International Journal of Human Movement and Sports Sciences 10(3): 429-440, 2022 http://www.hrpub.org
DOI: 10.13189/saj.2022.100309

# The Effect of Modification Psychomotor Tasks in the Virtual Reality on Cadence and Behavioural Responses of Cycling

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*Received March 17, 2022; Revised April 24, 2022; Accepted May 23, 2022*

***Cite This Paper in the following Citation Styles***

***(a):** [1] Nurul Farha Zainuddin, Mohd Najeb Jamaludin, Izwyn Zulkapri, Hosni Hasan, Halijah Ibrahim, Mohd Syafiq Miswan , "The Effect of Modification Psychomotor Tasks in the Virtual Reality on Cadence and Behavioural Responses of Cycling," International Journal of Human Movement and Sports Sciences, Vol. 10, No. 3, pp. 429 - 440, 2022. DOI: 10.13189/saj.2022.100309.*

***(b):** Nurul Farha Zainuddin, Mohd Najeb Jamaludin, Izwyn Zulkapri, Hosni Hasan, Halijah Ibrahim, Mohd Syafiq Miswan (2022). The Effect of Modification Psychomotor Tasks in the Virtual Reality on Cadence and Behavioural Responses of Cycling. International Journal of Human Movement and Sports Sciences, 10(3), 429 - 440. DOI: 10.13189/saj.2022.100309.*

**Abstract** Virtual reality is an alternative tool to provide a safe and competitive environment, especially for training and competitions. This study aims to evaluate the effects of modified psychomotor tasks in the virtual reality on the alpha/beta ratio, power output, heart rate, and cadence. The participants are recruited among national development cyclists from National Sport School. The environment of virtual reality was modified from the available virtual reality TACX smart trainer system. The one-way multivariate of variance (MANOVA) identified the effects of the five different levels of psychomotor task (independent variables) in virtual reality on multiple variables of physiological responses. The MANOVA results indicate a statistically significant multivariate main effect for the five levels of task difficulty in road cycling, when jointly considering on the variables of alpha/beta ratio, power output, heart rate, and cadence. The multivariate general linear model for univariate ANOVA results demonstrates a significant difference between subject on alpha/beta ratio and cadence. Significant task pairwise differences were obtained for cadence between Task 1 and both Tasks 2 and 5. The results suggest human's interaction with virtual reality, specifically during the psychomotor task during road cycling. The significant effects on the joint physiological responses ensured that evaluation of the experiment on developed task difficulty in virtual reality was practical, applicable and can be modified when required for training or assessment. The involvement of cognitive functions in response to behavioural mechanism merits further investigation and are deferred for future work.

**Keywords** Psychomotor Task, Cadence, Behaviour, Virtual Reality, Cycling, Physiology

# 1. Introduction

The vast research and applications of virtual reality settings have been explored by a systematic review that revealed most of the environments that are meant for sports, such as running, cycling, rowing, and other interactive sports-related skills [1]. Currently, virtual reality has been extensively utilised in the sports industry as a training tool to prepare athletes for competitions [2]–[5]. It also has been employed in various conditions in need of simulating an actual real-world environment [6], [7]. Previous reviews indicate that several studies were conducted on the effects of virtual reality procedures across a series of qualitative and quantitative physiological, behavioural and psychological parameters [1]. It was previously highlighted that sports performance is anticipated with the interaction of athletes and their ecology, which involves individual perception and action [8]. These elements are part of an individual's psychomotor [9].

The virtual reality system allows the subject to be physically-attached to the system, as it provides sensors that are integrated within it [2]. The invention developed by Yeadon and Knight [10] provides the use of sensors for full real-time simulation to assess cognitive and motor tasks driven by real-limb movement. In sports, virtual reality applications have been widely-employed in training, especially during autonomous practice of specific skills [2]. Several virtual reality systems have been designed to encounter specific skills. For example, in basketball, virtual reality settings have been designed to evaluate shooting accuracy and successful throws that comprise some key components of realistic modelling [11]. Furthermore, virtual reality is more effective and accurate in comparison to video clip methods when, for instance, the handball goalkeeper executes an interception in catching the ball [12]. The participants were also able to perform faster. Apart from cognitive-motor performance, virtual reality has also been developed to understand the effects on psychological mechanisms. The effects of virtual reality revealed that anxiety can be induced during virtual soccer goalkeeping [13] with a baseline for reference [14]. Meanwhile, in shooting sports, an experiment conducted in a four-sided immersive projection room with retro-projected glass screens found a difference between subject effects of competition on mu (8-12 Hz) oscillatory activity during aiming [4].

Understanding the development of virtual reality requires various experts on the hardware, software, and human biofeedback, because the system works well with the integration between these particular areas of interest. The growing timeline of virtual reality systems was highlighted by Balkó and colleagues [3] in a summary of sports and health. The study described the progression of virtual reality systems from non-immersive to the immersive technologies. Non-immersive technology is principally motion game control that is transmitted from the sensors, into the game. Meanwhile, immersive technology manages to immerse users as they enter a virtual world. In this modern era, virtual reality is achieved by the development of special glasses called a head mounted display (HMD). After more than a decade, as technology grows, the trend moved to projection displays [15]. The earliest development of virtual reality focused on the effects of the system itself. In the latest development, researchers have focused on the biofeedback provided, as it should be as realistic as possible, and movements in the real world need to be synchronised with their virtual counterpart [16]. Nevertheless, the focus of the present study is not on developing a virtual reality system, but rather on using available virtual reality systems in cycling to complement the exploration of physiological (biofeedback) and behavioural responses to sport-specific tasks.

