A Fully Immersive Virtual Reality Cycling Training (vProCycle) and its Findings

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***Abstract*—Virtual reality (VR) technology is popularly applied in various sports training such as cycling, rowing, soccer, tennis and many more. In VR cycling, however, cyclists are not able to fully immerse themselves during the training due to the hardware and applications limitations required in the setup. In order to be fully immersed during the training, cyclists need to have similar effects to an outdoor training where they will experience cycling resistance, temperature effect, altitude, visual, and audio. For this reason, dedicated stimulus effectors or hardware are required to create these expected effects. On cycling resistance, a realistic cycling experience can be simulated by using a special device that simulates a resistance to the back wheel when cycling uphill in the VR simulation. In addition, the back wheel resistance would need to match the view displayed while paddling on an elevation slope. For higher immersion purposes, and the effect of temperature must be created that matches with the view visible in the display. For example, while the cyclist is on top of a virtual mountain, the cyclist would want to feel the effects of high altitude and low temperature. These stimulus effectors affect the realism experience while cycling in the VR simulation training. In the authors' previous papers, the setup using a combination of stimulus effectors including uphill elevation climb, altitude, temperature, interaction, visual, and audio were integrated into a product called vProCycle. The study tested on vProcycle was conducted with an assumption that virtual reality can enhance the experience of physical cycling training. The objective of this study is to determine whether or not vProCycle may improve cyclists' performance. This paper will discuss in detail the findings from data gathered during the experiment using vProCycle. More specifically, the findings are focused on the speed and the heart rate beats per minute which determine their performance improvement.**

Keywords*—*Virtual Reality (VR); presence level; technology acceptance; cycling performance; VR cycling training; vProCycle

I. Introduction

In this research, several literatures that focus on VR-based cycling training were reviewed in order to identify the current status of the effectors. This paper covers several topics including LR, system setup, experiment, conclusion and future works. According to Oxford Dictionary 2021, the biological meaning of effectors refers to a substance that carries out a response to the stimulus. Furthermore, stimulus refers to a substance or event that evokes a specific functional reaction to the human body. From the literature review, it is found that stimulus-effectors such as snow, water, and wind-effect can be applied in an event that evokes a specific reaction to the body [1]. In a VR-based training, several stimulus-effectors can be applied to replicate an actual life experience. According to Bohil Corey, "VR technology creates a simulation across the effector arrays and is attached to devices to create an immersive virtual reality system" [1, 2]. Until now, the commonly used VR effectors among cyclists are visual, audio, and interaction [2, 3]. It is suggested by a few researchers that adding more effectors on top of the regular effectors (i.e. audio, visual and interaction) will generate a more immersive experience [3, 4, 5]. In the area of sports, researchers have used different types of combination effectors to improve cyclists' performance [4]. In relation to cycling performance training, it is suggested by the researchers that the following six effectors are utilised: altitude, uphill elevation climb, realistic visuals and audio, realistic interaction, and temperature. As discussed in the authors' previous study, these effectors are obtained from the survey conducted [6, 7].

This research focuses on Virtual Reality (VR) performance cycling training setups using a combination of stimulus effectors as explained in the authors' previous paper [5, 6]. From the author's previous study, vProCycle setup integrated a selected combination of effective stimulus effectors to be used for VR cycling training. The previous author's papers were focused on identifying which stimulus effector is most effective to be selected and integrated into vProCycle [5, 6]. vProCycle uses a combination of stimulus effectors: uphill elevation climb, altitude, temperature, interaction, visual, and audio. In the author's previous study, the technology acceptance and presence towards the vProCycle were analysed during the pilot study [7]. From this pilot study, Imran concluded that the vProCycle's participants have given a high score on the technology acceptance and perception of presence [7]. On the other hand, this paper focuses on the cyclists' heart-rate level measured in Beat Per Minute (BPM), and speed measured in Kilometres Per Hour (KMPH). The data collected can then be used to measure the cyclists' performance while undergoing physical training.

