Acute psychological and physiological benefits of exercising with virtual reality

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Key words: Perception, Physical Activity, Exercise Performance, Perceived Exertion, VR

Abstract

Exercise is a powerful tool for disease prevention and rehabilitation. Commercially available virtual reality (VR) devices and apps offer an immersive platform to gamify exercise and potentially enhance physiological and psychological benefits. However, no work has compared immersive exercise to 2D screen-based equivalents, such as following a video workout. This study aims to compare the acute effects of an exercise session using a commercial immersive VR workout to an exactly matched non-immersive screen-based stimuli. 17 healthy participants (male=7, female=10; aged 24.18±4.56 years), completed a 12-minute guided VR boxing exercise session in FitXR™ and a screen-based matched equivalent. Physiological responses were recorded continuously using a heart rate monitor and telemetricmetabolic cart system. Psychological and perceptual responses were measured using ratings of perceived exertion, physical activity enjoyment scale, and the physical activity affect scale. Participants recorded significantly higher VO2 (*p*=0.044), higher levels of all enjoyment subscales *(p*<0.05), higher positive affect (*p*=0.003), and lower negative affect (*p*=0.045) in the VR workout compared to the matched screen-based equivalent. Exercising using a commercially available VR workout offers acute benefits for chosen work rate, enjoyment, and psychological responses. VR may offer a more efficient alternative to other forms of screen based and exergaming workouts and could be offered as a gateway into exercise.

Introduction

The positive effects of exercise and physical activity on health are well documented. These include reduction in obesity, cardiovascular disease, cancers, respiratory infection, osteoporosis, diabetes, lower back pain, anxiety, depression, and all-cause mortality [1-3]. Positive impacts include reduced pain, blood pressure, cholesterol, body mass, and enhanced sleep quality, stress, mood, and quality of life [3]. Most international governments recommend adults perform at least 150 minutes moderate intensity or 75 minutes vigorous intensity aerobic activity per week, with moderate intensity muscle strengthening activities performed two days per week [2, 4]. Despite the known benefits, over a third of the population remain physically inactive in England and almost half in the USA [5, 6]. There is a significant need to develop strategies to support individuals in engaging with exercise and physical activity and technological developments have the potential to support this need.

Attrition rates for participating in new exercise programmes have been reported up to 58% [7], with 50% attrition to exercise programmes within 3-6 months [8]. Lack of time and motivation are amongst commonly reported perceived barriers to exercise [9, 10]. Other potential reasons include lack of facilities/equipment, low energy, no exercise partner, low previous levels of physical activity, poor social support, anxiety, depression, pain, and low self-efficacy [7, 11]. Poor education, exercise self-efficacy and negative perspectives or previous adverse experiences to formal exercise are likely to decrease enjoyment and participation [12-15]. Researchers have investigated a myriad of interventions to enhance engagement with exercise and physical activity [16, 17]. A promising solution is exergames. These are digital games that require physical activity to play and operate active gaming experiences [18].

Exergames have been available since the 1980s [19], however technological advances in the past decade have allowed higher fidelity and better interfaces during gaming. As such, commercially available gaming consoles and devices have adopted exergaming capabilities and have become more accessible and affordable. These devices include immersive virtual reality (VR) headsets. VR involves immersive three-dimensional computer-generated simulations resemblant of various real or imagined environments, objects, and events. The user can interact with simulations with full body movement [20]. The element of environmental interaction significantly influences perceptions of immersion and effort [21, 22] and offers an opportunity for immersive gamified exercise that could support retention in exercise programmes beyond what can be currently achieved in exergames using 2D screens.

Efforts to increase sustained exercise participation can utilise the COM-B model of behaviour change. This model suggests that behaviour (B) is dependent on three components: capability (C), opportunity (O) and motivation (M) [23-25]. VR can target all elements of the COM-B model. For example, the capabilities of individuals to exercise, especially those uncomfortable with or intolerant to exercise, can be enhanced using VR. This is because, be it due to distraction [27-28] or deliberate manipulation [21, 29], participants exercise at lower perceived exertion for the same workloads and can choose to exercise for greater durations or at higher intensities when using VR [21, 30, 31]. When considering opportunity, the convenient and accessible nature of VR offers opportunities by allowing users to use them at home at any time and the gamification element allows for fun social interaction via multiplayer functions and competitions without needing to leave the house. Motivation to exercise has also been shown to increase with the use of exergames [18] and compared to non-VR exergames, VR users reported sessions to be more enjoyable

[32]. Such psychosocial factors are predictive to engaging in physical activity and exercise [33, 34]. VR exercise could increase the capability, opportunity and motivation and have a positive effect on the frequency at which individuals are motivated to engage with exercise and the intensity at which they exercise when they do [28, 35]. It could, therefore, enhance a person's ability to reach physical activity guidelines [36, 37].