Despite its growth, virtual reality raises the question on the extent this system provides realistic human interaction with the environment. This is crucial in the application of sports performance, especially in an open-skilled setting. It involves motor performance in which there are processes of visualisation as well as individual perceptions. In reality, athletes respond to the feedback of spatial reasoning and demand quick responses and minimal delay, where timing is critical in certain situations and conditions. A road cycling event is classified as an open-skilled environment where the environment is uncertain. The competitors, which act as objects, are also dynamic and indefinite. Cyclists could practise indoors as an alternative training for the outdoor environment, since outdoor training is restricted to weather and safety conditions. Nevertheless, without a simulated environment, cyclists may have different motivations to execute the specified workload. Therefore, the visualisation of an immersive environment would significantly maximise cyclists' efforts, which in turn contribute to the effectiveness of training [3].

As cycling is an endurance sport that involves mechanical efficiency, work rate and pedalling technique are crucial in determining overall athletic performance. According to previous studies, three physiological parameters that are frequently explored are power output, heart rate, and cadence [14], [17], [18]. These physiological functions typically respond depending on individual development and performance, as well as external factors such as environment and competitiveness. These three were also evaluated and investigated in the context to identify optimal pedalling for performance [17]. In fact, optimal cadence influences peak performance to modulate by movement frequency during pedalling as this physiological parameter was previously investigated to understand the integration with cortical brain activity [19]. Meanwhile, heart rate works as a physiological indicator to understand the demand of professional cyclist, as well as to identify the intensity during competition [20]. In terms of power output, monitoring the physiological function helps in finding valuable information, as elite cyclists require much energy production [21]. In addition, psychophysiological responses provide a new dimension in virtual reality [22] effects on neural activity during the cognitive-motor process. For this reason, there is a need to examine the manner in which these parameters are affected by psychomotor tasks that are related to road cycling. To evaluate these parameters, the simulation of the real environment has to be modified. Therefore, this study aims to explore the effect of five modification levels of psychomotor tasks in virtual reality on neurophysiological responses known as alpha/beta power, with other physiological responses such as power output, heart rate, and cadence. This study also discusses the behavioural mechanism of virtual reality and its potential as an alternative tool for training and evaluation.

## 2. Materials and Methods

### 2.1. Participants

This study recruited eight female trained development cyclists from the National Sports School. For demographic information, the mean (SD) for age, body mass, and years of experience were 16.25 (1.04), 51.54 (3.99), and 3 (1.41), respectively. The research design of this study complied with exploration and cross-sectional studies in which the cyclists were selected based on the predefined inclusion and exclusion criteria. All cyclists had similar hours of training hours per week (29 h) and were trained in similar environments. Before the experiment, we ensured that all equipment and devices were in good condition. The cyclists were given a participant information sheet, written informed consent, and a health questionnaire. This study was approved by the National Medical Research and Ethics Committee (MREC), and the ethical number is 18-3016-42591.

In this study, the selection of participants was done using the purposive sampling method. This method of sampling was employed to ensure that the participants were homogenously selected, as they shared similar traits and characteristics. As for the sample size, this sampling method is a non-random technique that does not need underlying theories or a specific number of participants [23]. The selection of a purposive sample is often accomplished by applying expert knowledge of the population to select a sample of elements that represents a cross section of the population in a non-random manner. In this case, a small population from Johor, Malaysia was selected to represent the cross section of trained cyclists.

### 2.2. Psychomotor Task in the Virtual Reality

The tasks were designed and modified according to the available virtual reality road tracks from the TACX smart trainer system (Figure 1). The cycling TACX smart trainer system comprises indoor cycling training tools that are built with a smart trainer connected to a software application. The smart trainer automatically simulates the resistance indicated by the user-defined slope, creating a subtle vibration in the tyres, which gives the participants the feel of riding on an actual surface. The virtual reality of the TACX application simulates certain forces according to its environment. The elements of difficulty are based on a previous study that discussed task complexity and the evaluation of human performance [24].

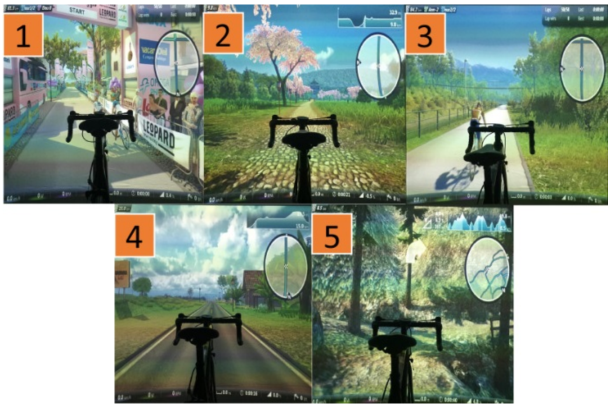

**Figure 1.** Five Different Levels of Psychomotor Task Difficulty in the Virtual Reality. The number indicated in the figure referring to the five task levels

The flow of the experimental procedure underwent a process of modification before finalising the different levels of task difficulty. The work on task modification involved three experts in sports science, who provided feedback and evaluated the contents. The first expert had a background in cognitive and motor learning. The second was an expert in motor skills, learning, and development. The third expert was a leader in the field in testing, measurement, and evaluation of sports and exercise. Their feedback was used to develop and modify the psychomotor task difficulty during cycling in a virtual reality setting. Details on content of the environments are described in Table 1. Level 1 is classified as easy, while Level 5 is categorised as complex. The level of difficulty was determined by three elements, namely, terrain, visual virtual environment, and virtual presence of competitors. The competitors are set at a medium level from the TACX application. These elements were included and modified with the available virtual tracks of the TACX smart trainer system. The table also describes the environment for each task. The slope described in the table refers to the resistance.

