Users' Acceptance and Sense of Presence towards VR Application with Stimulus Effectors on a Stationary Bicycle for Physical Training

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***Abstract*—This research's objective is to identify lacking elements in various effectors utilized in current physical training for cyclists. This encompasses both virtual reality-based system and indoor conventional training. Another objective is to identify user's acceptance from the use of vProCycle; which acts as the primary instrument of this study. Virtual Reality (VR) technology is a computer-generated simulation experience where immersive surroundings replicate lifelike environments – and is used for cyclists' physical training. Distinctive combinations of stimulus effectors (such as altitude, wind-effect, visuals, audio etcetera) have been applied to simulate actual world training environment. This is in order to increase the fidelity of presence for the participants involved, with emphasis on the five human senses. However, in this research the focus is only on hearing, sight, and interaction. The methodology of this mixed-mode pilot study is inclusive of 2 cyclists as participants and a 30 minute training session inside the hypoxic chamber room, whereby they have experienced a VR visual route replica of L'Étape du Tour, France. Variables composed of distinctive stimulus effectors are employed during the training, and survey interviews are utilized to gain users' insight. Results from this pilot study on the presence level indicate that the cyclists' have given high scores. This high score means that the cyclists were immersed while using the vProCycle system. In addition, the cyclists' also gave a high score on the level of technology acceptance towards using vProCycle. The main contribution from this study is to understand how various combinations of stimulus effectors can be applied in a VR-based training system.**

Keywords*—*Virtual reality; sense of presence; technology acceptance; stimulus effectors

I. Introduction

This research focuses on Virtual Reality (VR) physical cycling training that highlights several preferred stimulus effectors. Subsequently, this study proposes a new indoor cycling setup that includes the identified effectors. In the sports field, VR-based applications have been employed in several distinctive sports such as boxing, soccer, tennis, cycling, etc. VR has been in sports since the year 1990. In most VR applications, it requires a high-end computer in order to run [1]. Other than sports, VR can also be applied for exercising purposes. In addition to that, VR technological applications are also used to visualize realistic 3D modeling, interaction, data acquisition, analysis, product design, education, and even for medical practices. In terms of cyclists' physical training aims, VR-based applications have been found to gain its popularity [1,2,3]. An advantage of VR is that VR can induce a sense of being mentally or physically present in another place because VR allows individuals to interact with the environment [2]. Further advantages of VR are also noted by Sherman et al. [2], where he has stated that the VR environment can be manipulated in specific and reproducible measures. Sherman et al. [2] used these advantages to train participants to use a rowing and paddling pace strategy for a cycling race. Sherman et al. [2] also mentions that the VR exercising environment does not need to be limited to only a single person. Other individuals such as a coach, teammates, or opposing competitors, may be present even if they are physically located in another place.

In the context of cycling sports, interaction will occur based on how much physical effort from the body is applied to a machine (i.e. Kinetic Road Machine), and this interaction process is known as exertion interface noted by Alhadad et al. [1]. Kinetic Road Machine is one of the most well-known smart trainers available in the current market. A smart trainer is a machine which allows the cyclists to mount their bicycle back wheel, as shown in Fig. 1. Smart trainers are mounted onto the back wheel which have a feature to create a resistance effect. Meanwhile, ergometer is used to detect the motion speed that interactively changes the view in real-time.

Fig. 1. Smart Trainer Machine (in Red Circle).

In a more advanced VR-based cycling application, devices such as motion capture video systems, infrared beams, and wearable sensors can be used to generate haptic effects; which then translate physical actions into virtual activity. Thus, in general, a VR computer-based sport can be an alternative for an athlete to interact with the virtual environment.

II. Literature Review

In this research, several literatures were reviewed to identify the current status of effectors integrated into a VR-based physical training. According to the Oxford dictionary (2021), the meaning of effectors refer to a substance that carries out a response to the stimulus. This definition is also similar in physiological terms. Meanwhile, a stimulus refers to a substance or event which evokes a specific functional reaction from the human body. From the literature review it is found that stimulus-effectors such as snow, water, wind-effect, and many others can be applied in particular events to trigger a specific body reaction. In a VR-based training, several stimulus-effectors can be applied as replication of an actual life experience.

According to Lim et al. [3], “VR technology creates a stimulation across arrays of effectors and is attached to devices to create an immersive virtual reality system”. Until now, the commonly used VR effectors among cyclists comprise of visual, audio, and interaction. It is suggested by a few researchers that adding more effectors on top of the regular ones (i.e. audio, visual and interaction) will generate a significantly more immersive experience. In the area of sports, researchers have used various combination effectors to improve athletes' physical condition [3].

In various studies, different sets of combination effectors are applied to achieve specific objectives such as to increase performance, check physical fitness level, and improve body endurance [4,5,6,7]. In relation to cyclist physical training, it is suggested by the researchers that the following six main effectors; altitude, uphill elevation climb, wind-effect, visuals and audio, interaction and temperature are utilized. The strength and weakness of the effectors’ piled as a combination are also identified based on the literature review.