Despite the possible benefits of gamifying exercise and the potentially additional benefit of using VR for this purpose, no work has used gold standard measures of physical workload and compared physiological and psychological responses to VR exercise to a matched 2D equivalent, such as following an on-screen workout. Researchers have often artificially controlled the participants' exercise workload or compared VR to rest, rather than equivalent non-VR exercise. Work has also regularly used bespoke research equipment over affordable commercially available devices that are accessible to the general population. Therefore, this study aims to use a commercially available device and app to investigate the acute effects of a VR workout compared to a matched non-VR workout. This will be achieved through taking measures of physiological workload (Heart rate, HR, oxygen consumption), perceptions of effort, enjoyment and affect, as well as the acceptability, feasibility, and tolerability of using VR for exercise.

Participants completed VO_2 max testing and engaged in the same boxing workout both in an interactive and immersive VR setting or with the exact same stimuli appearing on a large 2D screen. We hypothesised that in the VR condition participants will show a great capability to exercise and choose to exercise at a higher workload and this will produce a greater physiological response through higher heart rates and VO_2 across the whole workout. This will be linked to a lower perceived amount of effort, measured through RPE. We also hypothesised that participants would enjoy the immersive exercise more and report higher scores on the physical activity enjoyment scale and enhanced scores on the positive affect dimension of the physical activity affect scale [38].

Method

Participants

We performed a sample size calculation using G*Power (3.1.9.7) based upon the RPE effect sizes from Zeng et al. [28] where within subject differences in RPE between a virtual and traditional cycling condition resulted in an effect of dz = 0.85. Using a matched pairs t-test, an α of 0.05, and Power of 0.95 (selected to historic issues with low power in this field), we calculated a required sample size of 17. 17 healthy individuals volunteered to take part (aged=24.2±4.6 years; height=168.21±10.49cm; body mass=69.62±14.43kg; BMI24.47±4.04kg/M^2). Individuals who trained >5 days/week, those who reported limitations or risk in physical exertion and exercise capacity such as medical conditions (e.g., COPD, CVD) or any history of metabolic or respiratory disease were excluded. Participation was entirely voluntary with no financial incentive. This study was approved by the local Research Ethics Committee (MRPP-22/23/3691) and all participants provided informed consent.

Materials and Stimuli

VR exercise was conducted using FitXR™ on a Meta Quest 2 VR headset with two handheld controllers. Specifically, participants engaged in an intermediate difficulty boxing workout called ‘pack a bunch’ with personal trainer Dillon supplying the instructional voiceover. The boxing workout consists of orbs flying towards participants with a white light glowing from one side to indicate the type of punch required. Each workout also incorporates ducks, weaves, and blocks (Figure 1). The activity duration was 12 minutes 25 seconds. The music and a coach verbally encouraged and guided users through four consecutive rounds (warm-up, defense & counter, conditioning, and fight; see Figure 2). FitXR™ allows users to select a location, all participants conducted this workout in the ‘rooftop’ setting. For the screen-based matched equivalent we created a 2D screen-based stimuli by screen recording the same workout from the headset meaning the two workouts out were identical aside from the immersive nature of the VR version and the visuo-haptic feedback and real-time scores were visible to users in VR. No feedback or scores were recorded for the NoVR condition, given the nature of the task and technology.

A polar strapped HR monitor (Polar H10) was attached with contact with participant’s sternum. VO_2 was measured using a calibrated telemetric metabolic cart system (Metamax 3B), attached to an oronasal mask which participants wore throughout the activity (Figure 1).