**Table 1.** Contents of developed task difficulty in cycling

| Elements | Psychomotor Task Difficulty | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Distance | 2km | 2km | 2km | 2km | 2.5km |
| Level | Easy | Easy-Moderate | Moderate | Moderate-complex | complex |
| Terrain | Flat | Mountainous | Mountainous | Open road | Mountainous |
| Environment | City | Nature | Hilly | Windy | Nature |
| Competitors | No | No | 5 competitors | Crowd + 5 competitors | 5 Competitors |
| Description | The road in task 1 is flat the entire race. The environment was surrounded by buildings in the city. Max slope 1%, average slope 0%. | The Task 2 mainly involved mountain roads without no competitors.<br>Max slope 6.4%, average slope -1%, height 30m. | In this task, the level of difficulty increases as added to the five competitors in the environment.<br>Max slope 5.9%, average slope -1%, height 20m. | In this task, the open road means an environment that is highly exposed to the weather. There is a crowd involved in the middle of the race for 200m.<br>Max slope 6.1%, average slope 0.9%, height 10m. | This task was determined as the most complex as added the distance.<br>Max slope 6.4%, average slope -1.1%, height 30m. |

### 2.3. Procedure

The environment of the five different levels of psychomotor task difficulty is illustrated in Figure 1. The virtual reality system is shown on the front screen (2.5m × 1.7m) emitted by a computer system using 3-D graphics with an immersive environment. The senses of vision, hearing and touch were isolated from the real environment and were generated by the computer (Figure 2). The screen depicted a virtual reality road cycling environment. In order to measure the corresponding functions of alpha/beta ratio, power output, heart rate, and cadence, the virtual reality screen displayed five different environments that indicated different levels of difficulty. Meanwhile, all the sensors to record cadence and power output were attached to the bicycle and synchronised with the TACX smart trainer virtual reality system. Heart rate was recorded using a heart rate monitor. The power output, heart rate, and cadence were measured using a Garmin power meter, Edge 520. Sensor power output (Vector 2), heart rate monitor, and cadence sensor were calibrated with the Edge 520 power meter. The Garmin sensors were also calibrated with the measurement of the TACX smart trainer system. The bicycle used in this study was a standard carbon road bike with a drop bar handlebar and two round chainrings. It was supported by a smart trainer and fixed on a stand.

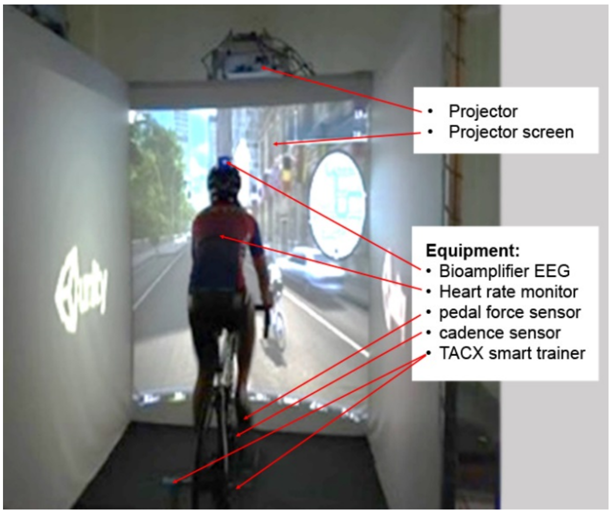

**Figure 2.** The virtual reality is completed by a front screen emitted by a computer system using 3-D graphics with an immersive environment

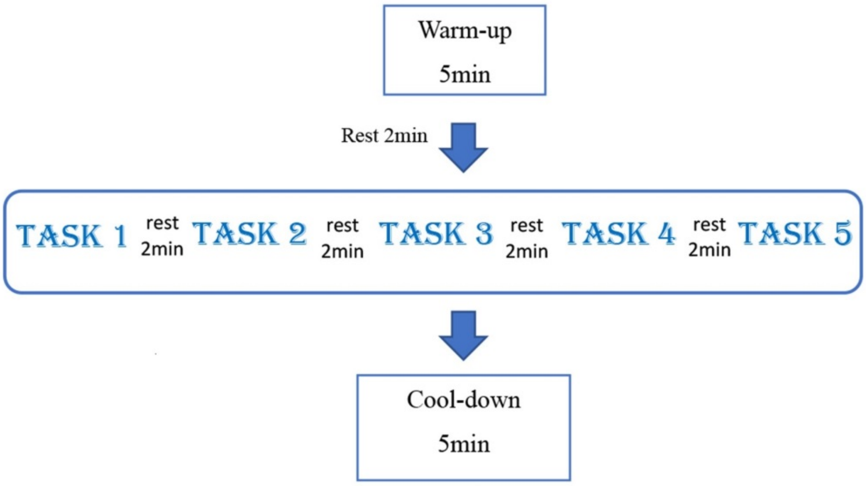

**Figure 3.** Flow of Experimental Procedure

The cyclists were instructed to wear a full set of cycling attire. The explanation was briefed before the experiment to ensure that the cyclists understood the experimental procedure (Figure 3).

