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Enabling Physical Activity with Augmented Reality Gamification for Reducing Internet Gaming Disorder

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Abstract: This paper provides an approach that addresses the negative social awareness of games and improves psychological and mental healing effects. It has been perceived that games can lead to reduced physical activity and psychological withdrawal. However, exercise games can simultaneously provide positive aspects of gaming enjoyment and the sensations of physical activities. In this study, we aim to verify a preliminary experiment for treating game-addicted adolescents with exercise games using augmented-reality (AR) technology. In this work, 20 students (average age: 19.5, male: six; female: 14) carried out offline exercise protocols or played an experimental game called AR Earthman with HoloLens2 AR devices. Regarding the measurement tools, a survey and NIRSIT were carried out (game addiction, mood state, and motion recognition), and heart rate and motor awareness were monitored. The experimental results showed no difference in exercise effectiveness between offline and AR exercise. It was confirmed that exercise based on AR technology is effective in treating game-addicted students. The results of this study are as follows: AR exercise games increase a subject's mental pleasure, and they become satisfied with the exercise's positive effect. Rather than offline exercise, fun AR exercise games with gamification effects can be suggested as a more helpful method for teenagers. There are differences between game addiction and over-immersion in gaming, but the treatment methods are similar. Therefore, it was confirmed that applying the AR exercise protocol to students who are overly immersed in games could realize psychological and mental healing effects due to excessive immersion in games.

Keywords: augmented reality; AR; internet gaming disorder; IGD; gamification; exercise effect; PFC

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1. Introduction

As PC penetration rates and smartphone users increase in the IT era, driven by the development of IT technology and social trends, society's negative views on the Internet, mobile phones, and game addiction have become more prevalent. In particular, since the World Health Organization (WHO) decided to list 'Gaming disorder' in the revised International Classification of Diseases (ICD), the governments of more than 200 countries around the world have made gaming addiction an official disease, and it has been sorted and managed since 1 January 2022 [1–3]. Opinions are divided between those who believe that the social side effects caused by game addiction can be corrected and those who are concerned about the impact that negative perceptions of games will have on the industry.

Game addiction is a type of Internet addiction. With an increase in internet usage, we have become so dependent on smart devices that life without them has become impossible. From the moment we open our eyes until we fall asleep, we spend our daily lives with smart devices. It is difficult to imagine life without electronic devices in fields such as communication, transportation, economics, work, medicine, and engineering and in the industry.

Internet addiction is a general term that refers to cases where excessive Internet use interferes with school or daily life and causes a person or those around them to perceive that there is a problem. Internet addiction can be subdivided into game addiction and chat addiction. Gaming addiction is an excessive obsession with games that causes physiological dependence [4–6]. Prolonged game use increases the time it takes to achieve the same level of satisfaction, and a pause in playing can suddenly lead to withdrawal symptoms, such as anxiety and nervousness, making it even more dangerous [7]. It reduces academic performance, affects family and interpersonal relationships, and affects daily life. It has a negative impact not only on your daily life but also on your health. Increased time spent playing games due to focus and competitiveness can lead to a variety of side effects, including sleep deprivation due to reduced physical activity [5], loss of appetite, and interpersonal problems due to prioritizing the virtual world over the real world. Despite being aware of these problems, it is easy to become addicted because you can feel vicarious satisfaction through a game character that represents you [7,8]. In particular, the reason people become addicted to games is because games provide cheap pleasure and a sense of accomplishment to the central nervous system. While it takes a lot of time and effort to achieve something in real life, games are solved within a short period of time from start to finish. Because of these characteristics, teenagers easily become addicted to games. In addition, it is becoming increasingly difficult to break away from gaming addictions because games provide a variety of interests that encourage an influx of game users [9,10].

