolat, E., McAlaney, J., Hodge, S., Thomas, S., & Phalp, K. (2023). Transparency in persuasive technology, immersive technology, and online marketing: Facilitating users' informed decision making and practical implications. *Computers in Human Behavior*, *139*(July 2022), 107545. https://doi.org/10.1016/j.chb.2022.107545

Wiafe, I., Koranteng, F. N., Kastriku, F. A., & Gyamera, G. O. (2022). Assessing the impact of persuasive features on user's intention to continuous use: the case of academic social networking sites. *Behavior and Information Technology*, *41*(4), 712–730. https://doi.org/10.1080/0144929X.2020.1832146

Wiafe, I., & Nakata, K. (2012). Bibliographic analysis of persuasive systems: techniques, methods, and domains of application. *Persuasive Technology: Design for Health and Safety, The 7th International Conference on Persuasive Technology, PERSUASIVE 2012*, *May 2014*, 61–64. http://centaur.reading.ac.uk/28976/

Wiafe, I., Nakata, K., & Gulliver, S. (2014). Categorizing users in behavior change support systems based on cognitive dissonance. *Personal and Ubiquitous Computing*, *18*(7), 1677–1687.

Wienrich, C., Döllinger, N., & Hein, R. (2021). Behavioral Framework of Immersive Technologies (BehaveFIT): How and Why Virtual Reality can Support Behavioral Change Processes. *Frontiers in Virtual Reality*, *2*(June), 1–16. https://doi.org/10.3389/frvir.2021.627194

Yang, H., & Han, S. Y. (2021). Understanding virtual reality continuance: an extended perspective of perceived value. *Online Information Review*, *45*(2), 422–439. https://doi.org/10.1108/OIR-02-2020-0058

Yang, X., Ma, L., Zhao, X., & Kankanhalli, A. (2020). Factors influencing user's adherence to physical activity applications: A scoping literature review and future directions. *International Journal of Medical Informatics*, *134*(November 2019). https://doi.org/10.1016/j.ijmedinf.2019.104039.