Coaches were also present to offer guidance. The subjects were informed to complete the first task. The instructions were given verbally by the researcher as follows: “You are required to complete a 2 km distance track at your own pace.” The explanation included the possible adverse effects of the projected screen, such as the cyclists might feel nauseous due to the screen view. However, it might vary according to each individual [25]. The nature of this virtual reality setting was considered an active projection screen, as the subject could control the system, which might help in reducing any nausea [15]. The participants would be stopped if they continuously demonstrated signs of nausea, uneasiness, or lack of breath, or if the participants requested to stop. The cyclists needed to pedal to generate the data synchronised with the Garmin power meter before Experiment Task 1 was initiated.

During the experiment, the researchers were assisted by medical personnel and a lab technician to monitor the safety and possible signs and symptoms of mental and physical changes. The cycling performance of heart rate, cadence, and power output were monitored entirely, and data from the cycling performance were recorded simultaneously with the electroencephalography (EEG) recording. The EEG was measured using wearable bioamplifiers with a differential channel. A bioamplifier is an electrophysiological device that is a variation of the instrumentation amplifier and was used to gather and increase the signal integrity of physiologic electrical activity for output to various sources. It may either be an independent unit or integrated into electrodes. The EEG recording during rest was 2 min. The cyclists were required to continue cycling. Then, they needed to warm-up for 5 min. The environment from the screen was changed after 2 min for each of the five different virtual reality environments, and the EEG was recorded continuously. The maximum time taken in this phase was 25 min, with inclusion of the warm-up session. The participants were allowed to cool down for 5 min after they finished all the tasks (Figure 3).

## 2.4. EEG Recording

In this study, EEG recording was employed to measure neural activity. An electrode was placed on Fp1 and Fp2 with a ground electrode placed on the earlobe. The EEG signals were filtered between high pass 0.1 Hz and low pass 50 Hz. An additional 50 Hz notch filter was applied. Electrode impedances were kept below 5 kΩ for the EEG. All signals were sampled at a frequency of 250 Hz, with a resolution of 24 bits. EEG data were pre-processed by removing drifts and low pass filtering (50 Hz). The signals were determined by applying epochs towards specified psychomotor tasks in the experiment. In the next step, the EEG signals were filtered by applying a fast Fourier transform (FFT) filter for the alpha frequency band (8–12 Hz) and beta frequency band (15–28 Hz). Subsequently, the alpha and beta waves were calculated and averaged over the epochs representing the recordings during the tasks. The alpha/beta ratio was defined as the alpha power value divided by the beta power value. The data acquisition was employed using the AttysScope software. The raw data was saved as a csv. file from the software. It was then imported into MATLAB and the alpha and beta waves values were analysed.

## 2.5. Data Analysis

A quantitative analysis was employed to evaluate the effect of virtual reality on the alpha/beta ratio and other physiological functions. The data were analysed using quantitative analysis, described as descriptive and multivariate analysis of variance (MANOVA), which were derived from the Statistical Package for Social Science (SPSS) version 20.0 software. MANOVA extended the capabilities of analysis of variance by assessing multiple dependent variables simultaneously and detecting patterns between multiple dependent variables. The analysis mainly identified the effects of the five different levels of psychomotor tasks (fixed or independent variables) in a virtual reality setting on multiple variables of physiological responses. The physiological responses were represented as dependent variables, which were alpha/beta ratio, power output, heart rate, and cadence. MANOVA was employed to examine the effects of the five different levels of psychomotor task difficulty on various physiological functions (alpha/beta ratio, power output, heart rate, and cadence). Further analysis was conducted from post-hoc comparisons with the Bonferroni test to obtain significant task pairwise differences ($p < 0.0125$). MONAVA analysis was also performed to examine the five different levels of task difficulty perceived by the participants. A descriptive analysis of performance data on each participant for each task was also presented. This result was presented after MANOVA as a sequence for reporting its results based on the participants' perceived level of task difficulty. The results of these physiological functions determined whether the modified psychomotor task difficulty of the virtual reality setting significantly affected the nurture of cognitive and physiological functions of the subjects of interest

## 3. Results

The Box's M assumption revealed that the covariance matrices of power output, heart rate, and cadence were not significantly different ($p > 0.05$) across levels of task difficulty in road cycling. Thus, it indicates that the model met the assumption of multivariate normality. The results from one-way multivariate analysis of variance revealed a significant multivariate main effect ($p < 0.0001$) for the five levels of task difficulty in road cycling, when considered jointly on the variables of alpha/beta ratio, power output, heart rate, and cadence; Wilk's $\lambda = 0.28$, $F(16,98) = 3.19$, $p < 0.0001$, partial $\eta 2 = 0.27$. The power to detect the effect was 0.98. Results from the multivariate general linear model for univariate ANOVA (Table 2) indicate a significant difference ($p < 0.05$) between subjects on alpha/beta ratio and cadence, but not on power output and heart rate ($p > 0.05$).