The first stimulus-effector in this research called altitude and temperature. Altitude is referred to as the height of an object or point in relation to sea level or ground level [4]. There are two primary types of altitude training, and they are known as acclimatization and acclimation. Acclimatization is the natural outdoors and acclimation involves indoor training. In acclimatization the actual outdoor oxygen level is used during the training, while for acclimation oxygen level is generated. During a VR–based physical training, cyclists often conduct their training at a simulated high altitude with the aim to train their lungs to perform less oxygen intake [4, 5, 6].

During altitude and temperature training, three main factors may impact the cyclists’ body and they are; atmospheric pressure, reduction of oxygen molecules in the air, and colder temperatures as the altitude gets higher from sea level [8]. The first factor which is atmospheric pressure, affects the cyclist as the altitude gets higher. Changes to atmospheric pressure may lead to a situation where there is less oxygen in the cyclists' blood to carry to their muscles [9]. When cyclists train with less oxygen intake, their muscles may adapt accordingly, which means that the cyclist does not need to breathe harder or more when they are at sea level altitude. Most of the Olympic cyclists are trained at 1000 meters above sea level. At that level, the body will take in at least 20 percent lesser oxygen. This is caused by a reduction of oxygen in the atmosphere compared to sea level. Generally, higher altitudes of 5000 and above are considered dangerous due to the amount of oxygen molecules being below 17% in the air [8,9].

In a paper by Lei et al [5], they have mentioned that there is a significant impact when integrating altitude and temperature within VR-based applications. In Lei’s [5] research, a setup involving a special room replicated the environment’s altitude of 1000 meters above sea level; whereby the users were required to wear a HMD. The amount of oxygen was based on that height. It is to be noted that his experiment was conducted in multiple sessions. The findings from her research show that the cycling speed has improved where the difference between the first and the final sessions was greatly significant. Furthermore, Lei [5] also studied the effects of physical sport equipment such as a ball. Lei’s [5] findings show a positive outcome where athletes have improved their accuracy as the participants were able to aim and kick the ball directly into the goal post.

Another essential research conducted by Mujika et al. [6] highlighted the measurement of altitude using the Meters Above Sea Level (m.a.s.l) technique. In his research, the user is also required to wear a HMD. Altitudes can be controlled indoors for training by using a chamber room. This chamber room can simulate any hypoxic environment by both latitude and longitude. Latitude is the angular distance of a place north or south of the earth's equator. On the other hand, longitude is the angular distance of a place east or west of the Greenwich meridian. As the latitude is higher above sea-level, fewer oxygen molecules are in the air and this consequently makes temperature to get colder. The longitude of a location can also determine the temperature on Earth. For example, the equator has different temperatures near the south and north poles. During the experiment, three different levels of altitudes were tested: low, medium, and high. Low altitudes represent the sea level where, at this altitude, the percentage of oxygen molecules is 20.9. This is the standard level of oxygen required by the human body to breathe normally. Meanwhile, at medium altitude (between 3000 and 4000 feet), the percentage of oxygen molecules is between 18.6% and 17%. Next at 5000 feet is considered as high altitude, whereby the oxygen may reach below 17% in the air.

Mujika’s et al. [6] experiment involved the usage of a hypoxic dose, a timer, and confounding factors. Hypoxic dose is a medication given to the participating cyclists at an early stage. It helps cyclists to adapt themselves during altitude training. Meanwhile, a timer refers to a load periodization where it involves progressive cycling of various aspects in a training program during a specific period. Lastly, confounding factors used by Mujika [6] involved the use of simulated altitude, such as Meters Above Sea Level (m.a.s.l) and oxygen intake. Simulated altitude refers to the pressure and oxygen molecules available to the users while using a VR-based system similar to that of a real-life situation. This training was conducted over multiple sessions. The impact of the training depicts that VR-based training enhances athletes' muscle buffering capacity which subsequently improves athletic physical fitness. This study also suggested that simulated altitude is incredibly effective to train athletes' endurance.

The only difference between Mujika's [6] and Lei's [5] study is that in Lei's [5] study, she did not include multiple high altitude studies.

The second effector preferred by many cyclists for training purposes is called an uphill elevation climb. Uphill elevation climb is a stationary cycling training simulated by the resistance effect on the back wheel. This resistance effect gives the cyclist the sensation of cycling uphill as they would in the real world. A back-wheel resistance machine is a piece of hardware that makes it possible to ride a bicycle with an uphill climb effect. This machine consists of a frame, a clamp, a roller on the back-wheel, and a motor which provides resistance [8, 9]. However, Yap et al. [7] has stated in his paper that the combination of back wheel resistance together with the common effectors (visual, audio and interaction) is not realistic enough to imitate an actual real life event. Many researchers have also suggested adding more varieties of different effectors to the current stationary training method.

In relation to the back-wheel resistance, Farrow et al. [8] have used HMD and uphill elevation climb to study a haptic effect. In his study, he highlighted that enjoyment levels and the force needed to paddle increases when haptic effects are experienced. Back-wheel resistance machines can be equipped with sensors that monitor the cyclists' physical fitness. Physical characteristics such as power output, cadence, virtual speed and heart rate are among the metrics that can be transmitted electronically [8]. Analyzing these physical outputs can help to fine-tune the athlete's training sessions. These sensors can also monitor data such as speed, distance traveled and time duration [8,9].