In this context, the problems of gaming disorder are emerging as a social issue. In particular, the immersion of young people (aged 9 to 24) in games results in people's negative perception of the game industry, and concerns about side effects related to crime are also emerging. As a way to solve these problems and improve Internet game disorder (IGD), exercise prescriptions are being introduced based on the results of research that report that medium-to-low-intensity aerobic exercise is suitable. However, a patient's continuous exercise treatment is difficult, and due to the nature of IGD, the problem of concentration deterioration occurs. To address this problem, exercise content, such as games that arouse interest, is required [3]. In particular, a necessity for augmented reality (AR)-based exercise content for combating IGD has arisen [11,12].

In order to stimulate interest and require game-like concentration, a computer-based game, rather than a typical exercise game, is needed. However, PC-based games cannot realize brain changes through exercise even if a joystick is used. Therefore, AR exercise games that combine reality and virtuality comprise suitable content for people who are familiar with games. However, as a preliminary experiment to check whether the corresponding movements are suitable for the AR exercise game, movements suitable for virtual reality (VR) exercise games must be extracted.

As a result of producing a pilot exercise game based on a VR environment and conducting preliminary experiments, offline exercise performed with the body and without equipment and VR exercise games showed the same exercise effect [13]. Exercise games using VR are interesting, but because there is no view of real space when more movement and exercise are carried out, the risk of injury is higher. Therefore, the need for AR-based exercise content to combat IGD has emerged [12].

AR technology refers to a situation where virtual objects are superimposed onto reality, and this reality is viewed while wearing a HoloLens2 headset equipped with holographic technology. AR exercise content is designed to allow users to exercise while wearing AR technology equipment; users directly interact with virtual objects overlaid on reality. It is still greatly affected by lighting, and there are technical limitations that prevent virtual objects from being 100% completely fixed. In addition, since it is necessary to check whether the AR exercise content is effective before diversifying the movements, the movements must be simplified to extract movements suitable for low- to medium-intensity aerobic exercise that causes users to slightly sweat.

The medical community, especially psychiatric clinics, has attempted to use gaming in physical activity as a way to treat excessive gaming problems. A recent research trend is to use VR content as a treatment tool, but there is not much research on treating gaming addiction using AR. In this paper, considering the above matters, we conducted a preliminary experiment to plan, design, and treat AR exercise content for patients with Internet Gaming Disorder.

2. Related Work

The following treatment methods are used to treat IGD problems: There are pharmacological treatments, Cognitive Behavioral Therapy (CBT) treatments, randomized control trial (RCT) treatments, family-based treatments, and many other approaches [11]. Typically, doctors and researchers try a variety of approaches to discover treatments that can lead to effective interventions to address these problems. CBT therapy is often used as a first-line treatment for IGD.

However, it is hard to obtain treatment effects in the short term, and it is difficult to sustain treatment in the long term. So, we focus on long-term treatment effects rather than short-term effects. Therapy for this disorder may also improve IGD symptoms and comorbid depression.

Gaming addiction is due to exposure to stimulating media or games. So, patients need motivation that has a stimulating effect similar to the gamification effect. An online, prosocial game that incorporated a CBT protocol was as effective as an offline CBT intervention in ASD adolescents [12].

Digital therapeutic takes a new direction in the field of healthcare [14]. The role of digital therapeutic is to provide patients with new treatment options for unmet medical needs and to work independently. The value of games is important, especially in IGD patients. Gamification is achieved by applying various game mechanics such as social elements, experiential learning, competition, challenging goals, positive and negative feedback, and other elements that make up a game, or utilizing people's natural desires for the gameplay situation [14,15]. The most basic gamification strategy is to provide rewards in various forms including points or next levels to users who complete a mission. From business training to school activities, gaming has gradually found a place over time. Particularly in the medical field, the number has begun to explode [11,12].

A meta-analysis was conducted to investigate the correlation between gaming motivation and various elements of IGD based on several databases between 2002 and 2020. The results of the study showed that IGD had a stronger association with achievement motivation (r = 0.32) than with flow (r = 0.22) or social motivation (r = 0.20). The strongest association appeared to be escape motivation (r = 0.40), which is a subcomponent of flow motivation. As a result, it was shown motivation of the game and the strength of the association were interrelated, and various components of gaming motivation in one can impact the others confirmed in relation to the role of gaming motivation [15,16].