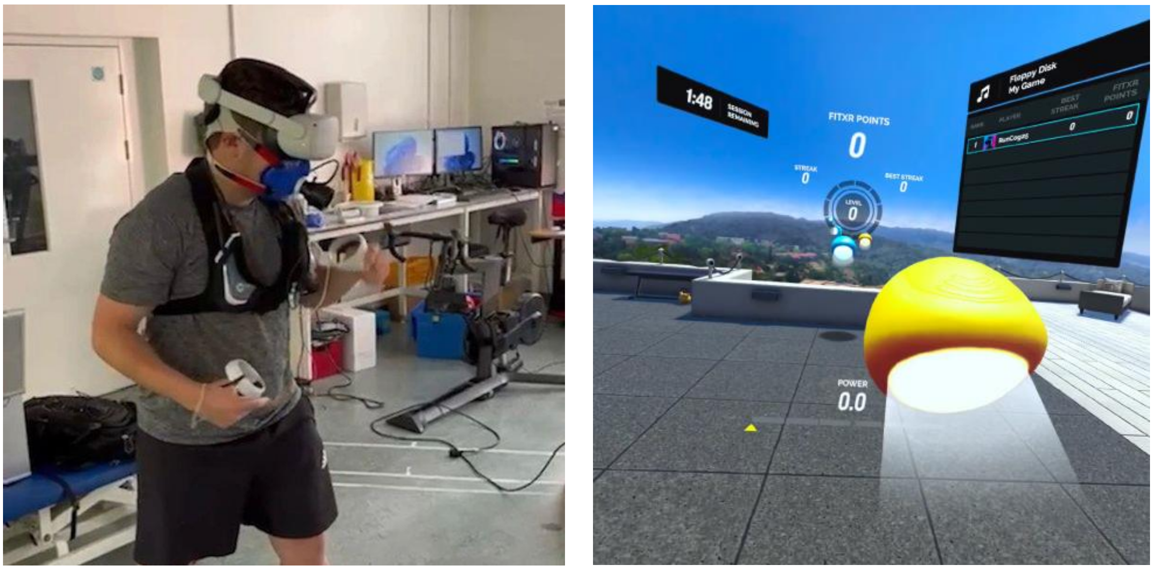

Figure 1. Left. Participant wearing the headset and portable metabolic cart. Right. First person view of FitXR™ as displayed in VR and on screen.

Protocol

All participants performed the activity using a VR and a ‘NoVR’ or screen condition. The order of conditions was counterbalanced. Both sessions preceded with a 1-minute rest period, where baseline physiological measures were recorded. There was an approximate 5-minute rest period between sessions. After both versions were completed, participants undertook a Modified Balke Protocol walking treadmill VO_2 max test [39]. A 1-minute rest period preceded walking to obtain baseline measures. Due to sex-specific differences, the initial walking speed was gender dependent (males=3.3 mph, females=3.0mph). The incline was increased by 2% after 2 minutes of walking and by a further 2% every proceeding minute. If a maximum incline of 20% was achieved, speed would increase by 0.2mph every minute. Participants were instructed to continue up to maximal effort. Maximal VO_2 (VO_2 max) was considered to be achieved if HR reached +/-10% of the predicted maximal value (220bpm – age). All participants achieved this criterion.

Measures

Physiological measures

Throughout the workouts we collected heart rate (HR) in beats per minute (bpm), oxygen consumption (VO_2) in ml/kgmin. Maximal oxygen (VO_2 max) was calculated as the highest mean VO_2 over a 20 second period and percentage of VO_2 max during activities were calculated.

Exercise Perception and Affective Responses.

Incrementally, rate of perceived exertion (RPE) scores was reported by participants verbally using the CR10 Borg scale [40]. Three short Likert style self-assessment questionnaires were administered upon completion of each condition. The Physical Activity Enjoyment Scale (PACES) questionnaire was administered to quantify enjoyment of activity [41]. A Physical Activity Affect Scale (PAAS) questionnaire distinguished the psychological response to each condition [42]. Subscales of the PAAS are used to categorise impacts as positive (upbeat, energetic and enthusiastic), negative (miserable, discouraged and crummy), tranquillity (calm, peaceful, relaxed) or fatigue (tired, worn-out and fatigued), as demonstrated by Lox et al. [42]. The post-VR questionnaires proceeded with qualitative insights regarding motivations for using VR, engagement, fears and barriers to using VR.

Feasibility, Acceptability, and Tolerability

Participants were asked to answer a series of questions after the VR condition, designed to gather participant feedback of the acceptability, tolerability, and feasibility of exercising in virtual reality**.** Simulation Sickness Questionnaire (SSQ) [43] to assess tolerability and potential cybersickness effects and the open-ended questions were asked to further investigate acceptability and feasibility (see Table 1).

Table 1. Follow up questions that participants were asked after completing the VR exercise workout and the reason for these questions based on Birckhead et al. [44].

Question/Measure	Category
Simulation Sickness Questionnaire	Tolerability
What motivated you to participate in this virtual reality and exercise-based research?	Acceptability
Did you have any worries or fears about using virtual reality during exercise? If yes, please tell us what they were.	Feasibility
What do you think using virtual reality can add to your exercise sessions?	Feasibility
Would you like to use virtual reality again in an exercise session at another time and why?	Acceptability
How often would you like to use virtual reality? It could from any time you exercise, every once in a while, or never!	Feasibility
Are then any barriers that would prevent you from using virtual reality during exercise?	Acceptability/ Tolerability

Data Analysis

Breath-by-breath VO_2 and HR data was recorded and extracted for the MetaSoft studio software. JASP 0.18 was used for statistical analyses. We used two 2 conditions × 27 time points repeated measures ANOVA to investigate the effects of condition (VR and NoVR) and time (30 second intervals) on heart rate and VO2. To measure effects of condition and time on RPE we used a 2 condition × four time point repeated measures ANOVA. A Bonferroni adjustment was employed when multiple comparisons were being made for time points in order to lower the significance threshold and avoid Type I errors. Violations of sphericity were corrected by adjusting the degrees of freedom using the Greenhouse–Geisser correction when ε was less than 0.75 and the Huynh–Feldt correction when greater than 0.75. Partial eta squared was used as a measure of effect size for all analyses. To compare enjoyment and affective responses in VR compared to NoVR we used paired sample t-tests for each subscale. All comparisons made were preplanned; therefore, alpha value was kept at $p = .05$ and effect sizes (Cohen's d) and 95% confidence intervals were reported [45].