The effector of the uphill elevation climbing effect using bicycle was created using many different methods such as rollers on the back-wheel, attaching machines directly on to the bicycle wheels with the utilization of a 3D platform. One of the most popular methods in virtual reality to create the simulation of an uphill climb is by using a machine attached to the back wheel. The machine would cause resistance on the back wheel depending on the virtual environment as seen by the cyclist. In Farrow's [8] experiment, athletes' force and enjoyment levels were tested using HMD. The effector uses haptic effect from having the athletes paddle on the bicycle with resistance based on the VR system. In the study conducted by Farrow [8], he stated that with exercise enjoyment, athletes were still able to improve physical fitness using VR to train. In his findings, his results demonstrated that VR-exercise is an effective intervention as well as being credible to increase enjoyment while training [8,9]. It was calculated that 20 participants 222 were needed to identify a statistically significant gap in mean power output between 223 tracks and conditions (effect size = 0.67), with a power of 0.8 and alpha set at 0.05.

In Farrow [8] research, they developed a stationary bike reality simulation training with a back-wheel resistance device. The research was conducted using a back wheel road machine, which creates a virtual environment simulating an uphill climb. In his research, the users select the cycle path using a human–machine interface [9,10]. The stationary bicycle is used as an assisting training device that was proposed to help riders undertake simulation-based training before cycling on a real cycle path. The result of this research calculated the riding speed and accumulated the mileage as well as time-trial. Each riding session recorded distinctive elements such as mileage, time duration, average speed, and the route chosen. The results of his study using the Kinetic road machine shows that it had improved the cyclist's average speed when riding.

The third effector preferred by the cyclists during physical training is called wind-effect. Wind-effects can be used to enhance the experience and improve cyclists by exposing them to a more naturally aesthetic environment. This wind is created by using a fan. In order to simulate the wind-effect during cycling and enhance the cycling experience, a real time wind speed is needed to be generated [9, 11].

The wind speed can be measured in kilometers per hour. Integrating wind-effects for cycling training is used for endurance training focused on adaptive hypoxic training. Coaches train their athletes in a condition where the cyclist is required to paddle at maximal speed at a setup with high wind speed [9, 10]. The effect of the wind physical training is measured by the cyclist's speed together with the amount of wind speed in kilometers per hour. When used for training purposes, cycling in the wind can potentially cut one's speed in half with the same effort expended as when there is no wind. This means that the cyclist has to work twice as hard to generate the same output. The measurement from wind-effect training can be seen by the cyclist's energy output, and distance traveled in a specified time trial as in Petri et al. [9].

Research conducted by Schwind [10] found that the usage of HMD in VR sports has widely changed the way simulated sports are practiced. However, he claimed that experts still understand only a little about the use of antecedents for cyclists' sports applications. He examined attitudinal and norm-based factors that influence users' continuous intention towards sport applications usage. His research consisted of 362 sport practitioners where basic realism fidelity was integrated into the system. The results indicated that all attitudinal factors and norm-based factors have optimistically affected users' acceptance towards the inclusion of sport applications. His findings portrayed a promising acceptance level to all stimulus effectors of uphill elevation climb and wind-effect.

The last two effectors; visual and audio, are often integrated into cycling physical training aiming to produce highest fidelity of realism. A Virtual reality system renders visuals for the users to experience in a controlled virtual environment. The environment visuals are usually based on the user's bodily interactions, such as while the user rotates their head during HMD utilization, and the visuals are viewed according to the orientation of the head. Also, while using virtual reality force feedback on bodily interactive motion, the visuals can move the 3D user's avatar in the virtual environment. This force feedback bodily interaction is what makes the VR sports exercise experience more pleasurable. Another effector is sound-effect that the user can auditorily hear while they are immersed in the virtual environment. Sound-effects in the virtual environment are 3D-surrounding. In VR, the 3D-surround sound effect uses multiple audio cue channels to stimulate the effect of an object's sound from the distance; the sound is sighted from 3D-surround sounds that come together with visuals as the two effectors complement one another for a realistic experience.

In a research conducted by Yap et al [7], a HMD with a fully immersive 360 degree view and 3D audio was used. Inside the HMD, one view is for the user's right eye and the other view is for the left eye. These two stereo views were fused by the viewer's perceptual system in the same way as humanistic right and left eye views of natural scenes [7]. The HMD system must also compute the synthetic views, track the viewer's location, and viewing orientation in the virtual world to create the correct right and left eye views. The latest VR technologies allow the development of better and cost-effective spatially immersive visualization and audio systems. His findings showed that 38 out of 50 preferred to display the simulation in HMD in comparison to non-VR-based displays such as on projectors and monitor screens.

In another research conducted by Koivisto et al. [11], he identified that users' characteristics may influence the quality of the VR experience. He also stated that users' characteristics may be influenced by the quality of the VR system. For example, the quality between visualizing through a monitor screen and using a HMD will give different impacts on the users' immersion level. It involves progressive cycling of various aspects of a training program during a specific period. Koivisto et al. [11,12] used a questionnaire method called the International Physical Activity Questionnaire (IPAQ). By using IPAQ, he found significant improvements compared to VR and non-VR visuals as well as audio.