3. Materials and Methods

We formed an experimental group (AR-based exercise) and a control group (offline exercise) and asserted the similarity between the AR and offline groups when performing similar exercises. The study procedure followed the Declaration of Helsinki and was approved by the Institutional Review Board of Chung–Ang University approved this research protocol (1041078–20230214–HR–033). The participants were informed of the aims of this study and the procedure and were allowed to ask questions. Written informed consent was obtained from all participants.

3.1. Physical Activity Contents (Offline Control Group)

3.1.1. Design

We designed an exercise protocol that resulted in the participants being slightly out of breath even in AR exercise contents, and based on the research results, offline low- and medium-intensity aerobic exercise was effective. We designed a gamified exercise protocol in which users can earn points by touching and removing or avoiding obstacles [17].

It is augmented-reality gamification content that creates a virtual space half the size of an indoor gymnasium (approximately 13 m by 13 m).

This AR content contains low- to medium-intensity aerobic movement that maintains medium-intensity exercise. The configuration of movements mixes four movements including tapping, avoiding obstacles, jumping, and bending at a light running speed of about 7 km per hour for about 10 to 15 min. We classified and divided it into upper and lower body. The upper body performs a tapping motion using the right and left hands, and the lower body moves at a jogging speed using the legs. When the intention is to use the upper and lower body together, the user follows advanced dodge movements (jump and tap, duck to dodge, dodge to the right, dodge to the left).

Participants wore a polar device on their hearts over bare skin for measurement. First, the participants took a rest for 1–2 min to reach a stable heartbeat. Then, the control groups followed a 'pace–maker' who demonstrated the movement. The pacemaker moves similarly to an AR player. To avoid the obstacles in the AR content and execute the movement to be taken, they perform the same exercise accordingly.

3.1.2. Method

The full-body movements that showed the greatest effect of exercise were selected after conducting preliminary research, and exercise intensity was classified according to simplicity, degree of exercise, and running speed. We tested a prototype before designing the actual study, where we examined whether the exercises caused sweating. We found that mixing the four movements of tapping, dodging, jumping, and ducking was the easiest to learn when completing repetitive low- to medium-intensity exercises. In addition, the same results could be obtained even if the order of the exercises was changed, such as running and jumping, bending down, and running and then jumping.

Therefore, it consisted of 4 movements make 6 movements, as described below:

1. One-handed tapping: Stretching forward and tapping with one hand (right/left).
2. Tapping with both hands: Stretching forward and tapping with both hands.
3. Cross-tapping: Performing a tap gesture with one hand and the other hand (e.g., tapping with right hand → left hand or opposite side).
4. Dodge down by bending: Keep walking and bend the knees with a little bow.
5. Jumping: Keep walking while jumping.
6. Move diagonally to the bottom sides: Keep moving forward and diagonally to the bottom right/left sides.

These 6 movements were classified into 9 movements as listed in Table 1.

Table 1. Tapping and avoid gestures are categorized into 9 movements below.

Abbreviation: Name of Movements	Explanation of Movements
TL: tapping left	Stretching and tapping with the left hand
TC: tapping center	Stretching and tapping with both hands
TR: tapping right	Stretching and tapping with the right hand
BL: barrier left	Dodge to the right
BR: barrier right	Dodge to the left
BD: barrier down	Dodge up by jumping
BU: barrier up	Dodge down by bending
DL: diagonal left	Move diagonally to the bottom right
DR: diagonal right	Move diagonally to the bottom left

Figure 1 shows a scene demonstrating jump tapping. Infront of the subject, the pacemaker shows the movements. After that, the subject follows the same gesture.

3.2. Physical Activity Contents (Online Experimental Group: AR Exercise Group)

3.2.1. Design

We designed a game where in real life, when user wears an AR device, they run forward and break or avoid obstacles. Interacting with a virtual object involves performing specified actions. The experimental space is a large indoor physical environment, such as an indoor gym or indoor playground. We designed the method below so that users can perform the same exercise as the offline users.