We also collected qualitative feedback to explore opportunities to exercise in VR focusing on participants perceptions of acceptability, feasibility, and tolerability [44]. For yes or no answers we simply present descriptive counts. Where participants expanded on answers, we were not able to generate categories for a content analysis based on previous literature due to the lack of previous work in the area. Therefore, to analyse the follow-up questions, we used a blended approach where we first analysed interview content inductively to produce themes that could then be used for categories in a count-based content analysis (Runswick et al., 2022) [46]. This process was conducted for each question and participants were not limited to single codes per question.

Results

Physiological Responses

Heart Rate

Figure 2 shows how HR changed throughout each round in both conditions. Mean±SD HR values (bpm) during each round were: '*Rest*' VR=84±14.854, NoVR=87±16; '*Round 1*' VR=113±27, NoVR=107±25; '*Round 2*' VR=127±26, NoVR=119±27; '*Round 3*' VR=127±29, NoVR=121±27; '*Round 4*' VR=139±29, NoVR=130±28. There was a main effect of time on HR (p=<0.001, F=73.234, η^2=0.686). However, there was no significant effect between exercise type (p=0.074, F=3.667, η^2=0.018) and no significant time-type interaction (p=0.087 (G-G), F=2.842, η^2=0.10). Peak HR for VR was 142.38bpm and 131.49bpm for nVR. The mean difference between exercise types was 5.379bpm.

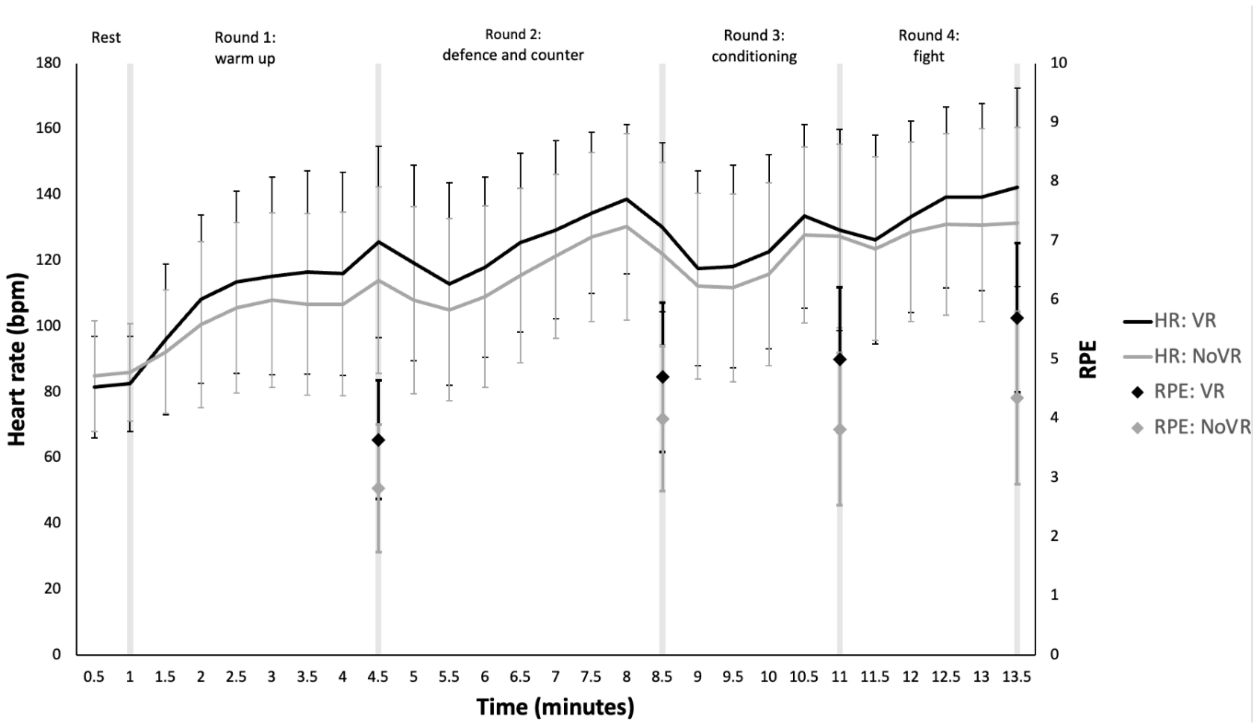

Figure 2. Heart rate and RPE at 30 second intervals across the VR and NoVR workouts.