The key contribution of this paper can be divided into three. The first contribution of this paper is identifying the stimulus effectors that can be used for the vProCycle setup. The second contribution is the finding on the correlation between presence level and technology acceptance of the vProCycle setup. The third contribution is related with performance level where it is found that the new setup can be an effective alternative for cycling training. Based on these findings, it is logical to assume that vProCycle can be used for producing a well-prepared cyclist.

II. Literature Review

Training using vProCycle has several benefits. As mentioned earlier, vProCycle consists of uphill elevation climb, altitude, temperature, interaction, visual and audio. The first benefit is generated by uphill elevation climb. The positive effect of uphill elevation climb is supported by McIlroy and Al-Kefagy [8, 9]. They have found that the cyclists benefit from the training when they are able to view an uphill elevation climb displayed on the head mounted device. McIlroy and Al-Kefagy also claimed that the interactive view triggers the cyclists to exert more power to paddle forward in the simulation [8, 9]. When the cycling route changes from a steep elevation slope to a flat surface, the elevation would decline and less power is needed to paddle forward. As a result, cyclists will reduce the power required [9, 10, 11]. In the study conducted by Al-Kefagy [9], an urban city environment was used in his VR application E-bike. In his study, the back wheel resistance machine improved the cyclists' safety awareness, their balances, and increased their immersion level significantly.

The second stimulus effector that benefits the cyclist is called altitude. Training in a high altitude with less oxygen can prepare the cyclist for endurance to strengthen the lung capacity [10, 11, 12]. In a study conducted by Hoeg [10], altitude together with virtual reality technology were tested using the cycling track of the Tour de France. The participants were two elite cyclists training for competition where it was found that their performance had significantly improved. The experiment was conducted at 2000 feet above sea level with 20 percent less oxygen molecules in the air as compared to on the sea level [10]. Training at higher altitude would make cyclists to feel more difficult to cycle and get tired more quickly. When a cyclist trains at a higher altitude, the red blood cell delivers less oxygen to the muscles because of the lesser oxygen level in the air. The oxygen is used to produce energy which helps the muscles to move and perform activity. When training multiple times in high altitude, after the third week, the red blood cells will begin to produce more in the cyclist's body [11, 12]. The basic cycling training using altitude begins at 2000 feet above sea level for thirty minutes, one session a week for three weeks. Within the first 7-10 days, there is little to no difference in the number of red blood cells produced in the body. For the next two weeks, the human body produces more red blood cells. In the third week the human body begins to produce a significant amount of red blood cells that affect the cyclist to perform better [11, 12, 13].

The third stimulus effector is temperature, where it is set according to the altitude height. For example, if the height is set at 2000 metres above sea level, the temperature will be set to 20 degrees Celsius. Lower temperature benefits the cyclists to adapt to various body conditions which helps in physical endurance [13, 14, 15].

The last stimulus effectors are called visual and audio. Visual and audio benefit the cyclist by being able to view and hear the virtual environment. Visual and audio can benefit the cyclist when other stimulus effectors are working synchronously [16, 17]. For example, if the visual displayed to the cyclist is on top of a mountain, then the effect experienced by the cyclist has to match with the view [18, 19, 20, 21].

In order to create an immersive experience simulation setup, integration of various effective stimulus effectors are required [5, 6]. Using a particular set of stimulus effectors, cyclists can adapt to the uphill terrain to improve performance. Adaptation to the uphill terrain cycling training can also be achieved by the familiarisation to the environment [22, 23]. In the study conducted by Mehdi [24], the seven cyclists were familiarised within three fixed-duration sessions of 12 minutes training. Cyclists were able to determine how much power output is required to reach the maximum speed required to reach the destination. In order to determine the effectiveness of the familiarisation to the training terrain, a better performance of speed and heart rate level from the cyclists need to be improved over the three sessions [25, 26, 27]. In another study, Darvish conducted a VR experiment of familiarisation sessions set for a continuous eight minutes where the speed was held for the final three minute[28]. In his experiment, the speed and heart rate (HR) of all 18 cyclists had improved in two sessions [28]. This indicates that the performance can be improved when cyclists are familiar with the environment and more immersive simulation experience would provide a better realism effect for the cyclists.