Figure 1. An example of the offline version with a pacemaker, jumping, and tapping left (TL).

3.2.2. Method

There are three types of obstacles, and the users perform nine actions in each stage. When the user presses the start button in front of the field of view, the holographic sensor records the vector coordinates of the headset's position.

Then, sensors in the user's HoloLens headset calculate whether or not there is a collision with an obstacle. It then calculates a success or failure score based on the user's play. A jump is considered a jump if the user rises more than 15 cm from the headset position in a vertical position. There are 9 operations, as listed in Table 2.

Table 2. Description of the three types of obstacles and how the nine movements work.

Abbreviation: Defined Movements	Explanations of Movements
TL: tapping left	Stretching and tapping with the left hand
TC: tapping center	Tap the moving meteorite in the center with both hands
TR: tapping right	Stretching and tapping with the right hand
BL: barrier left	Dodge to the right
BR: barrier right	Dodge to the left
BD: barrier down	Jump over the obstacles on the floor
BU: barrier up	Dodge down by bending
DL: diagonal left	Move diagonally to the bottom right
DR: diagonal right	Move diagonally to the bottom left

Figure 2 shows screenshots of scenes from the HoloLens2 device. When the user wears AR glasses, they can see these objects: (a) tapping center: the user needs to tap the meteorite approaching the center with both hands to destroy it; (b) barrier left/right: if the alien comes from the right side, the user needs to move left to avoid it; if the alien comes from the left side, the user needs to move right to dodge to the left; (c) barrier down: when a meteorite appears, the user must jump to pass it; (d) barrier up: when a spaceship appears, the user needs to dodge down by bending their knees like a frog; (e) and (f) diagonal left and diagonal right: when a satellite appears, the user needs to follow the arrow symbols by moving forward and twisting their body to the opposite side.