VO$_2$

The average VO$_2$max (ml/kg/min) for participants was 45.41±9.52. Figure 3 shows how VO$_2$ (ml/min/kg) changed throughout both exercise types. Mean±SD VO2 during each round were: ‘*Rest*’ VR=5.31±1.23, NoVR=5.03±0.99; ‘*Round 1*’ VR=14.75±7.24, NoVR=12.87±6.32; ‘*Round 2*’ VR=20.00±5.64, NoVR=17.56±7.11; ‘*Round 3*’ VR=18.33±6.80, NoVR=16.57±7.48; ‘*Round 4*’ VR=22.43±8.39, NoVR=19.56±8.29. There was a significant main effect of time (p=<0.001, F=68.853, η^2=0.695) and type of exercise (p=0.044, F=4.765, η^2=0.019) on VO$_2$. There was no significant time-type interaction (p=0.289 (G-G), F=1.281, η^2=0.004).

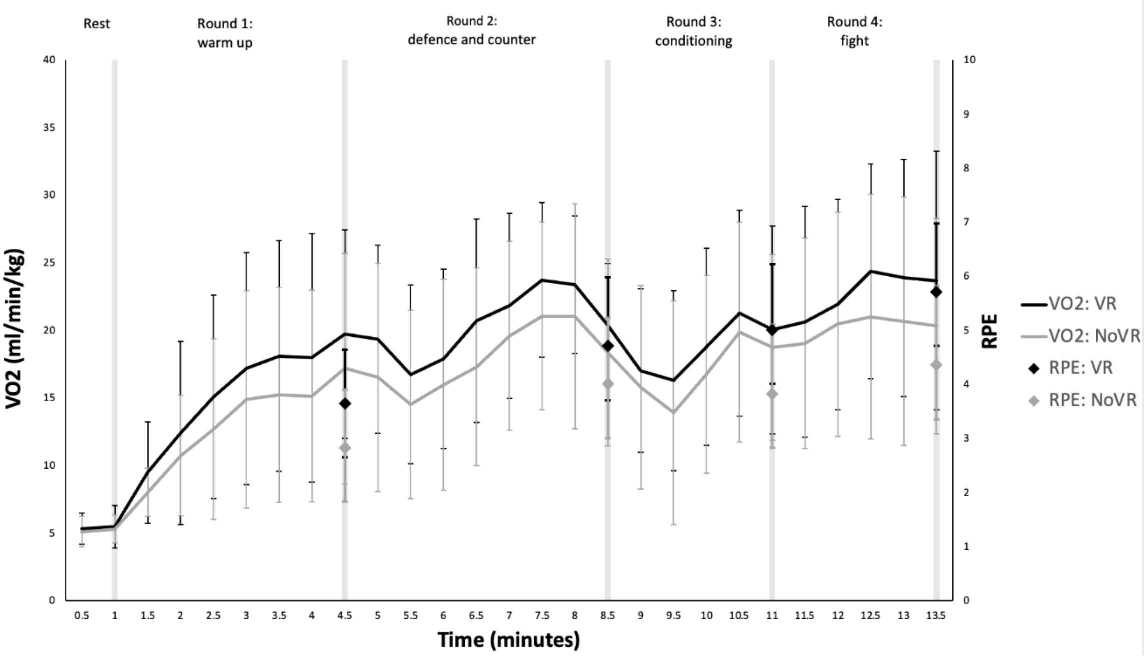

Figure 3. VO2 and RPE at 30 second intervals across the VR and NoVR workouts.

Rate of Perceived Exertion

Mean RPE values for VR and NoVR at the end of each round were: Round 1=3.6±1.0 and 2.8±1.1, Round 2=4.7±1.3 and 4.0±1.2, Round 3=5.0±1.2 and 3.8±1.3, Round 4= 5.7±1.3 and 4.3±1.5. There was main effect of both time (p<0.001, F=51.379, η^2=0.403) and exercise type ($p<0.001$, $F=45.289$, $\eta^2=0.248$). The was no significant time-type interaction ($p=0.100$, $F=2.205$, $\eta^2=0.016$).

Exercise Perception and Affective Responses.