According to Mascret an effective VR-based setups used for sport physical training requires a high level of technology acceptance and perception of presence immersion fidelity [29]. When the technology acceptance level is high together with the sense of presence, VR-based training will benefit athletes in improving their sport performance [29].

Table I shows the list of VR-based bicycle setup and its effectors. In this table, four of the previous research setups including vProCycle are shown where the differences between each setup in terms of effectors applied are listed. These four setups provide distinguished experiences to the cyclists.

TABLE I. List of VR Setup and Effectors

No.	List of VR bicycle setup and effectors	
	VR-based bicycle setup	***Effectors***
1	vProCycle	Altitude, uphill elevation climb, temperature, audio and high realistic visuals
2	Al-Kefagy [9]	Uphill elevation climb, audio and visuals
3	Hoeg [10]	Altitude, temperature, uphill elevation climb, audio and less realistic visuals
4	Wu [16]	Uphill elevation climb, audio and visuals

Table I shows four distinctive VR-based cycling training setups using different types of effectors. In the study conducted by Wu [16], he integrated uphill elevation climb, audio and visual into his VR-based bicycle setup. The visuals of the track used in Wu's experiment was based on the 360 recording video. Wu's [16] result shows that the cyclists were able to improve their speed performance using the setup. In another research conducted by Hoeg [10], he added another effector that simulates the altitude effects of a virtual mountain environment. However, in his research, the effector to generate temperature was not integrated. It is expected that without this effector, the cyclist's would be less immersed as compared to the real world. In the experiment conducted by Al-Kefagy [9], the setup was similar to Wu's, except for the track displayed inside the HMD which was based on the 3D visuals environment created by the VR engine. It is suggested that with a 360 recording video the cyclists would be more immersed.

As discussed above, using a limited set of effectors may improve cyclists' performance. It is also anticipated that cyclists' perception of presence will improve when more effectors are integrated into the system [7].

III. System Setup

This paper is a continuation from the authors' previous research [5, 6, 7], where the vProCycle used during the experiment is discussed in detail.

Table II shows the list of effectors and technology providers used in vProCycle. The six effectors are matched to a specific technology that provides a distinguished experience for the user.

The first effector, as shown in Table II is audio and visual. In this setup, HMD is used as the technology provider. There are many brand names of HMD available in the market such as Oculus and HTC VIVE. In this research, the Oculus Quest 2 unit was used to produce a full 360 degree viewing angle with an immersive audio effects. The second effector is called altitude effect. This effect is gained by using a chamber room, as seen in Fig. 1.

Fig. 1 shows a chamber room and the control panel that simulate altitude, temperature, oxygen level and humidity level. Fig. 1(a) shows the chamber room from the outside view and Fig. 1(b) shows the control panel that adjusts the settings for the simulation. The objective of using a chamber room is to create a high fidelity of realism to the VR simulation cycling training.

TABLE II. List of Effectors and Technology Providers

No.	List of effectors and technology provider	
	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	Paddling interaction	Bluetooth device

(a) (b)

Fig. 1. Chamber room.

The third effector is called uphill elevation climb with the technology provider of a back wheel machine that grips the back wheel of the bicycle to provide a resistance effect. There are many brand names that provide back wheel machines such as Wahoo, Magene, Kinetic, and etc. In this research, Kinetic was used to provide an immersive effect of uphill elevation climb.

The fourth effector is called temperature. The temperature effect is simulated inside a chamber room through the control panel, as seen in Fig. 1(a) and (b).

The last effector is called paddling interaction. The paddling interaction is determined by a bluetooth device that affects the movement inside the virtual world. This bluetooth device is attached onto the bicycle paddle which calculates the Revolutions Per Minute (RPM) in real time. The bicycle in the virtual world would move forward based on the calculated RPM. There are many bluetooth devices available such as Magene, Vzfit, and Wahoo. In this research Magene was used to provide a realistic paddling interaction effect in the virtual simulation. Note that each brands requires their own applications downloaded and controlled using a handphone. Vzfit technology is the major component applied in vProCycle. Vzfit technology consists of the HMD application that connected with backwheel machine using a bluetooth device. Inside the chamber room, the altitude of the height is also set according to the virtual environment seen by the cyclist.

