Journal of Korea Game Society 2021 Jun; 21(3): 147-156
http://dx.doi.org/10.7583/JKGS.2021.21.3.147

기능성 게임

Does VR exergame increase a user's physical performance? : An Exploratory Study Design

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ABSTRACT

In this paper, we planned to see the positive effects of the immersive virtual environment. In particular, the positive effect of presence on physical performance was explored. A total of 25 participants were recruited for this experiment and his/her physical performance was measured by Electromyography (EMG) while they were exercising (rowing), and presence was measured by a self-reported measure. The participants were randomly assigned to experience either a) Virtual Reality (VR) or b) non-VR (2D screen) condition when they played the exergame. The result showed that 1) there was a positive relationship between representation mode and presence and 2) the higher level of presence reinforced the user's physical performance. The limitation of the study and future study were also discussed.

Keywords : Virtual Reality (VR), Exergame, Physical performance, VR exercise, Rowing

Received: May. 24. 2021 Revised: Jun. 14. 2021
Accepted: Jun. 20. 2021
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ISSN: 1598-4540 / eISSN: 2287-8211

1. Introduction

The benefits of exergaming (exercise + gaming) have been garnered a lot of attention by researchers in various fields. It has been shown that exergames have strong benefits for physical health because it induces more situational interest than a traditional fitness setup[1]. Beyond traditional forms of exercise, game mechanics of exergaming provide users a form of entertainment on their work. In addition, it engages in the user in actual physical behavior during gameplay. It was found that exergaming provided not only cardiovascular benefits[2] but also positive psychological states[3]. For this reason, computer games have been considered as a tool for health promotions[4].

Beyond a general PC gaming environment (e.g., keyboard and mouse), advanced exergames run with motion-based interfaces (e.g., PlayStation VR, Wii fit, Nintendo Ring Fit, etc.). Compared to a traditional setup of exergaming, they provide more natural gaming surroundings: especially they capture user's active physical behavior as an input source of the gameplay. Therefore, a more advanced computer environment (more embodied physical games) can engage the user's actual physical behavior that they perform in actual exercise. In other words, it can embody a game player into the actual gameplay.

Given the fact that there is a huge improvement in an input device to increase the effectiveness of exergaming, the development of the immersive representation of gameplay could not follow its speed. Recently there have been attempts to use VR technology as an exercise tool. VR can offer users a full sense of "being there" immersion if it is working in conjunction with other interactive technology and media[5].

A key question in this study is to see whether immersive representation (VR) of gameplay (environment) can increase the user's physical activity or engagement. Specifically, the study is designed to examine the user's physiological responses to an immersive VR exergame and explore any positive benefits (e.g., encourage exercising) while playing VR exergame. The goals of the study are first to use Electromyography (EMG) to measure the user's physiological performance accurately. By using EMG, we can compare the user's exercise performance between a VR and non-VR condition of exergaming.

2. Immersion in Exergaming

2.1 Basic concepts of Exergame

A lack of enjoyment is known as a challenge to a regular-based exercise habit. The concept of exergaming has two major standpoints: exercise and entertainment[6]. Exergaming can eliminate a sense of being tired or boring during exercise. It was shown that exergame play could have people focus and concentrate more on their short-term exercise compared to regular exercise[7]. Moreover, research has shown that exergame also induces acute cognitive benefits such as working memory[8], concentration[9], and mood [10].

For those reasons, exergames can be used

as a regular-based exercise tool. The benefit of game mechanics is motivational feedback such as encouraging commentaries, rewards (bonuses), and graphical or musical attractions to facilitate training and task improvement. The exergame trend public sectors' increased interest in leveraging those game mechanics as entertainment-educational cues. For instance, an exergaming has been using in physical education classes in the United States[11].

Dance Dance Revolutions (DDR) developed by Konami of Japan in 1988 was one of the successors in the early exergaming. Lots of studies found that this kind of a Dance-and-Rhythm exergame increased heart rate, "a facet of aerobic activity"[12] needed for physical fitness, and this worked for adolescents[13], young adults[14], and overweight people[15].