Figure 4 shows PACES results. Total scores show VR performed superiorly to NoVR (VR=4.4±0.9, NoVR=2.7±0.8, $p<0.001$, $d=1.291$, 95%CI=0.630-1.930). VR exercise performed greater than NoVR exercise for subscales; pleasurable (VR=4.4±1.2, NoVR:3.0±0.2, $p<0.001$, $d=1.064$, 95%CI=0.454-1.653), fun (VR=4.9±1.1, NoVR=2.7±1.0, $p<0.001$, $d=1.363$, 95%CI=0.685-2.019), pleasant (VR=4.2±1.1, NoVR=2.9±0.7, $p<0.001$, $d=1.132$, 95%CI=0.507-1.735), invigorating (VR=4.5±0.8, NoVR=2.8±1.2, $p<0.001$, $d=0.995$, 95%CI=0.399-1.570), gratifying (VR=4.1±1.1, NoVR=2.2±1.1, $p<0.001$, $d=1.070$, 95%CI=0.459-1.660), exhilarating (VR=4.5±0.7, NoVR=2.4±1.2, $p<0.001$, $d=1.4435$, 95%CI=0.739-2.109) and stimulating (VR=4.8±0.9, NoVR=2.7±1.1, $p<0.001$, $d=1.355$, 95%CI=0.679-2.009). No differences were detected in refreshing subscale (VR=3.5±1.125, NoVR=2.6±1.1, $p=0.051$, $d=0.511$, 95%CI=-0.003-1.010).

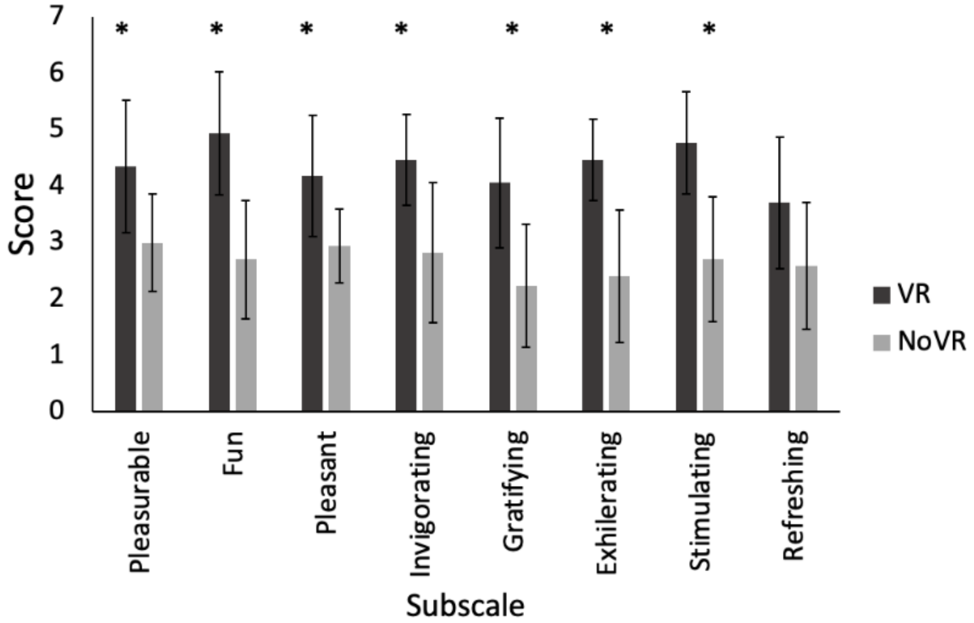

Figure 4. PACES subscales for the VR and NoVR workouts. * Denotes significant differences.

Figure 5 presents the outcomes of PAAS. There was greater positive affect post-VR exercise (VR=2.5±0.7, NoVR=1.8±0.7, *p*=0.003, d=0.774). There were no significant differences in tranquility (VR=1.1±1.0, NoVR=1.4±1.0, p=0.943, d=-0.405). Compared to NoVR, there was less negative affect in VR (VR=0.02±0.1, NoVR=0.2±0.3, p=0.045, d=-0.438). There were no differences in fatigue (VR=1.0±0.7, NoVR=0.9±0.6, p=0.839, d=0.248).