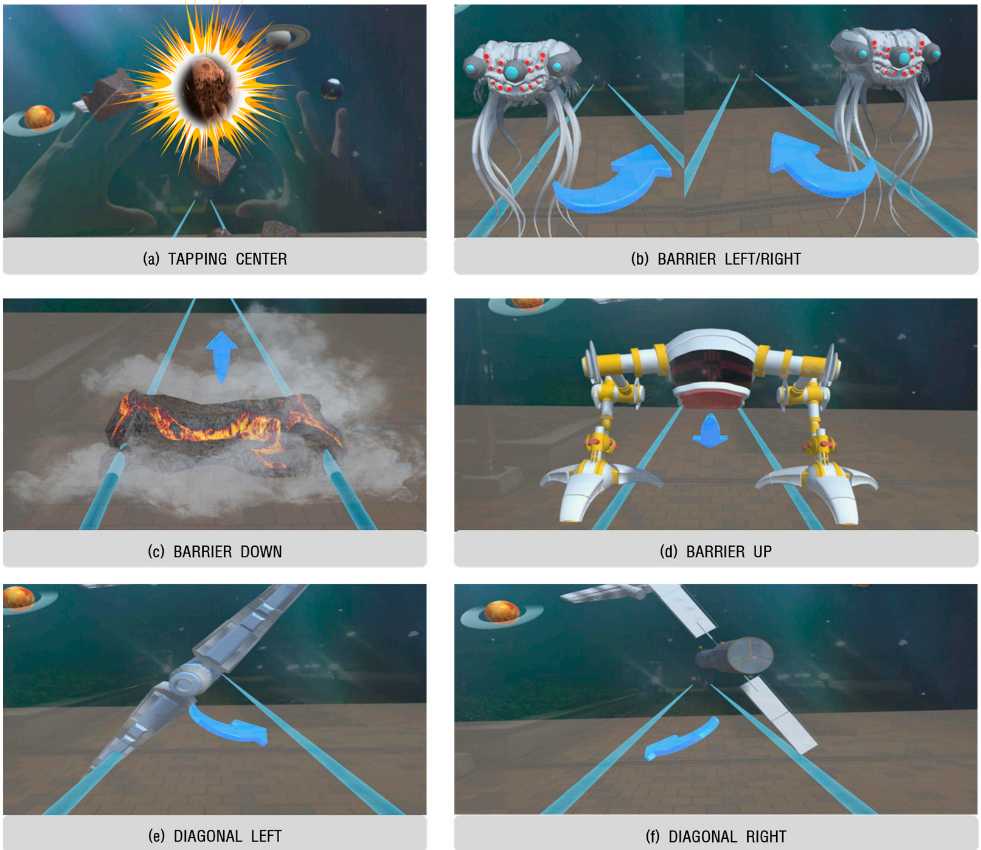

Figure 2. The in-game view of the AR exercise game called 'Earthman'. (**a**) Tapping the center of an obstacle flying toward the user's torso (center) with the hand. (**b**) Avoiding left and right obstacles by moving in the same direction as the arrow to avoid the obstacles. (**c**) Jumping to avoid hitting obstacles. (**d**) Avoiding obstacles by bending or lowering the head and torso to avoid touching the obstacle. (**e**) Leaning slightly to avoid diagonal left obstacles. (**f**) Leaning slightly to avoid a right diagonal and dodge in the direction of the arrow.

Figure 3 shows an environment where 3D objects are expressed as reality and holograms, which are visible when wearing AR glasses. This object is a spaceship that appears when the researcher sets an obstacle in the barrier. Points are awarded for successful tasks, such as avoiding or destroying obstacles. These scores are added up in real-time, and the total score is displayed on the left side of the screen. If the user cannot avoid or destroy it, points are deducted. When the user passes an obstacle, additional points are awarded depending on the number of combos and successes. Additionally, the time taken for each stage is displayed on the right side of the screen, and when each stage is completed, it is reflected in the total score, and the time is reset.

3.3. Measurement Tool Settings

3.3.1. Sample Size

The sample size was calculated using G*power software 3.1 (Heinrich–Heine–Universität Düsseldorf) [18] based on a statistical test using repeated measures ANOVA. A type 1 error of 0.05 and a statistical power of 0.9 were used. The correlation among repeated measures was set conservatively at 0. Based on previous similar studies, an effect size of 0.25 was estimated. Based on these calculations, 14 participants were required. After estimating a 10% dropout rate, we set a sample size that required 16 participants. As many participants were interested in our research, the required total sample size was set at 20 participants. During the experiment, all participants were instructed to refrain from intensive exercise and received monetary compensation at the end of the experiment for the time and effort they provided.

Twenty participants were divided into ten and assigned to an experimental group and a control group. We used a between-subjects design in which different participants receive different levels of treatment.

