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The effects of the presence of others during a rowing exercise in a virtual reality environment☆

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ABSTRACT

Objectives: The aim of the study was to test the performance, motivational, and affective impact of aerobic exercise within an immersive virtual reality environment experienced alone or with another individual.
Design: Sixty female participants aged 18–30 years were assigned to one of three conditions: no virtual reality (NVR), individual virtual reality (IVR), or companion virtual reality (CVR).
Method: Participants completed 9 min of self-paced rowing on an ergometer without any visual input or performance feedback (NVR), individually within a virtual reality environment (IVR), or within a virtual reality environment that included a companion depicted as an avatar (CVR).
Results: The two virtual reality groups rowed a further distance and at a higher power output than the NVR group. Furthermore, the CVR group outperformed the IVR group in distance and had a higher heart rate. Participants in the virtual reality groups did not perceive themselves to be exerting more physical effort and rated the task as more enjoyable than participants in the NVR group.
Conclusions: Virtual reality improves performance and the affective response to aerobic exercise, and performance effects are further enhanced by the presence of others in the virtual environment.

Many people live inactive lifestyles despite substantial evidence that regular physical exercise is associated with physical and psychological benefits (Warburton, Nicol, & Bredin, 2006). An Australian study by Cadilhac et al. (2011) suggested that 70% of adults are sedentary or have a low activity level. Similar levels of physical inactivity are shown in other countries (World Health Organization, 2014). Research is required to investigate new ways to increase participation in physical activity. New approaches have the potential to improve the personal health and lifestyle of individuals and to assist governments faced with the financial burden of disease caused by physical inactivity (Cadilhac et al., 2011).

Novel approaches to promote physical activity include the use of virtual reality (VR) technology. VR refers to a computer-generated environment that can lead to the sense of physical presence in a virtual world (Baños et al., 2000; Steuer, 1992). One approach, termed *exergames*, incorporates VR to play a game using a system capable of sensing movement (e.g., Xbox Kinect). Physical activity becomes the means by which individuals control features of the game, such as moving an avatar to avoid obstacles or enemies. VR has also been combined with traditional exercise tasks, such as stationary cycling (e.g., Legrand, Joly, Bertucci, Soudain-Pineau, & Marcel, 2011), treadmill running (Nunes, Nedel, & Roesler, 2014), and ergometer rowing (Hoffman, Filippeschib, Ruffaldib, & Bardy, 2014). In such applications, physical exertion on the exercise equipment allows the individual to move through a virtual environment. Unlike exergaming, where playing the game is the main focus, increasing physical fitness, strength, or technique is the main focus for VR-based exercise.

Research using traditional exercise tasks has suggested that the addition of VR can increase physical exertion and adherence to exercise. Using a cycling task, participants have shown greater physical exertion (as measured by revolutions per minute) when cycling in a VR environment than when cycling alone (Plante, Aldridge, Bogden, & Hanelin, 2003). Time to complete a distance has also shown to be faster when rowing in a VR course than when rowing alone (Hoffman et al., 2014). Similar findings have emerged using other measures of exertion, such as heart rate and ratings of perceived

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exertion (Plante, Aldridge, et al., 2003; Plante, Frazier, et al., 2003). Adherence is also enhanced when exercising with VR. Annesi and Mazas (1997) found increased adherence over a 14-week period for participants using an exercise bike in a VR environment when compared to those using an exercise bike without VR.

Ijsselsteijn, de Kort, Westernik, de Jager, and Bonants (2004) tested the effects of immersion on the motivation of participants using a stationary home exercise bike linked to a VR environment. Immersion was manipulated by presenting the VR environment from the point of view of the rider (high immersion) or from a bird's eye view (low immersion). Participants exercising in a higher immersive VR environment cycled faster, rated their experience of presence higher, and found the task more interesting and enjoyable than participants exercising in a lower immersive environment. Although the Ijsselsteijn et al. (2004) study lacked a control group to evaluate the benefits of VR on performance, it did show that there are variables related to the VR environment that might influence performance and psychological outcomes. In particular, these variables might exert an additive effect to further enhance the effects of exercise within a VR environment.

One variable that may increase motivation and exertion during exercise in VR environments is the presence of another individual. This is consistent with the lack of a training partner being cited as a barrier to regular exercise (Weinberg & Gould, 2015). Researchers have included other individuals in the VR environment for the aerobic exercise tasks of cycling (Anderson-Hanley, Synder, Nimon, & Arciero, 2011; Snyder, Anderson-Hanley, & Arciero, 2012), rowing (Hoffman et al., 2014), and running (Nunes et al., 2014). The effect of a competitor in the VR environment has been examined in several studies and has shown to produce performance enhancement, particularly for those who report being more competitive (Anderson-Hanley et al., 2011; Nunes et al., 2014; Snyder et al., 2012).