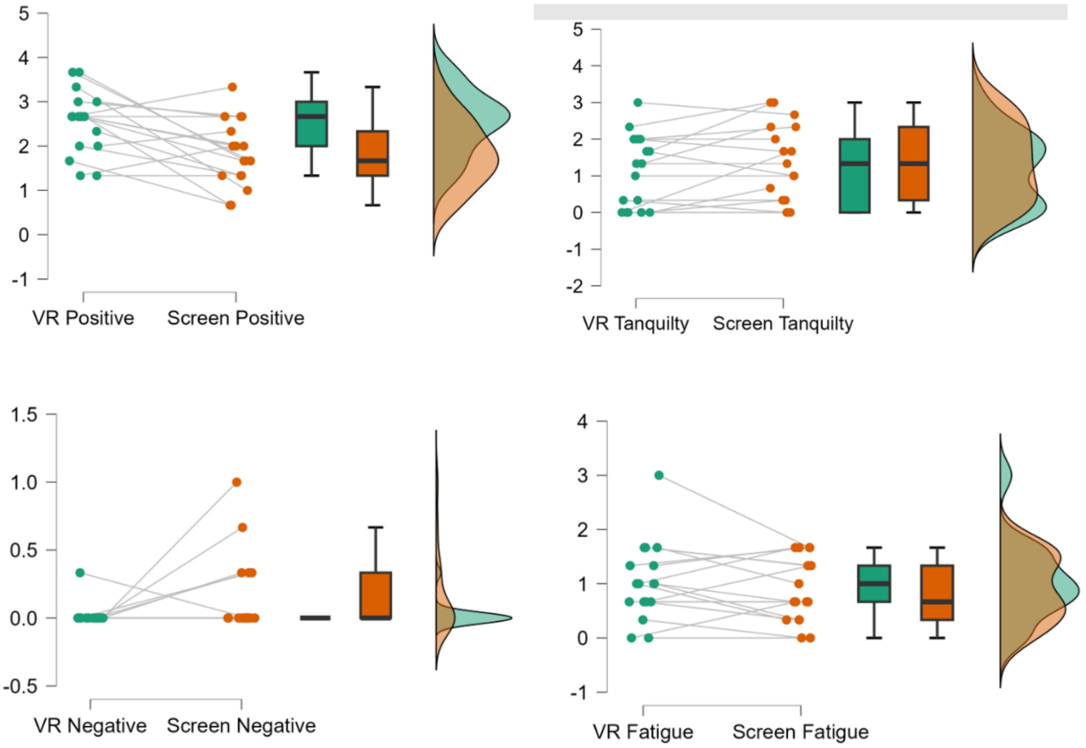

Figure 5. PAA results showing individual scores, means, and distributions for positive affect (top left), tranquility (top right), negative affect (bottom left) and fatigue (bottom right).

Feasibility, Acceptability, and Tolerability

No participants reported feeling motion sick after each condition. SSQ results indicated that general discomfort was reported in VR compared to NoVR (VR=0.5±0.8, NoVR=0.1±0.3, p=0.014, d=0.666). No significant differences were found in all other subscales (p>0.05). Responses to questions on feasibility and acceptability can be found in Table 2. Almost all participants saw VR exercise as a feasible and acceptability addition to their exercise programmes. This generally focused on an ability to add variety to exercise, increase enjoyment and add competition and motivation. 15 out of the 17 respondents would use VR again for exercise and the majority suggested that this would be on a regular basis or once a week or more.

Table 2. Themes and example quote alongside content counts or each follow-up question.

Question	Theme	Example	Count
What motivated you to participate in this virtual reality and exercise-based research?	Interest in VR	"I wanted to try VR"	8
	Novelty	"I wanted to try something new"	4
	Interest in Research	"The ball didn't bounce accurately"	3
	Fun	"A bit of fun to experience a VR workout"	3
Did you have any worries or fears about using virtual reality during exercise?	No worries or fears	"None"	11
	Spatial awareness	"Bumping into things"	3
	Self-consciousness	"Looking stupid"	1
	Sickness	"Slightly worried about motion sickness"	1
	Equipment	"Wearing the equipment"	1
What do you think using virtual reality can add to your exercise sessions?	Fun	"Makes it more fun and creative way to exercise"	6
	Variety	"Offers variety of different activities that I wouldn't do normally"	6
	Motivation	"Definitely adds motivation when it feels real"	5
	Feedback/ competition	"Really enjoy the competitiveness, points system - compete against self or others"	4
	Accessibility	"Good alternative if you can't go outside/ don't have access to facilities"	2
	Engagement	"It adds engagement and distraction"	1

Would you like to use virtual reality again in an exercise session at another time and why?	Yes - Fun	“Yes because it was fun”	7
	Yes - Motivation	“Yes, because it’s more engaging and motivating”	3
	Yes – Exercise perceptions	“Yes, it was more fun and didn’t feel like 'exercise'”	2
	Yes – Variety	“Yes because it's different to conventional exercise”	2
	Yes – Schedule	“Yes, easy to fit in with schedule”	1
	No - Ergonomics	“No because it was clunky, didn't allow proper movement”	1
	No - Space	“No because of lack of space and money”	1
	No - Cost	“No because of lack of space and money”	1
How often would you like to use virtual reality for exercise?	Once a week or more	“Once or twice a week”	11
	Every day	“Daily”	2
	Once a month or more	“Maybe twice a month”	3
	Never	“Never”	1
Are then any barriers that would prevent you from using virtual reality during exercise?	Cost*	“Price accessibility”	8
	Space	“Space”	6
	Equipment	“Technical difficulty of set-up”	3
	No	“No	4

*Participants were not informed how much headsets or app cost.

Discussion

This study aimed to use a commercially available device and app to investigate the acute physiological and psychological effects of VR exercise compared to a match 2D screen-based equivalent. We took measures of workload (HR and VO_2, perceptions of effort, enjoyment and affect, as well as the acceptability, feasibility, and tolerability of using VR for exercise. Results showed that participants chose to engage in higher work rates in VR compared to a matched screen-based equivalent, but at the same level of perceived exertion. The VR exercise was also rated as more enjoyable and resulted in more positive and less negative affective response. VR exercise was tolerable and was perceived as feasible and acceptable by the participants.