**Table 2.** Univariate analysis of variance between task difficulties

| Parameters | $F$ | Sig. | Partial $\eta^2$ |
|---|---|---|---|
| Alpha/beta ratio | 2.94 | 0.034* | 0.25 |
| Power output | 2.34 | 0.074 | 0.21 |
| Heart rate | 0.44 | 0.776 | 0.05 |
| Cadence | 6.89 | 0.000* | 0.44 |

* $p < 0.05$

There was a significant difference ($p < 0.05$) between the five levels of tasks on alpha/beta ratio; $F(4,35) = 2.94$, $p = 0.034$, partial $\eta^2 = 0.25$ and cadence; $F(4,35) = 6.89$, $p = 0.000$, partial $\eta^2 = 0.44$. In **Figure 4**, Task 1 ($M = 0.71$), and Task 3 ($M = 0.71$) scored the highest alpha/beta ratio, followed by Task 2 ($M = 0.69$), Task 4 ($M = 0.62$) and Task 5 ($M = 0.51$). In **Figure 5**, Task 1 scored the highest cadence ($M = 111.57$), followed by Task 4 ($M = 103.41$), Task 3 ($M = 102.09$), Task 2 ($M = 96.96$) and Task 5 ($M = 95.38$). Meanwhile, there was no significant difference ($p > 0.05$) between the five levels of tasks on power output; $F(4,35) = 2.34$, $p = 0.074$, partial $\eta^2 = 0.21$ (**Figure 6**) and heart rate; $F(4,35) = 0.44$, $p = 0.776$, partial $\eta^2 = 0.05$ (**Figure 7**). Significant task pairwise differences from post-hoc comparisons with Bonferroni Tests were obtained for cadence between Task 1 and both Tasks 2 and 5. The mean numbers were 111.57 for Task 1, 96.96 for Task 2, and 95.38 for Task 5. For alpha/beta ratio, the similar post-hoc test showed no significance difference between the tasks.