Many literature encourage 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 maximised used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

Fig. 2 shows the setup of a VR cycling training system with the combination of uphill elevation climb, altitude, temperature, interaction, visual, and audio. This VR training system is named as "vProCycle system" with the intellectual property copyright number 2022/CR/I5.71/OP.

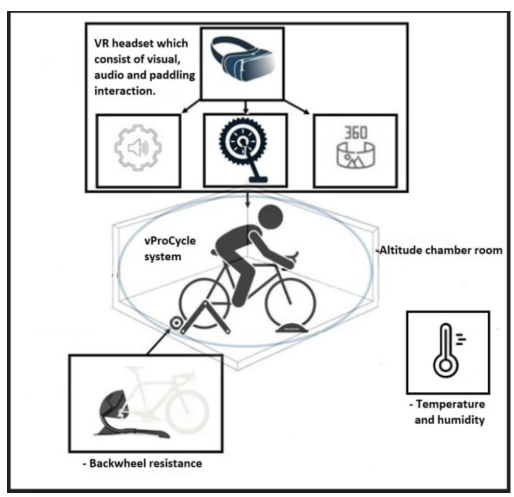

Fig. 2. Setup of the vProCycle

A. Hardware and Technology Requirement

This experiment was conducted at The National Sport Institute Malaysia, involving 10 volunteers with different background skills. The volunteers were two elite cyclists and eight athletes from a university football team. During the experiment, the cyclists' speed in the virtual environment and the heart rate level (BPM) were collected. In this subsection, the cyclists' requirements and materials used to conduct the experiment are explained in detail below. The figure below shows the setup design during the experiment.

Fig. 3. The vProCycle system setup.

Fig. 4. The vProCycle system setup side view.

The vProCycle system experiment was conducted at the National Sport Institute Malaysia hypoxic chamber as seen in Fig. 3. The experiment setup includes a back-wheel machine, Bluetooth sensor on the bicycle paddle, VR HMD, and heart rate device. This setup was similar to the pilot study with the exception of a heart rate device that was strapped on the chest of the cyclists. The location of the scene in the HMD was L'Étape du Tour, France. Before undergoing a training session, a consent form was signed by the cyclists. The experiment was conducted in three separate sessions with an interval of one week apart, each session was a continuous, non-stop session for 30 minutes. All the cyclists were briefed on the warnings of training in the hypoxic chamber. The temperature and carbon dioxide level was different than on sea level which may cause vomiting, drowsiness, or headaches. Cycling training in altitude for 30 minutes benefits long term endurance of at least three sessions in an interval of one week [8]. Note that all participants undergone training at 2000 metres above sea level (m.a.s.l), with 20 percent less oxygen as compared to sea level altitude and a temperature of 20 degrees. Fig. 4 shows the side view of the setup in the chamber room using vProCycle; different road bicycles can be mounted.

B. Experiment Participant Requirement

The selection of the participants were based on the following criteria:

- Age: An individual aged 20 years to 50 years.
- Experience: Have participated in a local or international cycling competition or event.
- Role: Have represented a sport organisation, club or school.
- Type of training: Have trained using a stationary bicycle.
- Demography: No restriction.
- Gender: No restriction.
- Weight: 50kgs-80kgs.
- Height: 1.6m-1.9m.

In this research, ten cyclists that met the above criteria have participated in the experiment. The first criteria is the participants' age. The age is appropriate for cycling performance training [8-13]. The second criteria is the experience of the cyclists. These experiences enable the cyclist to safely undertake cycling training. The third criteria is on the role of the cyclist. The role refers to the types of organisation or entities that they have represented. The fourth criteria is on the type of training they have participated in order to prepare themselves for the upcoming events. As for the fifth, sixth; demography and gender, there is no restriction applied. The seventh and eighth; weight and height, the restrictions are as stated above. The weight and height restrictions are due to the hardwares limitation such as the height and the capacity of the bicycle.