As hypothesized, VO_2 values were higher during VR exercise compared to NoVR, but participants did also perceive these high levels of exertion, evidenced in higher RPE scores in VR. HR did not show a significant main effect of exercise type but did show a small effect. Findings partially support those of Runswick et al. [22] who found participants cycled at higher intensities in VR. However, participants did not perceive the exertion to be higher. Similar findings were reported by Glen et al. [47] who found greater RPE values during exergame conditions compared to a blank screen. Here the higher workload was selected, but also perceived, this does not support a wider body of work that has shown reductions in perceptions of exercise intensity [28, 48] or breathlessness [29] in virtual environments. In this study we aimed to allow participants to exercise as they would naturally in VR, rather than control workload, as many studies focusing on reducing RPE have done. The higher work rate in VR may have been influenced by factors, such as enjoyment and live feedback.

As anticipated, enjoyment and positive affect scores were higher for VR exercise, despite the higher work rates. In traditional exercise settings, enjoyment can decrease as intensity increases [49], however, here we have shown higher levels of exercise intensity and enjoyment, suggesting a benefit from exercising in a gamified way. Our findings are consistent with several studies that find VR to be enjoyable [27, 50]. The environmental interactivity of VR exercise may have driven this affect where haptic feedback can positively influence the experience of VR users and improve performance [51-53]. Simulating kinesthetic information such as force and pressure with punches in VR via haptic feedback, may have increase sensory fidelity, sense of presence and immersion by engaging senses beyond the visuo-audio of NoVR [54, 55]. Adding to this previous work, we also captured the increase in positive emotions and decrease in negative emotions after the workout, suggesting investigating the role VR exercise could have in mental health to be a beneficial direction for future work.

As well as recording higher workloads, more enjoyment and more positive affect when exercising visiting the lab, we also aimed to collect information on how the participants perceived the feasibility, acceptability, and tolerability of using VR in the future [44]. No participants experienced any adverse effects of using the HMD, suggesting that the exercise is tolerable. Content analysis of the qualitative responses showed that exercise in VR was likely acceptable and feasible for these participants as well. The majority reported a desire to use VR for exercise at a regular basis due to increases in motivation and enjoyment and that VR exercise had few perceived barriers.

Revisiting the COM-B model of behaviour change, our findings suggest that VR could indeed increase exercise behaviour through increases in capability (C), opportunity (O) and motivation (M) [23-25]. In literal terms the VR condition here supported participants in doing more exercise, suggesting the capability to engage in higher intensity exercise may be impacted. This also suggested that motivation to engage in more intense exercise was affected. The increases in positive affect and enjoyment add to this motivation element, as was supported by the qualitative feedback from participants. Improved enjoyment can improve self-reported self-efficacy for exercise and attitudes towards exercise [56]. Participants also suggested that VR could increase the opportunity to engage in more regular, higher intensity, and more enjoyable exercise. It is well established that gamification of exercise can improve enjoyment and attitude towards exercise, as well as shaping behaviour to increase exercise activity [57, 58] but the findings here suggest that VR has potential to build on this further.

Whilst these results are promising, they should be considered in light of the limitations of this study and its design. Firstly, novelty may play a role in the findings reported here from acute bouts of exercise. Participants were new to VR and many reported they took part due to the novelty and were interested in trying VR (Table 2). This may lead to higher levels of interest and effort in the VR condition and future research should investigate the use of VR over longer training periods. Additionally, our cohort was relatively young and active. Therefore, our findings may not be applicable to the wider general population or older aged adults. In this study, a common comment by participants was that the VR headset could not be worn perfectly flush over the mid portion of the nose with the ventilatory mask on. This led to some discomfort and potentially had some effect on display clarity and adding to the sweating caused the VR headset. When wearing the VR headset, participants could not see BORG scale, which limits their reporting of RPE values to memory of the scale and did so verbally after being familiarized with the visual scale beforehand. There were some large individual differences in enjoyment and affective responses to VR in this study. It possible that some individuals less engaged or interest in VR may be ‘non-responders’. While we do not have enough power here for group-based analysis, future research may benefit from analysing individuals who do and do not enjoy VR.

Exercise in VR can increase chosen work rate, activity enjoyment, and elicit positive psychological responses compared to a non-VR screen equivalent. Health and fitness promoting efforts may be enhanced by suggesting VR as an alternative for of exercise. Whilst VR use continues to expand, embracing such technologies into healthcare systems can be beneficial for enhancing disease prevention and conditions management. Future, larger scale studies that explore these concepts further is needed to improve understandings of VRs applications and uses in exercise over longer training periods.

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