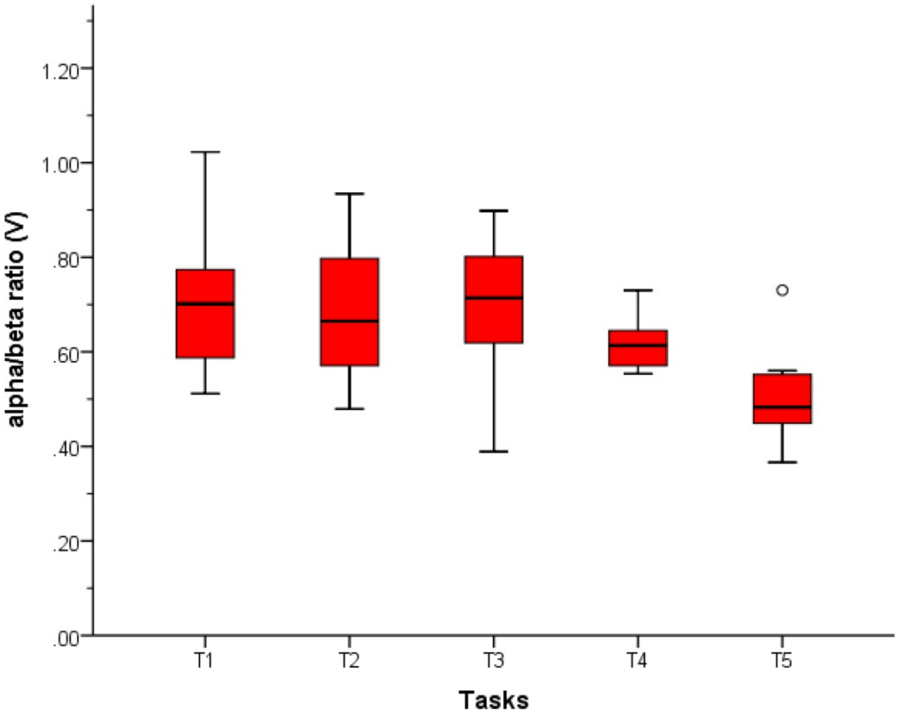

**Figure 4.** Alpha/beta ratio during 5 levels of psychomotor task difficulty

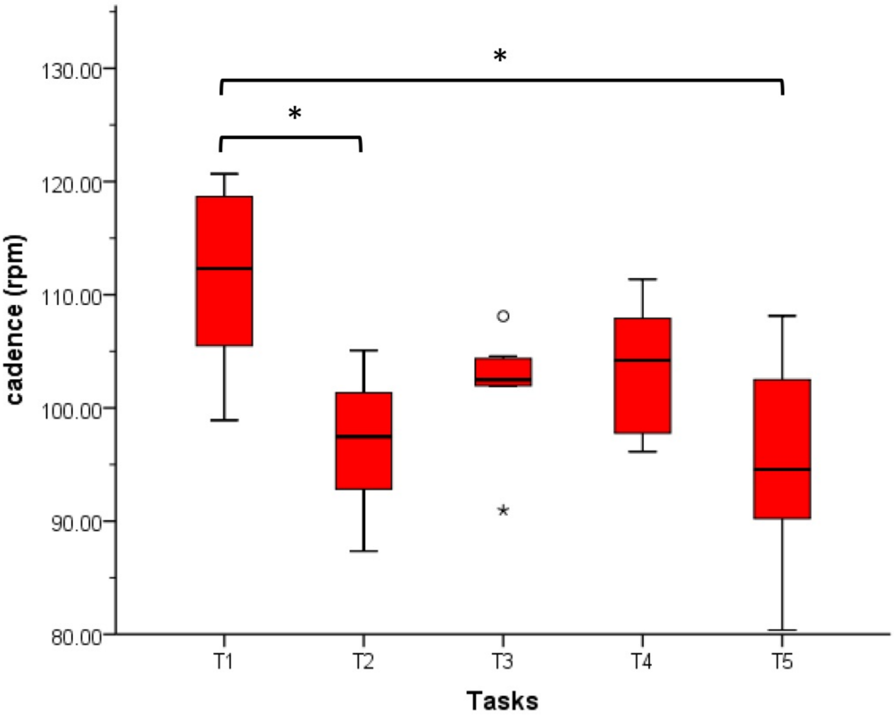

**Figure 5.** Cadence during 5 levels of psychomotor task difficulty

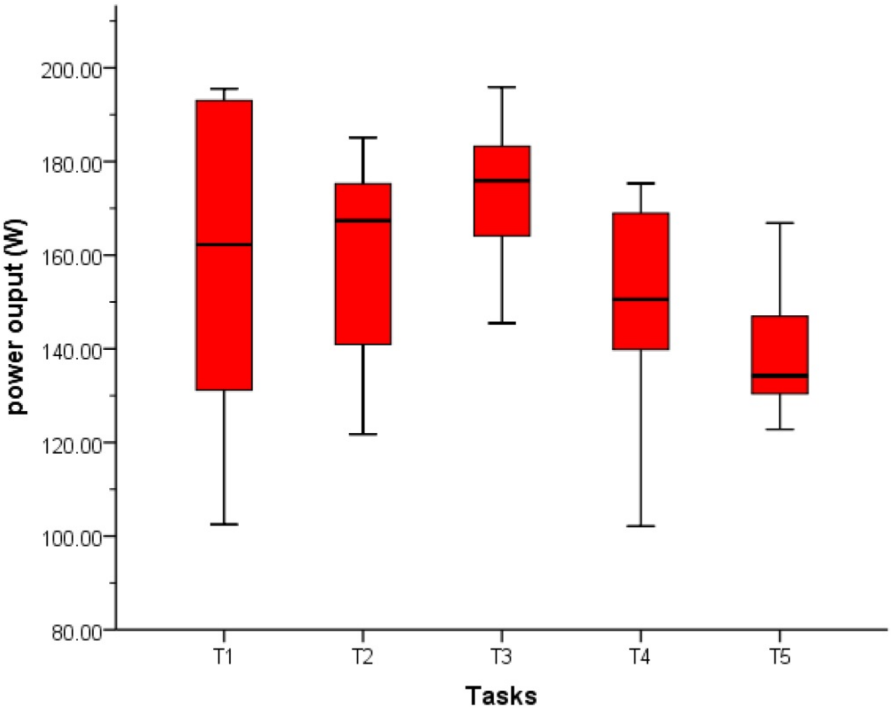

**Figure 6.** Power output during 5 levels of psychomotor task difficulty

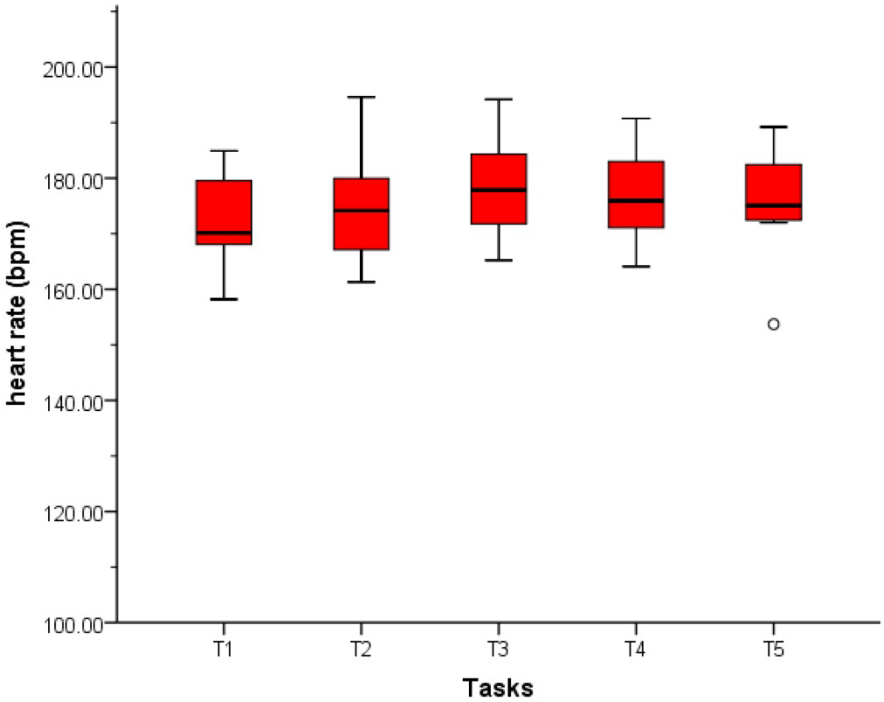

**Figure 7.** Heart rate during 5 levels of psychomotor task difficulty

For further investigation on the effect of modification of five different levels of task difficulty in virtual reality, we analyse similar MANOVA results on the five different levels of task difficulty based on the participants' perceptions on the level of difficulty. The Box's M assumption revealed that the covariance matrices of power output, heart rate, and cadence were not significantly different ($p > 0.05$) across levels of task difficulty in road cycling. Thus, this suggests that the model met the assumption of multivariate normality.