Similarly, Wii exergames such as Wii Sports and Wii Fit developed by Nintendo of Japan in 2006 became more popular to the public. It utilizes body movement to control the game. The unit has a motion-sensing controller, so they can enjoy sport video games such as playing golf, tennis, baseball, or boxing by controlling avatars with their physical activities. It was found that regular play of Wii exergames significantly improved user's physical balance, mobility, and decreased their depression[16].

One of the common reasons that those games have become successful is that their controllers are natural-mapped devices. The concept of natural mapping, defined by Steuer[17] as "the ability of a system to map its controls to changes in the mediated environment in a natural and predictable manner" (p.47), has been proposed as one variable of making game players have the feeling of realism in the virtual world.

Likewise, this concept can be adapted into a visual representation of the gameplay.

2.2 Immersion and Embodiment: Can immersive visual cues work in exergaming?

Immersion is a psychological state of being inside the immersive virtual environment[18]. In immersive exergaming, we can expect to see the user's higher level of immersion than traditional exergaming because they feel more like they are actually in the game. There are many factors that correlate with immersion. For instance, it was found that a large screen led to significantly higher feelings of physical and self-presence during gameplay[19]. In other words, realistic representation of the gameplay can induce a higher level of immersion.

Since the release of Wii fit on the consumer's market in 2006, many studies were exploring the effects of Wii controllers on health benefits in terms of embodiment. Instead of typing of clicking an input device, the Wii controller provided a higher embodiment in gaming. However, it had a limitation that a visual channel (e.g., display) was the same was a traditional setup. A bigger screen can increase user's immersion into the game, however what if they feel they can see the gamplay in 360 degrees?

Virtual Reality has a full sensorimotor integration of sensory information with bodily activity[20]. Comparing to the Wii game setup

discussed above, the VR disconnects real-world sensory information and provides only the gaming environment by wearing a headset. Therefore, users can be fully immersed into the game with the headset, and fully embodied with the motion-based interface. Yao and Kim[21] found that VR can increase the user's physical performance in biking by measuring their travel distances. However, there was a limitation that there was any physiological measure to support physical benefits of VR exergaming accurately. In addition, that study was focusing on the biking activity (legs), so we set up using a different exergame using the upper part of the body (arms): rowing exergame.

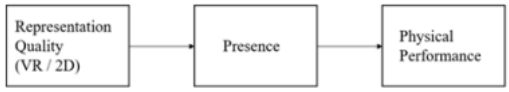
Therefore, we set up the research question here,

RQ1: Will high representation quality (VR) of gameplay significantly lead the user's higher level of immersion than the 2D gameplay in exergaming?

In our previous study[21], we found that immersion can increase users' physical performance in biking which mainly requires the bottom part (legs) of the body. In this study, we extend this concept and hypothesize the following statements:

H1: High representation quality will increase the user's sense of presence

H2: A higher level of presence will increase the user's physical performance



[Fig. 1] Research Model of the Study

3. Immersion in Exergaming

To examine these research questions, a between-subjects experiment was conducted comparing responses to a VR exergaming experience and a 2D exergaming charged experience. Physiological measurement (Electro myography, EMG) was used in this study.

3.1 Equipment

Electromyography (EMG). The user's physiological data were collected using the Biopac MP150 (Goleta, USA) device with the wireless EMG module to measure physical exercise performance by calculating degrees of muscle strength and the peak of the targeted area: arms for rowing.

[Fig. 2] EMG measurement setup
(Biopac MP150 with a wireless EMG module)

Channel configuration. One channel with two EMG sensors and one ground sensor was used in this study. Two electrodes work as positive and negative. EMG sensors were attached to the area of the biceps brachii. Rowing is known to mainly stimulate biceps

and forearms, and Electromyography is a confirmed measure to see the degree of rowing activity[22].

[Fig. 3] Configuration of EMG sensors and electrodes.

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

[Fig. 4] Experimental Conditions of the Study

3.2 Stimulus materials

VR rowing game

"Rowing on the river (ROR)" developed by D'carrick (2018) was used to test hypotheses. ROR is a VR rowing game that recognizes the user's physical motion of rowing with VR controllers. Also, the game also reflects user's rotating speed into the game with an accelerometer embedded in the controller.

