Immersion in Virtual Reality Can Increase Exercise Motivation and Physical Performance

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Abstract. We present an experimental study evaluating the effectiveness of immersive virtual reality games (combined with stationary cycling) on health-related physical activity in comparison to stationary cycling with the same game in a non-immersive (2D) setting. In the experiment, participants were asked to play a cycling video game with a stationary bike either in the immersive virtual reality (3D VR) environment or in a traditional 2D (Non-VR) display setting. Based on several theories, we anticipate that users of immersive virtual reality will feel more present in the game be induced to physically performed better than when they played the same game with a traditional 2D screen. In addition, we also expect to see people who are eager to accept and use a new technology will show better cycling performance in an immersive virtual environment than people who think accepting the newest technology in a timely manner is not very important for their lives.

Keywords: Health · Exercise · Virtual reality · Biking · VR workout
VR bike

1 Introduction

Tech Used for Health

Today, computer games have been considered as a tool for health promotions [1, 2] and for actual physical activity and exercise [3, 4]. In other words, computer games can be attractive because game mechanics engage users inactivity. Video games, so players spontaneously accept them during gameplay [5]. In addition, because of characteristics of games, players have unlimited chances to repetition of messages [6] and those can be individualized based on their game performance [5].

So, games are seen as tools for both promoting healthy behavior by modeling it, and more recently by engaging in the user in actual physical behavior via more embodied physical games. A key question explored in this study is whether the technological platform of a game dramatically influences user behavior and performance. A fundamental assumption of the technology is that playing a game in a more immersive or embodied platform will make the game appear more real and lead to more physical activity. Or to put it another way as the game simulation becomes more embodied the simulated game comes closer to the actual "real" activity.

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1.1 Activity and Interactivity in Simulated Gaming

Beyond just having fun during gameplay, video games for health (exergames) engage users in physical activity by motion-based interfaces mentioned above. One of key benefits of consuming interactive media at the user's level is that game platforms engage user's physical activity or involvement more so than non-interactive media consumption such as television viewing or reading printed articles, very sedentary behavior [7, 8]. In particular, body movements or a certain part of user's body can work as an input device during interaction with media [9]. For instance, most of major video game consoles today such as Nintendo Wii, Microsoft Xbox one, and Sony PlayStation 4 have their own motion recognition sensors to capture user's body movements and use them as controls in the game. With this benefit, users not only play video games but also expect more physical activity during gameplay.

Most games simulations do not fully reproduce the physical movement associated with the real-world equivalent of the simulated games such a biking, golfing, tennis, football, etc. Some simulation or restriction of the environment or movement is involved. Depending on the platform, for example, golf might be "played" by timing the push of a button or by swinging a stick with a sensor. To put it more broadly consoles and platforms vary in the degree to which the user is immersed or embodied in the virtual environment. How much does this matter and how much does it affect performance? We turn to this variable.

2 Immersion and Embodiment: Factors that Differentiate Virtual Reality

Game consoles vary technologically in the degree to which the user is immersed and embodied. Embodiment can be broadly defined as the degree to which the body of the user is captured, represented, and inside the virtual environment. More specifically we define the level of embodiment as the degree to which: (1) the senses are immersed in the virtual environment, (2) the user's body or motor activity is sensed by the technology, and (3) there is sensorimotor integration of sensory information with bodily activity [9]. Sensory immersion is defined as the degree to which the range of sensory channel is engaged by the virtual simulation. For example, immersion of a user's vision (visual channel) is influenced by field-of-view of the image and the resolution of the imagery among other variables. For instance, for any two media platforms say from Imax, PC, to virtual reality, we can distinguish them from a purely experiential viewpoint by the level of sensory immersion and embodiment. So that when the same "content" is shown across these platforms it is level of immersion and embodiment that varies.

In this study, we will explore whether higher levels of immersion and embodiment affect the users level of presence, arousal, and physical performance. We examine to two levels of immersion and embodiment that are encapsulated in two platforms: a virtual reality system and a standard fixed screen PC system extended with additional sensors and input devices (a bike a simulator).

Previous studies have looked the effects of level of embodiment and immersion on user motivation and exercise performance. Kim et al. [10] found that increased levels of embodiment operationalized as different forms of physical input and representations of body motion increased levels of presence in the game, motivation, and some aspect of physical exercise (performance).

Avatar
Several studies have kept the platform fixed and focused on the aspect of embodiment the effect of the representation of the user's body, the avatar, in the game. The avatar is the agent inside the virtual environment, the virtual body the user controls. In the game, the avatar represents a user; if you move left, your avatar also moves left in the game. Therefore, self-representation was a key role in exergames [11]. For this reason, the effect of the avatar in the game was widely explored in the past [12, 13]. Some studies focused on the identification of avatar [14] and how much does a player get immersed into that. Even though we have created a realistic avatar that resembles you, there is an always lag of reflecting yourself because it is not you. In other words, the avatar is communicating with virtual objects for you; you are not directly interacting with them.