The results from one-way MANOVA revealed no significant multivariate main effect ($p > 0.05$) for the five levels of task difficulty in road cycling, when considered jointly on the variables of alpha/beta ratio, power output, heart rate, and cadence; Wilk's $\lambda = 0.49$, $F(16,98) = 1.64$, $p = 0.072$, partial $\eta^2 = 0.17$. The power to detect the effect was 0.74. Results from the multivariate general linear model for univariate ANOVA show a significant difference ($p < 0.05$) between subjects only on cadence; $F(4,35) = 4.14$, $p = 0.008$, partial $\eta^2 = 0.32$; but not on alpha/beta ratio, power output and heart rate ($p > 0.05$). The descriptive results explain the mechanism on how participants perceived task difficulty. Meanwhile, based on the results of time finish the task and ranking in Task 3 to Task 5 (Table 3), it can be assumed that the competitors randomly responded to the virtual reality control system.

**Table 3.** Descriptive results for modification the five different levels of task difficulty

| | **Participant** | **Task 1** | **Task 2** | **Task 3** | **Task 4** | **Task 5** |
|---|---|---|---|---|---|---|
| **Time finish** | 1 | 3.51 | 4.26 | 3.33 | 4.02 | 6.07 |
| | 2 | 4.38 | 5.02 | 3.41 | 4.48 | 5.49 |
| | 3 | 4.38 | 4.56 | 3.27 | 4.43 | 7.13 |
| | 4 | 3.55 | 5.01 | 3.43 | 4.11 | 6.14 |
| | 5 | 4.31 | 4.45 | 3.41 | 4.23 | 5.49 |
| | 6 | 3.58 | 4.57 | 3.46 | 4.11 | 6.55 |
| | 7 | 3.55 | 4.37 | 3.33 | 4.04 | 7.14 |
| | 8 | 4.19 | 4.09 | 3.43 | 4.33 | 6.24 |
| | Mean | 3.93 | 4.54 | 3.38 | 4.22 | 6.28 |
| | **Participant** | **Task 1** | **Task 2** | **Task 3** | **Task 4** | **Task 5** |
| **Perceived level task difficulty (mean)** | 1 | 1 | 3 | 4 | 2 | 5 |
| | 2 | 1 | 2 | 4 | 3 | 5 |
| | 3 | 1 | 2 | 5 | 4 | 3 |
| | 4 | 1 | 3 | 2 | 5 | 4 |
| | 5 | 1 | 3 | 2 | 5 | 4 |
| | 6 | 1 | 2 | 4 | 3 | 5 |
| | 7 | 1 | 5 | 3 | 4 | 2 |
| | 8 | 1 | 2 | 5 | 3 | 4 |
| | Mean | 1 | 2.75 | 3.62 | 3.62 | 4 |
| | **Participant** | **Task 1** | **Task 2** | **Task 3** | **Task 4** | **Task 5** |
| **Finishing rank** | 1 | - | - | 5 | 3 | 6 |
| | 2 | - | - | 4 | 6 | 4 |
| | 3 | - | - | 5 | 6 | 6 |
| | 4 | - | - | 5 | 5 | 5 |
| | 5 | - | - | 3 | 6 | 5 |
| | 6 | - | - | 5 | 4 | 6 |
| | 7 | - | - | 3 | 4 | 6 |
| | 8 | - | - | 4 | 5 | 6 |

## 4. Discussion

Results from MANOVA appeared in two parts. The primary part involved the output from the modification of the five different levels of task difficulty endorsed by the participating experts. The second part was the output from how the participants perceived the levels of task difficulty. In the first part, the univariate analysis of task difficulty in a virtual reality setting showed a significant effect on alpha/beta ratio, despite the post-hoc comparison finding of no significant results on each task. Furthermore, there was no significant effect on power output and heart rate. This explains that virtual reality stimulated the production of sensory output from the cyclists, as they displayed effort in response to the task demands [26]. Figure 4 and 5 show that the average was higher towards Task 3, which indicates that either Task 3 might be the most difficult task, or the cyclists were adapting to Tasks 4 and 5. In addition, Task 3 might turn out to be an element of the adaptability of expertise towards Tasks 4 and 5, as it included competitors as an element of difficulty. It was shown that power output and heart rate declined from Task 3 to Task 5. Fans were included in the environment of Task 4 and a longer distance was added in Task 5. However, these might not be significant to increase the level of difficulty. It might also result in the cyclists' preferences, as competitors could induce arousal and attention in finishing the race. However, arousal was not aligned with physical effort, as indicated by power output and heart rate. In sports, athletes develop important skills and perceptual motor coordination to adapt to uncertain situations [27].