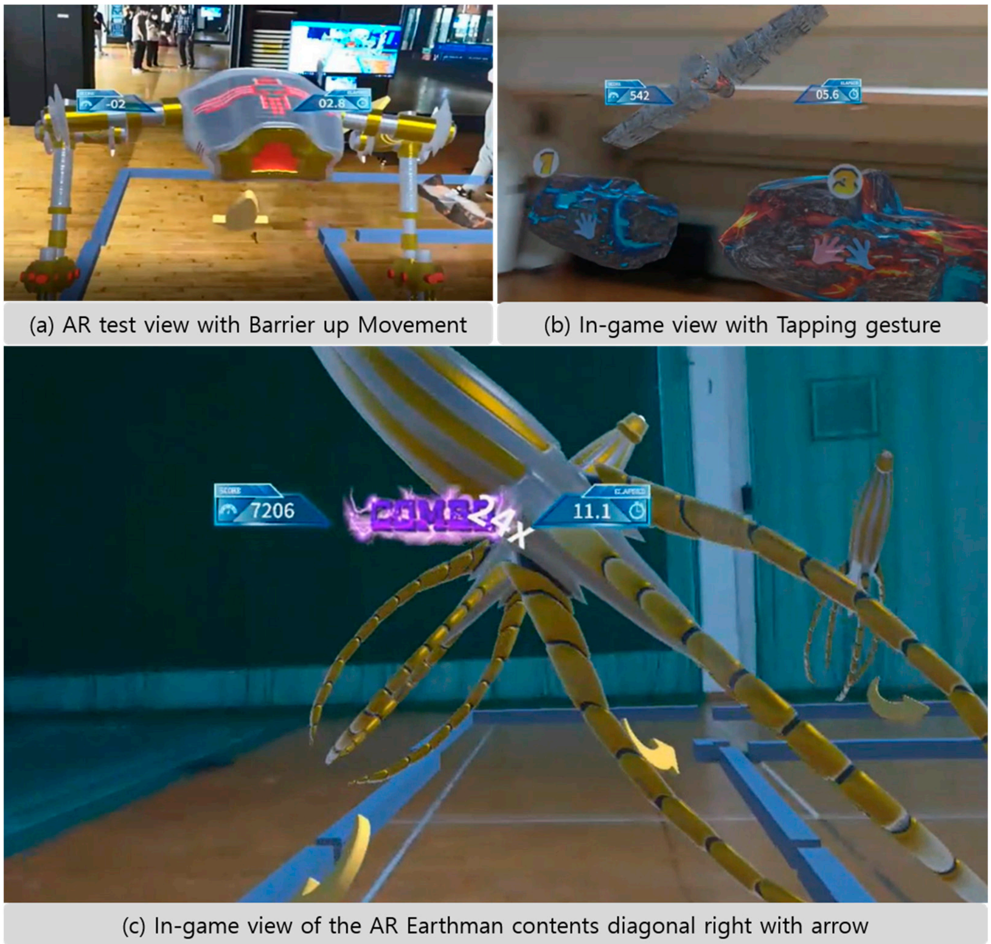

Figure 3. The in-game view of the AR exercise game called 'Earthman' as seen by a user wearing AR glasses. (**a**) AR earthman prototype test scene. (**b**) A scene where the user removes obstacles by tapping them in order according to commands. (**c**) In-game scene via HoloLens2, with scores on the left and elapsed time on the right.

3.3.2. Survey

1. The Internet Game Addiction and Over-engagement Scale (IGAOS)

We recruited college student subjects without psychological or physical limitations who liked games and were interested in AR physical activities using online and offline flyer advertisements. Among the recruited people, we selected 39 people by conducting a pre-test of the Internet Game Addiction and Over-engagement Scale (IGAOS) using an online Google survey that Shin, Y.M. and Park, K.H [19–21] made. It is one of the self-report questionnaires that is easy to complete. We selected a total of 20 people in order of their highest IGAOS scores.

First, we chose to measure the IGD score, a questionnaire technique for measuring the degree of IGD was used. It consisted of a total of 21 questions in 7 sub-factors: withdrawal, tolerance, daily life problems, control failure, mood swings, physical–emotional problems, and virtual world orientation [20–22]. Participants rate the degree to which they believe they are consistent with themselves regarding the use of Internet games on a 5-point Likert scale, with higher scores indicating a higher degree of agreement [22,23]. Cronbach's α = 0.94 for all questions. We selected twenty subjects with high scores and divided them into a comparison group and a control group, and then the experiment was conducted. The average score for each subject was 60.6 points out of 100.

Wearing an AR headset may cause VR sickness and dizziness, making it difficult to conduct experiments. To prevent this in advance, as part of the survey, we conducted telephone interviews with 22 people to check whether they had VR sickness or discomfort. We excluded two women participants, one with VR motion sickness and one with car sickness because car sickness and VR sickness have similar reasons and symptoms. Finally, we set 20 people and randomly divided them into a comparison group and a control group, each with 10 participants.

As a next step, we asked the participants to perform pre-validation and post-validation questionnaires, which allowed us to measure their mood and current status related to exercise.

2. Mood state (K–POMS–B)

The Korean version of the Profile of Mood States–Brief (K–POMS–B) [24], a Korean version of the Profile of Mood States–Brief (POMS–B) [25], was used. It is a 30-item shortened scale with a 5-point Likert Scale consisting of tension, depression, anger, vigor, fatigue, and confusion.