An example of motivational increases in the presence of non-competitive others is the Köhler motivational gain effect. The Köhler effect occurs when a less capable individual performs better in a team or coaction situation than if they were performing individually or independently (Feltz, Kerr, & Irwin, 2011). Most researchers agree that there are two mechanisms underlying the Köhler effect: upward social comparison and group/task indispensability (Kerr & Hertel, 2011). The upward social comparison mechanism states that individuals use their superior co-worker's performance as a benchmark for their own performance. The group indispensability explanation suggests that weaker members are motivated to work harder in conjunctive tasks due to the increased interdependence and the realisation that their contribution is important to the group's performance.

Feltz, Forlenza, Winn, and Kerr (2014) measured plank exercise performance while individuals viewed a prerecorded video of a human partner or computer-generated nearly human partner or hardly human partner, all of whom were said to be moderately more capable (+40%) than the participant's initial performance. Participants performed better with partners, particularly those that were more human-like. There were no significant differences among the partnered conditions in perceived exertion, enjoyment, or intention to exercise the next day. Feltz et al. interpreted the better performance in the partnered conditions as reflecting the Köhler effect. Although a strength-based exercise was used, the findings suggest that the presence of a more capable companion in a VR environment will result in better aerobic exercise performance (see also Irwin, Scorniaenchi, Kerr, Eisenmann, & Feltz, 2012).

The present study investigated the effects of different types of VR environments on the aerobic exercise task of rowing. Performance, heart rate, and affective responses were examined in three conditions: (i) an individual condition with no virtual reality (NVR), (ii) an individual virtual reality (IVR) condition, and (iii) a companion virtual reality (CVR) condition where another team-mate's boat was included in the VR environment. Participants in the CVR condition were informed that their team-mate had performed moderately better than them in a baseline row. The present design allowed for testing the hypothesis that the two VR conditions would produce better performance outcomes than the NVR condition, consistent with previous findings of performance enhancement when cycling (Plante, Aldridge, et al., 2003; Plante, Frazier, et al., 2003) and rowing (Hoffman et al., 2014) in a virtual environment. Although Hoffman et al. (2014) previously examined rowing, their study used a combination of a VR environment and an avatar of another rower to implicitly train participants to adopt “fast start” strategy. In contrast, the present study included a condition in which the VR environment did not show other rowers (IVR condition) and there was no explicit instructions regarding pacing. In addition to enhanced performance, it was hypothesised that rowing in a VR environment would increase motivation and enjoyment relative to rowing alone, consistent with prior findings of enhanced motivation (Ijsselsteijn et al., 2004), positive mood (Plante, Aldridge, et al., 2003; Plante, Frazier, et al., 2003) and enjoyment (Mestre, Ewald, & Maino, 2011) when exercising in a VR environment.

The design also allowed an examination of the additive effect of another non-competitive individual in the VR environment by comparing the CVR and IVR groups. It was hypothesised that the CVR group would show a performance enhancement due to the Köhler motivational gain effect. Irwin et al. (2012) examined the Köhler effect while participants cycled in a VR environment. In the partnered conditions, participants watched a video feed of the other participant on a different screen and performance was measured by how long participants maintained the required level of intensity during the task. In contrast, the present experiment showed the partner as an avatar within the VR environment and performance was measured by distance and power output. It was hypothesised that performance would be higher in the CVR condition than in the IVR condition, consistent with the findings of a Köhler motivational gain effect by Irwin et al. (2012). In addition, participants in CVR condition were predicted to rate the activity as more motivating than those in the IVR condition.

1. Method

1.1. Participants

Sixty-two female students with a mean age of 20.20 years ($SD = 2.73$) enrolled in a psychology course participated in exchange for partial course credit. Two participants in the CVR group were excluded and replaced because they reported a disbelief of the CVR manipulation. The remaining 60 participants were assigned to the NVR group, IVR group, or CVR group through matched assignment such that there were 20 participants in each group. Matching was based on age, body mass index and physical activity level as measured by the International Physical Activity Questionnaire – Short Form (IPAQ-SF; Craig et al., 2003). The groups did not differ significantly in mean age, BMI, Exercise Thought Questionnaire (ETQ) scores, or Exercise Benefits/Barrier Scale (EBBS) scores, all $Fs < 1$. The frequencies of the IPAQ categories were also similar across groups, Likelihood ratio = 1.26, $p = .868$. The descriptive statistics for each group are shown in the Supplementary material.

1.2. Apparatus

The experiment was completed in a 8.1 m × 2.7 m climate-controlled room set with a light intensity of 10.1 lux. Participants