3 Effects of Embodiment in More Immersive Virtual Environments: What If You Feel as If You Are There Exercising?

The goal of more immersive media like virtual reality and more realistic and body responsive input devices is to make the user feel as if they are "really there" So when it comes to virtual exercise, what if the user feels as if they are actually there? If the user feels as if they are there in the virtual environment without a third-person avatar, then can they focus more on the exercise?

3.1 The Users Sense of Presence in the Virtual Environment

Presence, or the users sense of presence, is the term coined to capture the degree to which a user has a sense of 'being there' in the virtual environment, or to put it another way the user's sense that their body is located not in the physical environment but in the virtual environment [15]. Numerous studies show that the level of embodiment and immersion affects users sense of presence, or more simply that virtual reality systems, which have higher levels of body motion sensing (head movement) and increased sensory immersion (field of view) and higher levels of sensorimotor integration (head movements linked to visual flow) increase levels of presence.

We hypothesize that:

H1. An exercise game platform with a higher level of embodiment and immersion will increase the user's sense of presence in the exercise environment.

3.2 Feeling More Aroused While Exercising in the Virtual Environment

While manipulating a user's sense of "being there" or presence is often a goal of virtual reality systems, it is often assumed that higher levels of presence are related to other desirable psychological outcomes such as increased performance, enjoyment, memory, persuasion, and other effects. For example, with the content of gaming Calvert and Tan found that a greater immersion and realism in a video game would influence players' emotional state [16]. Similarly, it is assumed that a more embodied media platform such as virtual reality may influence players' level of psychological or physiological states directly or mediated by the degree to which they feel present in the environment. One component that can contribute to presence is interactivity [17, 18]. Heeter [19] suggests responsiveness is one dimension of interactivity and that a highly responsive virtual environment could induce a higher sense of presence than less responsive environments.

Arousal. Arousal is a psychological and physiological state marked by the individual's level of alertness, attention, and readiness for physical response [20]. Both exercise and virtual environments affect user arousal. Scholars suggest that technological advancement in video game realism (including graphics, sounds, and controllers) could increase not only players' presence but also their arousal [21]. Arousal can be measured in different ways: broadly by assessing physiological arousal and/or psychological arousal. Physiological arousal has been measured by body sensors that assess blood flow and muscle activation such as skin conductance, muscle movement, or heart rate. Arousal and presence are sometimes correlated [17]. Therefore, we hypothesize that:

H2. An exercise game platform with a higher level of embodiment and immersion will increase the user's arousal in the exercise environment.
H3. A user's level of presence will affect the users level of arousal in an exercise environment.

3.3 Increasing "Real" Exercise Performance in the Virtual Environment

At some point, we can suggest or theorize that increasing levels of realism and presence make the virtual exercise indistinguishable from "real" exercise or activity. Of course, no medium or game platform comes close to mapping all the sensory cues and motor activity of the simulated sport or activity in the physical world. But we can theorize that with increasing levels of embodiment that actual exercise performance should increase. Of course, it is that case that pressing a button to play golf will involve less physical performance that swinging a stick sensor. But holding the physical sensor or activity constant do other levels of embodiment affect actual physical exercise performance?

We hypothesize that:

H4. Higher levels of sensory immersion (embodiment) will lead to higher levels of physical exertion and performance in the virtual exercise environment (Fig. 1).

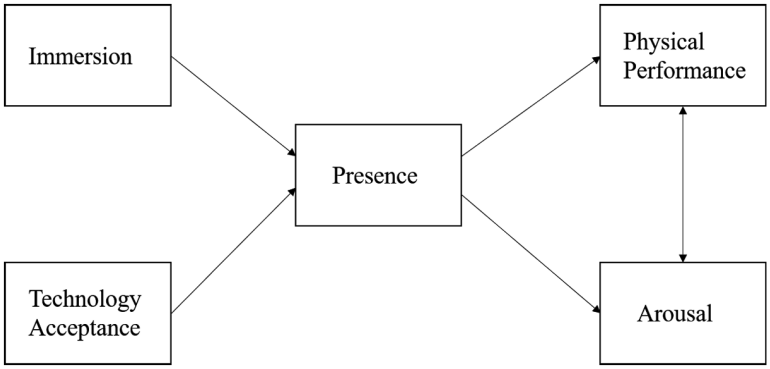


Fig. 1. Research model of the study

4 Method

We conducted an experiment to explore whether a platform with increased levels of embodiment, operationalized as virtual reality system, affected user cognition and performance. A within-subjects experiment was conducted with one independent variable, level of immersion, with two levels high immersion (virtual reality) and low immersion (a standard PC screen platform). We explored the effect on several dependent variables: user sense of presence, psychological arousal, and exercise performance. We also explored a control variable, user's individual differences in technology acceptance, as this might affect a user's comfort and interest in using a new technology.