The score is calculated by adding the scores of negative emotional factors (tension, depression, fatigue, anger, and confusion) and subtracting the vitality score of positive emotional factors, which is called the Total Mood Disturbance score (TMD). A higher score means a higher total mood disorder score. The reliability is Cronbach's α = 0.59~0.85.

3. Exercise intensity measurement (Heart Rate)

The average resting heart rate of adults is about 60–80 beats/min, and the heart rate increases as activity intensity increases. Therefore, exercise intensity was interpreted using heart rate changes according to physical activity. We measured the participants' heart rate with a polar device. We predicted heart rate and exercise intensity without any additional equipment or tools.

Very light activity: maximum heart rate < 50%, light activity: 50–63%, moderate activity: 64–76%, hard activity: 77–93%, very hard activity: $\geq$94%. The following were used in this study, low–medium intensity: RPE 6~12, medium–high intensity: RPE 13~15, maximum intensity: RPE 16~20.

4. Rating of Perceived Exertion

The Rating of Perceived Exertion (RPE) was used as a questionnaire to measure the participants' exercise awareness level [26,27]. It is a scale that subjectively rates how you feel about your body status. You can predict your current heart rate and interpret exercise intensity by multiplying the RPE score by 10 [28].

3.3.3. Hemodynamic Changes in the Prefrontal Cortex Measurement Device: NIRSIT

The validity of the designed study was confirmed using qualitative research methods, experimental data analyses, and heart rate measurements. However, the reliability of this study was secured by additionally confirming hemodynamic changes in the prefrontal cortex related to actual game addiction and overindulgence [29,30].

Hemodynamic changes within the prefrontal cortex were assessed using a high-density functional near-infrared spectroscopy (fNIRS) device, NIRSIT (OBELAB) [31,32]. NIRSIT's curved panel has 24 laser diodes (sources) that emit light at two wavelengths (780 nm and 850 nm) and 32 photodetectors with a sampling rate of 8.138 Hz. The unit distance between the light source and the photodetector was 15 mm. In this study, only the 30 mm channel was analyzed because 30 mm is the most appropriate sensor–detector separation distance for measuring cortical hemodynamic changes.

Hemoglobin combined with oxygen is called oxyhemoglobin (HbO_2). An infrared camera captures oxidized hemoglobin and measures its increase or decline amount. The more blood flow, the more active the area becomes. The Beer–Lambert law is commonly applied to chemical analysis measurements to determine the concentration of chemical species that absorb light [33]. The Bouguer–Lambert law is an empirical law that relates the extinction or attenuation of light to the properties of the material through which the light is traveling in physics.

The extinction law is also used to understand attenuation in physical optics, for photons, neutrons, or rarefied gases. The modified Beer–Lambert law (MBLL) is the basis of continuous-wave near-infrared tissue spectroscopy (cwNIRS) [33,34]. The differential form of MBLL (dMBLL) states that a change in light attenuation is proportional to changes in the concentrations of tissue chromophores, mainly oxy- and deoxyhemoglobin. If attenuation changes are measured at two or more wavelengths, concentration changes can be calculated. The dMBLL is based on two assumptions: (1) the absorption of the tissue changes homogeneously and (2) the scattering loss is constant. An analytically treatable special case (semi-infinite, homogeneous medium with optical properties of the cerebral cortex) was utilized here to estimate its order of magnitude [31].

3.3.4. Heart Rate Measurement Device: Polar H10

The participants wore a polar device on their hearts over bare skin. This device helped to obtain more exact heartbeat data. First, the participants took a rest for 1–2 min to reach a stable state. Then, the control groups followed the 'pacemaker' who demonstrated the movement. The pacemaker moves similarly to the AR participants. To avoid the obstacles in the AR content and execute the movement to be taken, they perform the same exercise accordingly.

Heart rate was measured using a wireless heart rate monitor device (Polar H10 [35,36]). The device measures heart rate using a sensor and transmits the signal to a mobile phone. A decrease in the heart rate means that the heart has become more efficient. Normally, the heart rate of people who exercise less is higher than regular exercisers.