The subject nature of complexity and difficulty was described in a previous study [24] that critically highlighted the interaction of qualitative and quantitative measures to describe the level of task complexity. In this study, despite the insignificant effects on alpha/beta ratio, power output, and heart rate, it is interesting to note the pattern between these parameters. Alpha/beta ratio seemed to deteriorate from Task 3 to Task 5. Meanwhile, heart rate increased towards Task 5, while power output decreased from Task 3 to Task 5. This pattern may indicate the increased task difficulty. Measuring physiological functions from EEG and heart rate was previously carried out as an evaluation for the cognitive load [28]. Previous studies interpret the alpha/beta ratio as neural efficiency to indicate a decrease in beta waves and an increase in alpha waves that are associated with decreased arousal [29], [30]. An increase in beta activity portrays higher cortical activity because of greater processing demand during task difficulty, as the sensorimotor system works to fulfil task demand [31]. There are changes in the alpha/beta ratio according to Figure 4. Since this study did not find a significant difference in the post-hoc univariate for the alpha/beta ratio, this remains inconclusive. However, as the alpha/beta ratio was one of the physiological factors that contributed to the significance of multivariate variance of analysis, this indicates an insight potential phenomenon of interaction between neural activity and movement function.

Meanwhile, the pattern of power output is not able to relate with the alpha/beta ratio and heart rate. Since the tasks have been modified, the argument is limited in comparison with previous studies. In fact, the analysis is also limited to the five levels of psychomotor tasks. In the meantime, the significant results for cadence on the five different modified psychomotor task difficulties regarding road cycling revealed the inherent factors that lie within the area of psychomotor tasks and human interaction with the environment. The results were supported by previous studies conducted on the effects of virtual reality on certain skills or tasks [5], [14], [27] despite their different experimental designs. This study defined the five different task demands as psychomotor task difficulty that involved the mechanism of the central nervous system [32] and perception reasoning [33].

In the second part of MANOVA analysis, based on the results from univariate analysis on cadence, as well as on how the participants perceived the level of task difficulty differently, we found that this is closely related to the perceptual-cognitive interaction with the environment. This interaction involves planning behaviour and invited the cyclists to respond and adapt their pacing behaviours [34].

Furthermore, the mechanism of perceptual-cognitive interaction with behaviour can be discussed with the significant findings of the univariate main effects on cadence. These findings are encouraging about the effect of the virtual reality setting that induced task difficulty on physiological and behavioural responses. The significant difference in cadence showed that terrain and competitors affected the cyclists' pedalling. In cycling, pedalling involves autonomous and controlled processing. The autonomous processing occurs due to neuromuscular adaptation to training, eventually developing the pattern of movement [35]. Therefore, it reduces the effort in pedalling. On the other hand, controlled processing requires the memory to carry out intentions or action plans to react during uncertain sports conditions [36]. While the designated tasks involved competitors, especially in Task 3, the cyclists were required to make some adjustments in their actions. In the process of interaction between autonomous and controlled, the cyclists demanded cognitive abilities to encounter varied terrains and actions from competitors. These situations contributed to the acceleration and deceleration of cadence [37]. In fact, some cyclists changed their position from seating to standing as a response to inertia. Therefore, the significant results of the main effect for cadence demonstrate human interaction with virtual reality.

This is critical, as the researchers highlighted a user's concern on the presence of interaction in virtual reality [1], [4], [5], [8], [12]. This study is similar to a recent study in terms of using virtual reality as a tool to evaluate brain activity of spectral power [26]. The previous study also used virtual reality simulations to evaluate human psychophysiological behaviour, including EEG, during skiing tasks. To compare between the virtual reality simulation and the real environment, it revealed similar patterns of brain activity that eventually described the presence of realism in the virtual reality system, in the context of reproduction of the cyclists' cognitive and peripheral motor programme. Meanwhile, increasing multisensory input in virtual reality even with substituting multimodal sensory feedback (e.g. visual, tactile, audio) can potentially increase performance and users' perceived sense of presence [5]. Moreover, adding competitors as another visual sensory cue in the rowing task improved the participants' performance as measured by the heart rate [38].

As alpha/beta ratio and cadence showed significance in univariate ANOVA analysis, the effect size from partial eta squared indicated that 25% probability for alpha/beta ratio and 44% probability for cadence contributed to the differences between the Tasks. According to Lakens [39], despite $\eta 2$ being an efficient approach to compare the effect size in a single study, it cannot easily be compared between studies, due to total variability in a study, including the design and variables involved. Only female participants were recruited in the present study to avoid gender differences in terms of physiological, psychological, and behavioural factors. These factors previously found differences between genders, particularly in virtual reality studies on cycling [1]. The homogeneous factors also contribute to the advantages that samples shared similar characteristics and are more physiologically equivalent. However, this is limited to generalisation towards other participant levels such as younger adults, older adults or elite cyclists.

Cybersickness is a common occurrence for those experiencing virtual reality for the first time. Therefore, the procedure and evaluating the task by increasing the level of task difficulty may assist the user to adapt with the virtual reality application. Adaptation to virtual reality can reduce cybersickness [40]. The participants had once experienced cycling in a similar virtual reality set up. Meanwhile, complying a third person view has a better level of "presence" [41]. Application virtual reality is considered new especially for sport competitiveness. Thus, this exploration can introduce and discover the benefits of the system especially to the coaches to include the usage of virtual reality in training programmes or assessment.

## 5. Conclusions

In summary, the results highlighted the effect of the five different levels of modified psychomotor task difficulty on the multivariate parameter physiological functions, as well as the univariate parameter of cadence. The significant effects on physiological responses ensure that the evaluation of the experiment from the procedure in a virtual reality setting is practical, applicable and can be modified when required for optimal training or assessment. The behavioural mechanism explained during pedalling may offer potential insight on the involvement of cognitive processes, and merits further investigation in future work.

## Acknowledgements

The authors would like to thank the National Sport School for their assistance during the experiments, and all the participants who were involved in this study.

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