The study conducted by Ng [13] shows that motivated cyclists using VR virtualization can contribute greatly to achieve training purposes. Ng identified research gaps in the areas of virtual reality (VR) sport applications from a systematic literature review of VR sport applications research. It showed that different physiological and psychological factors have been investigated by conducting experiments on the use of these applications in the study by Alhadad et al [1], Neumann et al. [14]. However, in Ng's study, different task purposes, like training, competition or socializing, do influence the perceived benefits which have not yet been examined. Moreover, it is unclear whether perceived benefits and risks affect actual behaviour outside laboratory environments. His study showed a significant difference in the risk assessment perceived by the cyclists.

Based on the seven papers as discussed above, six effectors have been identified. Those effectors are altitude effect, uphill elevation climb effect, realistic audio and visuals, wind-effect, realistic interaction and temperature. The details of each of these stimuli are further explained in the following subtopics.

Through the seven main effectors as mentioned, it is noticed that many researchers have used effectors. However, the combination of implementing all stimulus effectors together into one complete system has not yet been established.

III. Findings Results from Author's Previous Study

This paper is a continuation from the authors' previous research as published in "A literature review on the usage of Technology Acceptance Model for analyzing a virtual reality's cycling sport applications with enhanced realism fidelity." [15,16] and "A literature review on the effects of 6-Dimensional virtual reality's sport applications toward higher presence." [16]. During the author's previous research, several selected stimulus effectors were identified. These findings were done by conducting a questionnaire interview session and feedback gathered from recreational cyclists who have undergone current stationary indoor training in professional gyms. In the last two papers, the number of interviewees was 30 in quantity, whereby all were conducted at a professional gym.

In the Table I, it shows the list of stimulus effectors used in the current setup for a conventional indoor cycling training.

TABLE I. Cycling Training Stimulus Effectors Setup Requirements

Stimulus effectors	Current setup (Available Y/N)	No. of cyclists have experienced the simulator	No. of cyclists that recommend the stimulus effectors
Uphill elevation climb	Yes	30	30
Altitude	No	Nil	28
Wind-effect	Yes	25	28
Visual and sound	Yes	28	28
Interaction	Yes	30	30
Temperature	No	Nil	28

Table I shows the usage of stimulus effectors for cycling training. The data is gathered from the interview conducted with 30 recreational cyclists between the ages of 18 years and 50. Out of the 30 cyclists, 20 were male and the latter10 were female. Column one of Table I shows the six stimulus effectors identified from the interview as discussed in the previous paper [15,16]. In the "current" setup, it is found that altitude and temperature stimulus effectors are not being integrated. It is also identified as shown in the table that all participants were trained with uphill elevation climb and interaction. As for visual and sound, only 28 participants used a device to display their physical or other visual activities during a training session. While cycling in the gym, the standard setup includes a big screen in front of the cyclist. However, some cyclists often watch or listen to other technological sources such as mobile phones and tablets. This action of extra displays can cause distraction while they undergo a training session. As for wind-effect utilization while training, every stationary bicycle comes with a built-in fan. Despite the availability of the fan feature, only 25 cyclists out of 30 actually employed it during training. Table I also portrays the number of cyclists who felt that using stimulus effectors while training is of great importance. A majority of the cyclists perceived all six stimulus effectors as necessary for the purpose of cycling training.

From the findings listed in Table I, it has been identified that the six stimulus effectors are important towards creating a highly effective training platform among cyclists. The combination of two or three stimulus effectors have already been experimented by other researchers as discussed in the literature above. In this paper, the combination of all six stimulus effectors is proposed, which deem it as distinctive from other researchers as cited in the literature review section. In the following sections (4.0), the implementation of the proposed VR setup with the combination of stimulus effectors to meet the requirement of a current cycling training system will be explained in detail.

IV. Hardware and Technology Requirement

Table II shows the list of technology providers that fulfill the requirements for a cycling training system. The six effectors are matched to a specific technology to provide a distinguished experience for the user.

Table II shows a list of effectors and their technology providers integrated into the vProCycle system. The effectors employed are audio and visuals, altitude, uphill elevation climb, temperature, wind-effect, as well as paddling interaction.

From the literature, it was found that with distinctive stimulus effectors, the cyclist had experienced a higher level of immersion and presence. This situation is similar to the experience gained by the cyclist during their training in the real world.

Many literature encourages the use of more distinctive stimulus effectors for a better VR application out-put. The individual stimulus effectors have already been investigated. However a comprehensive study on a VR application that consists of several stimulus effectors have not been maximized.

TABLE II. List of Effectors and Technology Provider

List of effectors and technology provider		
No.	**Effectors**	**Technology provider**
1.	Audio and visuals	HMD
2.	Altitude	Altitude chamber room
3.	Uphill elevation climb	Backwheel resistance machine
4.	Temperature	Altitude chamber room
5.	Wind-effect	Fan
6.	Realistic paddling interaction	Blue-tooth device

V. Implementation of VR-based System with Stimulus Effectors

From the findings where the providers and effectors have been matched, the following setup design inclusive of all the six stimulus effectors was generated. Before discussing in detail about the proposed setup, a few current cycling training systems are discussed here.