C. Experimental Material

The cyclists were required to cycle for thirty minutes in a virtual environment based on a realistic view of L'Étape du Tour, France. The distance of the training track of L'Étape du Tour, France was 13 KM in which the cyclists had to cycle as far as they can within the given time duration set. This location was set with many uphill elevation climbs and down hills. Based on the literature review, familiarization of terrain requires a minimum of three sessions and at least eight continuous minutes with an improved performance [26, 27, 28]. In this research, the technology acceptance questions were derived from the original TAM developed by Davis, 1989 [7]. Four questions for each of the TAM's factors were adopted. The presence questionnaire were adopted from the Witmer and Singer Presence Questionnaire. 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?" Both questionnaire (TAM and presence) were given after the cyclists had undergone the training session using vProCycle [7].

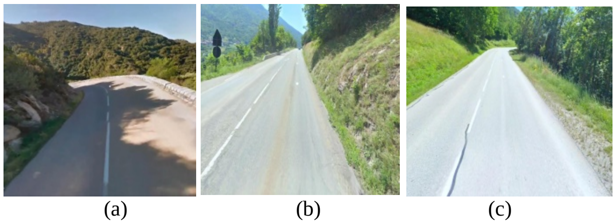

Fig. 5. Three views of L'Étape du Tour, France used during the experiment.

Figure. 5 shows three images of the view seen in the HMD at L'Étape du Tour, France. Fig. 5(a) shows the road surface in between one to five degrees of elevation uphill slope curving to the steep left angle. Fig. 5(b) shows a steep elevation slope of 10 degrees. Fig. 5(b) also shows the view of climbing a steep uphill on the road side going straight. Fig. 5(c) shows a downhill slope of zero resistance going downhill curving to the right side. The familiarisation to uphill adaptation from cyclist in altitude requires a minimum of 3 consecutive sessions of an interval of 1 week in between each session [5, 6]. This is due to the body producing more red blood cells in the third week of training in altitude [10, 11, 12].

D. Findings

The experiment focuses on two different findings. The first finding is on the average speed of the ten cyclists using vProCycle during performance training. The second finding focuses on the average heart rate level based on the BPM. The two main data collected indicate the cyclists' performance which was measured by the average speed, the heart-rate level and the correlation between the two.

Fig. 6 shows the cyclists' average speed in kilometres per hour while using vProCycle in 3 sessions. P1 to P10 indicates participant 1 to participant 10, respectively. Speed is the distance divided by time. Distance is measured in kilometres and time is measured in minutes. Heart-rate level is measured by the amount of beats per minute (BPM) that the heart pumps.

In session 1, the lowest speed was retrieved from participant 3, 4, 5, and 6 at 10 KMPH, whereas the highest speed was reported at 16.7 KMPH by participant 10 and 12.7 KMPH by participant 9. In session 2, the lowest speed was recorded by participant 5 at 10.8 KMPH, while participant with the highest speed was participant 10 at 17 KMPH. In session 3, the lowest speed was recorded by participant 3 and 5 with both recorded an average speed at 12 KMPH, while the highest speed was recorded at 17 by participant 10. Each participant had improved their performance by increasing their speed from session 1, 2, and 3, subsequently. Speed is measured as the ratio of distance to the time in which the distance was covered, and the time period given for each session was 30mins. From the average speed, it could identify the average Kilometres Per Hour (KMPH), and how many kilometres (KM) they have reached by the end of each session. By capturing the data of KMPH and the KM from each session, analysis can be made to identify whether the participants have improved their speed performance or not. Below is the analysis of each individual participant. In this analysis, the improvement from one to two KM was considered major while less than one was considered minor [10].

In relation to the KMPH, the cyclists' KMPH were lower in the first session and gradually increased during the consecutive sessions. It is logical that the cyclists' KMPH in the early session was lower due to the unfamiliar training conditions including altitude. It is also found that the changes in terms of KMPH between session 1 and session 2 was much higher as compared to session 2 and session 3.