4.1 Apparatus

Media Platforms. The independent variable was operationalized using two media platforms, an immersive virtual reality system, was used to manipulate high levels of immersion, and a standard PC platform with a fixed screen was used for low levels of immersion. On the level embodiment, the systems vary in the degree of visual immersion (VR = closed visual field and large field of view; PC open visual field and smaller field of view) and sensorimotor immersion.

(VR = head motion slaved visual feedback, PC = input sensor visual feedback only).

We controlled for input device so that the sports input device would be the same. Since current head-mounted display system for VR for a consumer market (e.g. HTC Vive or Oculus Rift) only recognizes user's movement within 10 ft. from the sensor, we used an exercise that does not need huge play area but requires enough workout intensity for a cardiovascular exercise. Therefore, we use cycling system and an input device for the experiment. The exercise bike (developed by VirZOOM) can interact with VR headsets and can be used with a simulated cyber cycling trail. In addition, the bike has a speedometer sensor sending bike's current speed into the immersive environment (See Fig. 2). We used Le Tour simulation race as the stimulus in both conditions (See Fig. 3).

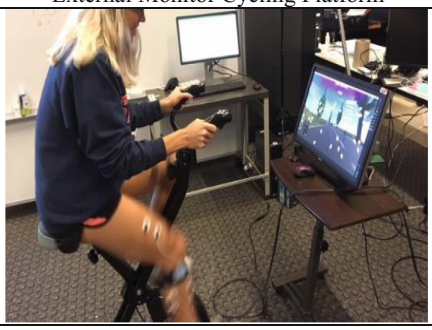
High Immersion: Virtual Reality Cycling Platform	Low Immersion: External Monitor Cycling Platform
	

Fig. 2. Experimental conditions of the study

Fig. 3. Gameplay of bike simulation, Le Tour (First-person point of view)

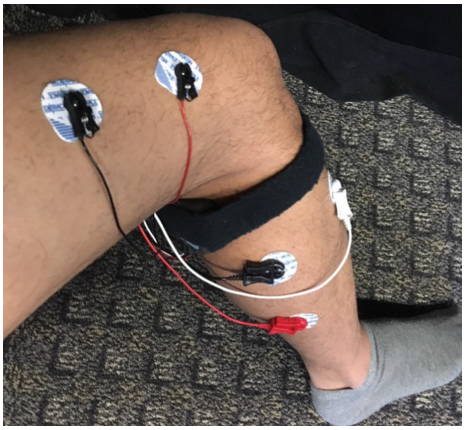


Fig. 4. Wireless EMG measurement setup for the study

Electromyography (EMG). Participants were instrumented with electromyography (EMG) to measure their physical muscle activity (Fig. 4).

4.2 Measures

Presence. Presence was measured using the ITC-SOPI questionnaire [22]. The scale includes three factors "Sense of Physical Space," "Engagement," and "Ecological Validity." Participants rated their levels of agreement using a ten-point scale, anchored by 1 (strongly disagree) to 10 (strongly agree) and a total of 12 items was used. Example items include: "I had a sense of being in the scenes displayed," "I felt that the characters and/or objects could almost touch me," and "I felt I was visiting the places in the displayed environment."

Psychological Arousal. Psychological arousal was measured using the Perceived Arousal Scale [23] which contains 24 items. Participants rated their levels of agreement using a ten-point scale, anchored by 1 (strongly disagree) to 10 (strongly agree). Example items included: "Active," "Energetic," "Exhausted," and "Inactive."

Physical Exercise Performance (by EMG). To measure participants' exercise performance, their muscle power was measured by electromyography, a physiological measurement. It was measured from two main muscles (vastus lateralis and gastrocnemius) of the leg used for cycling. Then in each condition, we found the peak and mean values of the EMG signal that is a valid EMG measurement for biking [24, 25].

4.3 Procedure

Participants were instrumented with the EMG sensors. Since each participant's muscle strength is different, we measured their baseline of muscle strength by averaging their 90 s of natural pedaling of the bike. After testing, instrumentation, and baseline measurement, they were asked to ride a bike for 10 min in each condition. The order of conditions was randomized for each participant. A rest period of 5 min was used between conditions. EMG data were collected throughout. After each condition (ride), participants completed a questionnaire assessing their level of presence and arousal.

5 Conclusion

Based on theories and concepts we discussed above, it's highly anticipated that the interactive immersive environment affects user's level of immersion and this could finally induce or dissuade his or her work performance.

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