As shown in Fig. 2(a), (b) and (c), the cyclists are conducting their training using a conventional setup where they are not complementing the training with VR technology visual and audio. In Fig. 2(a), the cyclist is interactively viewing the cycling track based on the paddling speed. However, there is no interactive resistance applied while cycling as viewed when climbing uphill. Fig. 2(b) shows a combination of both external visuals (i.e. big screen TV) and a backwheel resistance that simulates the effect of cycling uphill. Fig. 2(c) shows the training setup done inside a chamber room where no VR is applied. However, the cyclist gets the effects from temperature, humidity and latitude control. VR is also applied as mentioned in the LR, however with a limited combination of stimulus effectors. Based on all the existing setups as discussed above, it is found that there is no setup that exists yet that integrates all the components comprehensively. As a result, a new setup is then proposed.

Fig. 2. Traditional Training without VR (a), (b), (c).

Fig. 2 shows a traditional training without VR and with back wheel resistance (a). Fig. 2(b) shows a traditional training without VR with big screen and backwheel resistance to stimulate uphill climb. Fig. 2(c) shows a cycling training without VR in an altitude chamber room. From the findings as discussed above, the following design setup involves all the six stimulus effectors.

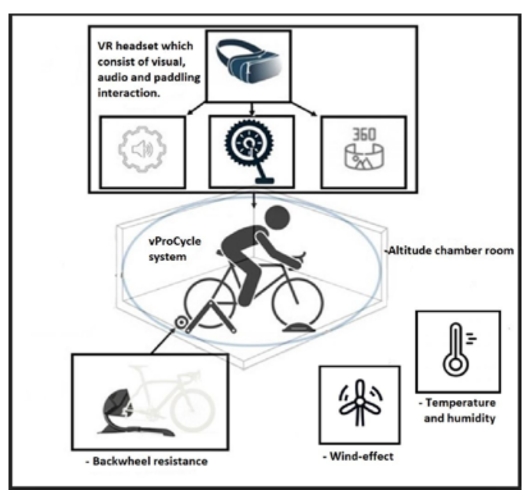

Fig. 3. Proposed Setup of VR Cycling Training System.

Fig. 3 shows the proposed setup of the VR cycling training system with the combination of various effectors. As previously stated, the elements encompass uphill elevation climb, altitude, temperature, wind-effect, interaction, visual, and audio. This proposed VR cycling training system is named as the "vProCycle system".

The selected effectors and technology providers must match the requirements of the current cycling system, hence the methodology is justified in the next section.

VI. Experimental Methodology and Results

In this section, the generated vProCycle is used for the experiment and will be discussed in detail. Through this vProcycle cycling training system, the sense of presence and users' immersion rate in the virtual environment are both evaluated. In addition, the technology acceptance of the cyclist is also to be determined. The first stage of the experiment involved a pilot study by two well- trained cyclists. After the data is collected from the pilot study, the vProCycle system is then further tested in experiment 1.

VII. Pilot Study and Objectives

The objective of the pilot study is to evaluate whether the designated reaches a high fidelity of VR presence level from using the vProCycle system. Another objective is to evaluate their acceptance or outlook towards the technology when using vProcycle.

VIII. Pilot Study Setup Requirements and Design Materials

In this subsection, the cyclists' setup requirements and design materials used to conduct the pilot study are identified. The figure shows a visual of the setup requirement and design materials utilized throughout the pilot study.

Fig. 4 shows the setup requirements and design materials during the pilot testing. This pilot test is conducted at Institut Sukan Negara (ISN). ISN is a Malaysian government agency - and it is established to provide sports science services, conduct research and development in the sports spectrum. Specifically, the study was conducted inside a hypoxic chamber. A stationary bicycle was used in the experiment whereby it was mounted on a back wheel machine. The machine is used to create an effect of resistance to the back wheel of the bicycle to simulate an uphill elevation climb. The paddles were also equipped with a Bluetooth sensor that sends signals to the HMD. This indicates that the bicycle is being paddled for it to move in the virtual environment. When the cyclist paddles forward, the visuals in the HMD change accordingly to the motion speed of the paddles. The HMD provides a complete 360ºaudio of the virtual environment sound to the cyclist participating. The visuals used in this study was a 360º view of L'Étape du Tour, France, as recorded by a 360 camera.

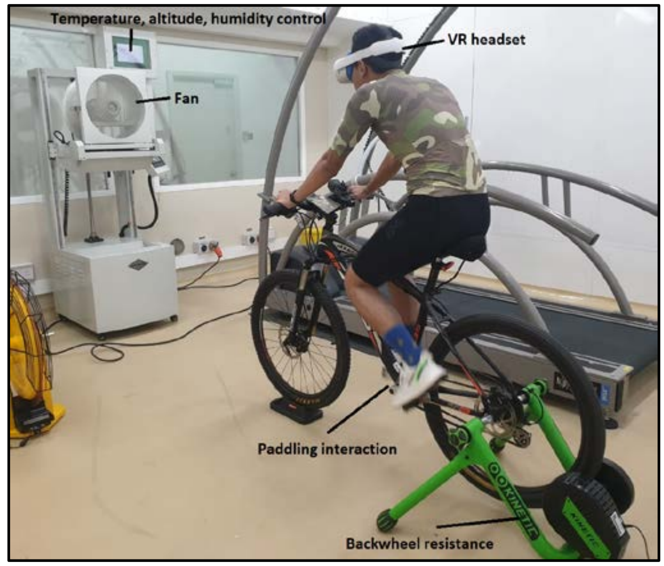

Fig. 4. Pilot Study Setup.