As a summary, it can be seen that all participants' average speed increased throughout the sessions. All cyclists' speed performance improved when using vProCycle. The following is the findings on the participants' heart rate level based on BPM.

Fig. 7 shows the average heart rate based on the amount of beat per minute (BPM) with 90% of the cyclists' average heart rate (BPM) in session 1 was above 150. The lowest score reported in session 1 was 140 BPM and the highest was 172. In session 2, all cyclists were below 162 BPM whereas in session 1 four cyclists were above 170. The highest BPM score in session 2 was reported at 161 and the lowest was at 130. This would indicate that as compared to session 1, the heart rate BPM for all cyclists had dropped in session 2. This might be due to the fact that the cyclists may have not yet adapted to the new setup and not comfortable in the first session as compared to the second session within a one week interval.

In relation to the BPM, the cyclists who are not familiar with training at 2000 metres above sea level may find discomfort during the first session [24, 25, 26]. Due to the unfamiliar conditions of the altitude and uphill elevations, the cyclists' BPM would be higher in the first session compared to session 2 and session 3. The BPM indicates the endurance level of the cyclist when undergoing training. An increase in BPM usually occurs when the cyclists are required to exert more power when increasing their speed or climbing uphill [24, 25, 26].

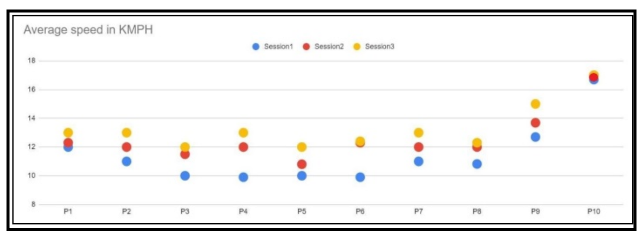

Fig. 6. Participants' average speed in kilometres per hour (KMPH)

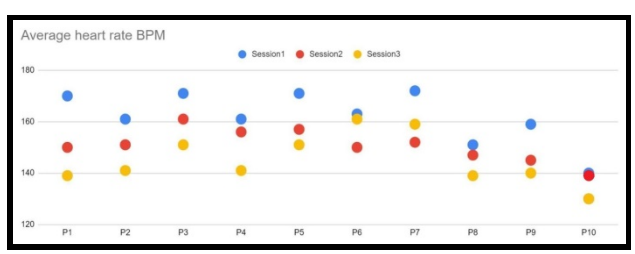

Fig. 7. Cyclists' average heart rate in Beat Per Minute (BPM)

As a summary, all participants' BPM decreased throughout the sessions. It shows that their heart rate level improved when using vProCycle. Below are the findings on the participants' average heart rate level correlation to the average speed.

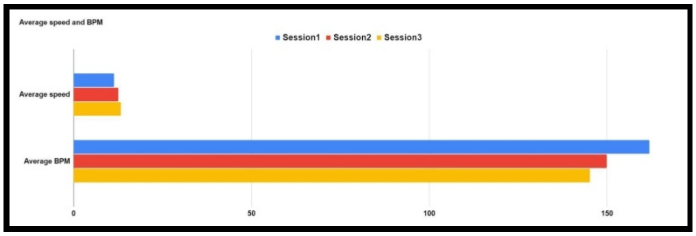

Fig. 8. Cyclists' average speed (KMPH) and heart rate in Beat Per Minute (BPM).

Heart rate level improved when using vProCycle. Below are the findings on the participants' average heart rate level correlation to the average speed.

Fig. 8 shows the cyclists' average speed on the top and the average BPM at the bottom. When the speed is high and the heart rate level BPM is low, this indicates that the cyclist is at a better cycling performance. The average speed of the cyclists in session 1 was reported at 11.402 KMPH, session 2 at 12.559 KMPH, and session 3 at 13.27 KMPH. The average speed in session 1 was at 11.402 KMPH as compared to in session 3 at 13.27 with the difference of 1.9 KMPH. This would indicate that the average speed of the cyclists between session 1 and 3 in this experiment would have improved by 1.9KM. The difference between the average speed of session 1 and 2 was 1.157 KMPH, which indicates that between session 1 and 2, the cyclists improved by 1.157 KMPH on average. For session 2 and 3, the average speed improved by 0.7 KMPH. There was a gradual increase of average speed from session 1, 2, and 3.