[Fig. 5] Screenshot of VR rowing game, Rowing on the River (ROR)

3.3 Measurement

Presence. Presence as immersion was measured by the Temple Presence Inventory developed by Lombard, Ditton, and Weinstein[23]. The factor "Spatial Presence," that consist of seven questions such as "How much did it seem as if the objects and people you saw/heard had come to the place you were?" in a seven-point Likert scale was used to measure the level of presence. Participants rated their levels of agreement using a nine-point scale, anchored by 1 (strongly disagree) to 9 (strongly agree)

Physical Exercise Performance (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 rowing[24,25].

3.4 Procedure

A total of 25 was be recreuited for this study. Subjects were randomly assigned into two groups: One group with a VR headset and the other group with a flat computer screen (2D condition). Subjects were instrumented with the EMG sensors. Each subject was then asked to finish a demographic questionnaire regarding their age, gender and race. They had a one-minute trial session to understand controls of the game.

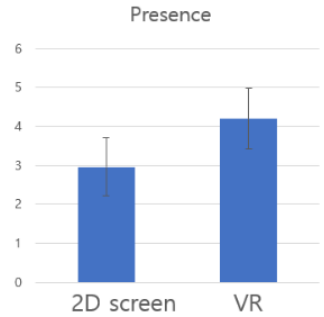
After the initial stage of the experiment, each subject was then asked to play the same

stage of VR rowing game for 10 min. They were asked to try their best. An accelerometer was attached to one of the controllers of the subject to measure the rowing cycle data based on the readout of the accelerometer. After 10 min, EMG data and the rowing cycles of each subject within the game was recorded.

After the rowing section of the experiment, subjects were asked to complete a questionnaire assessing their levels of presence, arousal, and enjoyment within the game. The subjects were then thanked and finished the experiment.

4. Result

Supporting Hypothesis 1, users using the VR headset experienced a higher level of presence (M = 4.2, SD = 1.81) than those who played using a 2D screen (M = 2.97, SD = 1.75). $F(1, 23) = 16.34$, $p < .01$, $\eta^2 = 0.42$. Participants reported significantly higher levels of presence when they played in the immersive virtual environment than when they played with a 2D screen as their viewpoint. This effect held true across the various sub-dimensions of presence.



[Fig. 6] The Level of Presence in Two Conditions

To test Hypothesis 2, we excluded 6 participants' physiological data due to an error of recorded data. Supporting Hypothesis 2, users using the VR headset used more skeletal muscles of arms (M = 0.014, SD = 0.0003) than those who played using a 2D screen (M = 0.0008, SD = 0.0005, $t=-2.456$, $p < .05$). This result showed that participants exercised more and used their muscles more naturally in the natural representation mode than the 2D representation mode.

5. Conclusion

Based on the theories and concepts we discussed above, we noticed that the interactive immersive environment affects user's level of immersion and this could finally induce or dissuade users' work physical performance. In this study model, the more natural visual cue guided the more natural work-out environment. In the VR condition, participants enjoyed rowing the paddle which was exactly synced with their arms and their work-our performance showed better than those who played the exergame in the 2D condition. Therefore, we strongly believe that this type of the immersive workout environment could enhance people's work out performance (e.g., workout at home or office room) without being other people in the same work-out place.

In addition, we strongly believe that this immersive work-out environment could contribute to other types of exercise. In this study, we only measured participants' arms to see their work out performance because the sport they played was rowing. However, we

can expect the similar result on any type of sports such as biking, dancing, or running. Moreover, players can exercise wherever they want. Beyond the immersive virtual reality, letting a player choose the place to exercise would give more fun and higher motivation to concentrate on work-out. For those reasons, we highly recommend that future exergames should contain the implication of the study.

Although we found the meaningful result from this study, it has some limitations. First, we could not collect enough number for this study. In the COVID-19 pandemic, it was very difficult to run this kind of a "face-to-face" experiment. This will be overcome when the pandemic is over.

Secondly, we could not include other factors related to presence and physical performance. Some factors such as arousal or attention are deeply related to presence[23]. In addition, other measuring method of physical performance (e.g. count rotation number) was not included in this study. Those will be added onto the future study and their relationship will be also explored for cross-validation.

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