Fig. 5. A Sample Visual of L'Étape du Tour, France.

Fig. 5 shows a sample visual of the cyclist's view in the HMD while undergoing the pilot study. As mentioned earlier, another effector applied in the system is wind-effect. The wind-effect is generated by a fan placed at one and a half meters in front of the cyclist. The overall listed requirements and design materials are placed in a hypoxic chamber room; which controls the altitude, temperature, and humidity in the designated area. During the pilot study, a 1x9 MTB gear setup mountain bicycle was mounted onto the back wheel machine. This bicycle was selected to test the detected changes on the back wheel elevation climb-effect. This climb-effect is computer generated and controlled by the virtual reality program, which means that it adjusts the resistance of the wheel. This is executed by gripping or releasing of the rotation wheel as the virtual landscape changes. The session of this experiment was conducted for 30 minutes.

IX. Pilot Study Cyclists' Requirement

The pilot study involved identifying the basic requirement of the cyclist participating. The first requirement is that the cyclist must be above 18 years old. The second is that the cyclist must have the experience of participating in a cycling state event and have completed the flag-off time limit.

X. Pilot Study Tools Settings

The pilot study tool settings were that both cyclists are required to cycle at least 30 minutes in a virtual environment based on the Google map view of L'Étape du Tour, France. L'Étape du Tour map view is an official, professional cyclist training route. This route is 13 kilometers in length, with an altitude of 1,800 to 2,000 meters above sea level. The temperature level at this location is between 18°C to 26.5°C and at this altitude, the oxygen molecules in the air is about 20 percent lesser than at sea level. On this route, there are a lot of uphill elevations in narrow turns, which indefinitely creates a physical challenge when cyclists train at that exact location.

XI. Pilot Study Result

In this study, two participants were involved, one male and one female. The data collected were divided into two categories: (1) sense of presence level and (2) technology acceptance. Presence is measured using a questionnaire based on the Witmer and Singer Presence Questionnaire [3], which uses a Likert scale from 1 to 7. The indicator of the Likert scale is the lowest of 1 being not immersive and 7 being highly immersed. An example of the questions used are "When you bicycle forward, did the feeling of moving forward in the virtual world seem realistic?" and "When you paddled the bicycle, did you feel the movement speed as realistic according to the change of view?" The two participants were required to answer a series of questions addressing each effector. The presence questionnaire was given after the cyclists had undergone a training session using vProCycle.

XII. Pilot Study Result: Sense of Presence

Results of the cyclists' sense of presence data can be used to determine whether the vProcycle system is credible in creating the sense of realism as though they were cycling in L'Étape du Tour, France. The table shows the results of the cyclists' sense of presence using vProCycle system.

The number of questions asked in relation to the effectors listed in Table III were: 14 questions related to visuals, 5 questions on audio, 6 questions on altitude, 6 questions on the uphill elevation climb, 3 questions on temperature, 3 questions on wind-effect and lastly, 7 questions on interaction. Table III shows the cyclists' sense of presence using the vProCycle system. The first effector listed is "visual". The score given by the male cyclist is 4.1 out of 7, which indicates that the visuals are moderate for him. On the other hand, the female cyclist rated the "visual" with a score of 5.1 out of 7, which is considered upper-moderate. Secondly is audio effects, whereby the male cyclist gives it a score of 5.2 and simultaneously, a score of 5.6 by the female cyclist, which indicates that both cyclists give the audio presence level an upper-moderate score. Thirdly, in regard to the altitude-effect, the male gives it a score of 5.4 out of 7 while the female gives it a score of 5.7. Both rated the altitude-effect score as highly immersive, an almost exact replica of being at the high altitude of the L'Étape du mountain. Fourth is on the uphill elevation climb, where the male gives it a score of 2.6 out of 7 and the female gives it a score of 4.5 out of 7. This signifies that the uphill elevation climb has the lowest score out of all the other effectors. An open-ended interview session gained insight on why the male cyclist gave the very low score on the uphill elevation climb. It was mentioned that the maximal 10 degrees angle uphill inclination that the VR back wheel machine produced does not feel immersive. This is in liaison as the visuals appeared to look like more than a 10 degrees angle slope. Fifth is regarding the temperature, whereby both participants scored a 5.3 out of 7. This indicates that the temperature simulation within the VR immersion experience was very realistic. Sixth is on the wind-effect, the male gives it a score of 5.3 out of 7 while the female gives it a score of 5.66. This indicates that both cyclists found the wind-effect to be quite similar to lifelike surroundings. Lastly is the paddling interaction, whereby the male cyclist gives it a 4.5 and the female cyclist gives it a 4.6. Both cyclists gave the paddling interaction a reasonably decent, high score. All the scores from the questionnaire were added, then averaged based on the effectors.