As shown in Fig. 8, the improvement in cyclists' performance was also found when analysing the negative correlation between the average speed and the average heart rate level. A negative correlation between the average speed and the average BPM means that while the speed is increasing, the BPM is also decreased.

Session 1 average BPM was at 161.9 BPM as compared to session 3 at 145.2 BPM, with the difference of 16.7 BPM. This would indicate that the cyclists have improved their BPM by 16.7 between session 1 and session 3. The difference between the BPM of session 1 and 2 was 12 BPM, which indicates that between session 1 and 2 the cyclists improved their BPM by 12. For session 2 and 3, BPM was improved by 4.7 BPM. There was a gradual decrease of BPM from session 1, 2 and 3. The lower the heart rate over session would mean that the cyclist is improving.

There is a correlation between speed KMPH and heart rate BPM, in which the higher the speed KMPH across the sessions would decrease the heart rate BPM. The reason for this is because as the cyclists train more frequently, their physical body become more adapted to the higher altitude, thus creating more red blood cells and is able to endure the harsh conditions of this cycling performance training.

As discussed above, all the participants' speed increased throughout the three sessions while their heart rate beat dropped. This indicates that while using vProCycle, participants' performances have improved as there is a negative correlation between the average speed and BPM from all cyclists. As discussed in the author's previous paper [7], the cyclists' were required to answer a questionnaire on TAM and perception of presence. In addition to TAM and perception of presence, an open interview was also conducted. From the interview, it was found that during the first session, all ten cyclists were not familiar with the altitude and uphill elevation climb which affected their performance. During the second session, all the cyclists stated that they had adapted to the training better. In the final session, the cyclists highlighted that they feel more confident resulting in better performance. Based on the average speed and heart rate level, all cyclists showed that they have improved in performance during the final session when using vProCycle.

E. Experimental Outcome

From this research, the outcome shows that cyclists' speed performance and heart rate have improved when cycling in the simulated VR terrain using vProCycle. This outcome also suggests that the cyclists' technology acceptance and perception of presence level as explained in the previous paper [5, 6] may have positively impacted the cyclists' performances. In the previous paper, it was found that cyclists gave high rating to both technology acceptance and perception of presence. The findings on the speed and heart rate level also suggest that with a high level of technology acceptance and perception of presence, positive correlations can be seen where cyclists' performance have improved when using vProCycle.

IV. Conclusion and Future Work

In conclusion, this study shows how vProCycle may offer new possibilities in cycling training by combining various stimulus effectors. It is highlighted that distinctive stimulus effectors do greatly influence the performance level of participating cyclists when familiarized with the simulated terrain. This performance 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 cyclists' performance thus generates a gradual improvement by the speed and heart rate level throughout the sessions.

It is found that the cyclist's performance has improved based on the real time data collected from the devices (RPM and heart beat rate) attached to the cyclist during the training. A negative correlation between the RPM and heart rate shows that there is an improvement in performance over three sessions.

Cyclists have positively accepted the vProCycle based on technology acceptance and perception of presence level questionnaires. Findings show a positive correlation between RPM and heart rate level with technology acceptance and perception of presence.

This study contributes to the fact that using highlighted distinctive stimulus effectors do greatly influence the performance level of participating cyclists. VR as a tool can be used to simulate an effective cycling training destination when integration is set distinctively. For future work, a motion platform will be integrated with the vProCycle in order to simulate a tilting effect. This tilting effect occurs when cyclists are turning their direction based on the VR simulated road condition.

V. Intellectual Property

The findings from this paper were conducted using vProCycle. vProCycle has been copyrighted (2022/CR/I5.71/OP).

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