TABLE III. Pilot Study of the Cyclist Sense of Presence

The cyclists sense of Presence using vProCycle system			
No.	**Effectors**	**Male cyclist (Average)**	**Female cyclist (Average)**
1.	Visuals	58/98 = 4.1	72/98 = 5.1
2.	3D Audio	26/35 = 5.2	28/35 = 5.6
3.	Altitude	27/35 = 5.4	27/35 5.4
4.	Uphill elevation	16/42 = 2.6	32/42 = 4.5
5.	Temperature	16/21 = 5.3	16/21 = 5.3
6.	Wind-effect	16/21 = 5.3	17/21 = 5.66
7.	Paddling interaction	32/42 = 4.5	33/42 = 4.7

XIII. Pilot Study Result: Technology Acceptance

This section explains both cyclists' technology acceptance using vProCycle system during the pilot study. All the scores from the questionnaire were added then later averaged based on the independent variables of TAM. The number of questions asked in relation to the independent variable listed in Table III are composed of 8 questions related to perceived usefulness, 7 questions on ease of use, 4 questions on behavioural intention to use, and 5 questions on attitude towards usage.

Table IV shows five independent variables of TAM. Those variables are: perceived usefulness, perceived ease of use, attitude towards using, behavioural intention to use, and actual use. The first independent variable is "perceived usefulness", the male cyclist rated it a 7 while the latter gave it a 5.5. This shows that both cyclists found it quite useful; using vProCycle as a hypoxic cycling training. The second variable is "perceived ease of use"; the male ranked a score of 5.7 while the female gave it a score of 6.2. This implies that the vProCycle system was very easy to use by both cyclists. The third variable is “attitude towards using vProCyle”, where the male rated 5.6 while the female gave a 5.6. This signifies that the cyclists' attitude towards using vProCycle is incredibly positive. The fourth independent variable is on the “behavioural intention to use”, the male puts a value of 6 while the latter gives it a score of 6.75. This indicates that both cyclists would have the intention to continually use vProCycle. The last variable is called “actual use”, with the male giving a score of 7 and the female cyclist a score of 6. Both cyclists highly recommended vProCyle to be used for hypoxic training.

TABLE IV. PILOT STUDY OF THE CYCLISTS’ TECHNOLOGY ACCEPTANCE TOWARDS USING VPROCYCLE

The cyclists’ technology acceptance towards using vProCycle			
No.	**Independent variables of TAM**	**Male cyclist**	**Female cyclist**
1.	**Perceived Usefulness**	**49/56 = 6.18**	**44/56 = 5.5**
2.	**Perceived Ease of use**	**40/49 = 5.7**	**44/49 = 6.2**
3.	**Attitude towards using**	**28/35 = 5.6**	**28/35 = 5.6**
4.	**Behavioural intention to use**	**24/28 = 6**	**27/35 = 6.75**
5.	**Actual use**	**21/21 = 7**	**18/21 = 6**

XIV. PILOT STUDY AND ISSUES

It was advised by ISN that some cyclists may encounter hypoxemia which may lead to nausea, headache, dizziness or even vomiting. Fortunately, none of the participants encountered any of the symptoms of hypoxemia during this study.

Another issue was related to the uphill elevation climb. This is when the cyclist sees an incline of greater than 10 degrees steepness slope angle; while the back wheel machine can only create a maximum of 10 degrees. Some cyclists may expect to get greater resistance when encountering a stiff uphill climb as the hill has a steepness of 60 degrees. However, there is a device that can go up to 60% but is not currently available in VR. From the open interview in relation to the uphill elevation climb, the middle score is given only in relation to the back wheel resistance compared to the elevation climb that is visible in the HMD. There is a solution available that gives a better uphill climb using other devices. However, that device will not be used in the VR environment.

XV. PILOT STUDY CONCLUSION

From the pilot study, it was highlighted that both the sense of presence in the VR cycling stimulation and technology acceptance of vProCycle were given high scores as well as positive feedback. This suggests that further testing can be conducted for professional cyclists. The test conducted in experiment 1 will be explained in detail below. In experiment 1, additional data from a heartbeat reader will be collected on top of other data similar to the pilot study executed.

XVI. CONCLUSION

In conclusion, this paper shows how vProCycle offers new possibilities to understand and experience VR potential to be used for cycling training; when combined with a combination of stimulus effectors. It is to be highlighted that distinctive stimulus effectors do greatly influence the presence level of participating cyclists. This presence level is experienced by a realistic simulation integrated with the system. This simulation creates an experience as though the cyclist is cycling in the distinctive actual real environment. This high level of presence thus generates a positive outlook in terms of the users’ acceptance towards the generated VR-based system.

However, there were also a few research limitations in this study, inclusive of the possibility that the participants may encounter hypoxemia which may lead to nausea, headache, dizziness or vomiting. In this pilot study, the cyclists who had undergone training using vProCycle did not encounter any hypoxemia experience. In addition, the availability of the hypoxic chamber room is limited and costly. As a result, conducting an experiment is limited by the financial and chamber room availability. Some recommendations for future studies may include the usage of backwheel resistance machine that can increase the elevation uphill climb resistance more accurately. In this pilot study the Kinetic machine used to stimulate resistance on the backwheel can only create a resistance equivalent to 10 degrees uphill slope. This specific machine was selected due to the ability to connect to the virtual reality devices. Other backwheel machines currently do not have the features to connect to the virtual reality devices. The cyclists during an open interview did mention they would like to have a higher resistance to the back wheel when climbing steep slopes as viewed in the HMD.

In addition, the 360 degree visuals provided by Google viewed inside the HMD were picture to picture based. In the future, a fully recorded video moving forward based on the cyclist paddling should be used if it is available.

Moreover, the wind-effect simulation speed generated by the fan is constant at all times. It is recommended that future researchers integrate the bicycle with a wind speed-based technology to simulate a realistic effect while inside the virtual environment.

Also, a stationary bicycle with tilting slope effect machine can be used for the cyclist to experience how to tilt their bicycle according to the virtual environment. This tilting slope effect can be achieved by using a motion platform that can tilt according to the body movement of the cyclists’.

This paper focuses on TAM analysis and the perception of presence using vProCycle. Based on cyclist’s feedback to the TAM questionnaire, cyclists have given a high acceptability level towards using vProCycle. A positive correlation between TAM and also perception of presence shows that this combination may produce a positive outlook.

The contribution and innovation of this research includes the setup of the vProCycle system with a more comprehensive stimulus effectors. These combinations consist of an uphill elevation climb, altitude, temperature, wind-effect, interaction, visual, and audio. For future research, researchers may integrate more stimulus effectors such as weather effect, road surface and light visibility.

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REFERENCES

[1] Alhadad SA, Abood OG. Application of virtual reality technology in sport skill. International Journal of Academic Management Science Research. 2018;2(12):31-40.

[2] Sherman WR, Craig AB. Understanding virtual reality: Interface, application, and design. Morgan Kaufmann; 2018 Nov 8.

[3] Lim JS, Hwang Y, Kim S, Biocca FA. How social media engagement leads to sports channel loyalty: Mediating roles of social presence and channel commitment. Computers in Human Behavior. 2015 May 1;46:158-67.

[4] Czuba M, Waskiewicz Z, Zajac A, Poprzecki S, Cholewa J, Roczniok R. The effects of intermittent hypoxic training on aerobic capacity and endurance performance in cyclists. Journal of sports science & medicine. 2011 Mar;10(1):175.

[5] Lei MK, Cheng KB, Lee YC. The Validity of using Virtual Reality Head-Mounted Display for Agility Training. ISBS Proceedings Archive. 2018;36(1):122.

[6] Mujika I, Sharma AP, Stellingwerff T. Contemporary periodization of altitude training for elite endurance athletes: a narrative review. Sports Medicine. 2019 Nov;49(11):1651-69.

[7] Yap HJ, Hau TC, Taha Z, Wee CS, Sekaran SC, Lim WW. Design and development of a spatial immersive track cycling simulator. Malaysian Journal of Movement, Health & Exercise. 2018 Jul 1;7(2):39-52.

[8] Farrow M, Lutteroth C, Rouse PC, Bilzon JL. Virtual-reality exergaming improves performance during high-intensity interval training. European journal of sport science. 2019 Jul 3;19(6):719-27.

[9] Petri K, Feuerstein K, Folster S, Bariszlovich F, Witte K. Effects of Age, Gender, Familiarity with the Content, and Exposure Time on Cybersickness in Immersive Head-mounted Display Based Virtual Reality. American Journal of Biomedical Sciences. 2020 Apr 1;12(2).

[10] Schwind V, Knierim P, Haas N, Henze N. Using presence questionnaires in virtual reality. InProceedings of the 2019 CHI conference on human factors in computing systems 2019 May 2 (pp. 1-12).

[11] Koivisto J, Hamari J. The rise of motivational information systems: A review of gamification research. International Journal of Information Management. 2019 Apr 1;45:191-210.

[12] Petri K, Ohl CD, Danneberg M, Emmermacher P, Masik S, Witte K. Towards the usage of virtual reality for training in sports. Biomedical Journal of Scientific & Technical Research. 2018;7(1):1-3.

[13] Ng YL, Ma F, Ho FK, Ip P, Fu KW. Effectiveness of virtual and augmented reality-enhanced exercise on physical activity, psychological outcomes, and physical performance: A systematic review and meta-analysis of randomized controlled trials. Computers in Human Behavior. 2019 Oct 1;99:278-91.

[14] Neumann DL, Moffitt RL, Thomas PR, Loveday K, Watling DP, Lombard CL, Antonova S, Tremeer MA. A systematic review of the application of interactive virtual reality to sport. Virtual Reality. 2018 Sep;22(3):183-98.

[15] Mahalil I, Yusof AM, Ibrahim N. A literature review on the usage of Technology Acceptance Model for analysing a virtual reality's cycling sport applications with enhanced realism fidelity. In2020 8th International Conference on Information Technology and Multimedia (ICIMU) 2020 Aug 24 (pp. 237-242). IEEE.

[16] Mahalil I, Yusof AM, Ibrahim N. A literature review on the effects of 6-Dimensional virtual reality's sport applications toward higher presense. In2020 8th International Conference on Information Technology and Multimedia (ICIMU) 2020 Aug 24 (pp. 277-282). IEEE.