This study examined the effects of exercise with measurements of resting heart rate, average heart rate during exercise, and maximum heart rate. The collected data were transferred to a mobile device through the Polar Beat application and measured manually.

3.3.5. Measure Process

The measuring process is shown in Figure 4.

3.4. Test Environments

3.4.1. Augmented Reality Device: HoloLens2

A variety of AR equipment exists to build an AR environment.

Among them are Nreal Light (Nreal) and HoloLens2 (Microsoft), which are suitable for development environments. Nreal is lightweight because it is worn on the head for exercises such as running or jumping. HoloLens2 is heavy but high-precision with hand tracking, eye tracking, spatial mapping, and a wide field of view so you can focus on your work without errors. We tested both devices and checked the following:

1. Mirroring function is needed: Testing required verifying that objects would appear properly as holograms to the user and that they would interact correctly when performing their actions in real-time.
2. It can be worn for more than 10 min: The subjects were required to jump and bend while jogging with the equipment on. In situations where they are out of breath or sweaty, they must interact with objects that appear as holograms. The actual location

of the hologram and the location coordinates of objects within the preset AR space may differ during gameplay. This can result in incorrect moves or affect the game score.

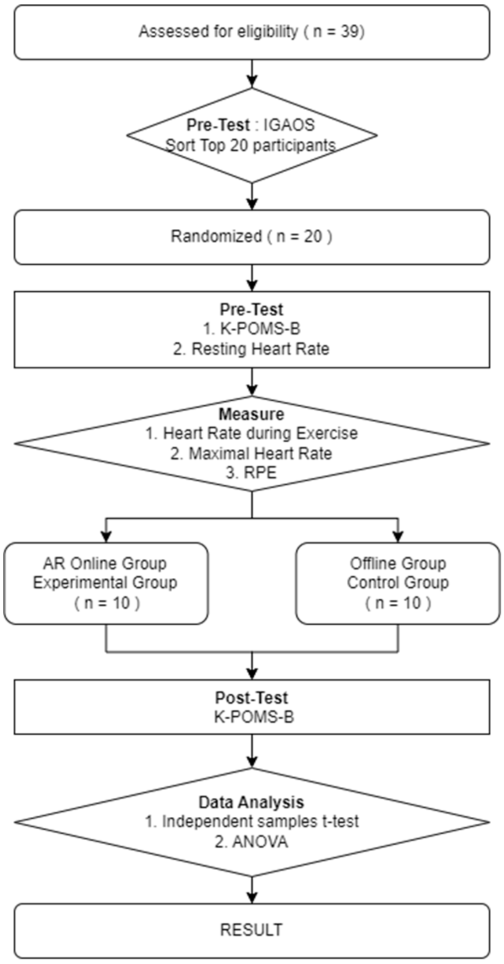

Figure 4. A flow chart of the measuring and testing process.

The advantage and disadvantage of the Nreal development environment was that it could be played on mobile phones using Nebula. Nreal and your phone have a wired connection. In other words, it was judged to be more suitable for static experiments than dynamic exercise because the mobile phone had to be moved while holding it in the hand or attached to the body. Although it was lighter than HoloLens2, it was difficult to jump and run at the same time.

Because HoloLens2 needs to communicate continuously, it consumes a lot of battery power and has the disadvantages of being heavier than Nreal and causing sweating in the area that touches the forehead. However, for the above reasons, HoloLens2 was finally selected as the AR equipment using a pilot test and purchased with funds to support this research. HoloLens2 is owned by the Chung–Ang University Sports Research Institute.

3.4.2. 'AR Earthman' Software (09.12.2022 Ver)

'AR Earthman' is an application that we made for use wearing HoloLens2. It allows you to move along a set path and avoid or destroy obstacles. The concept of this software is to save the earth and obtain high scores similar to Superman. You can create maps in this software and insert up to 12 obstacles in each turn. A total of 9 obstacles are recommended, and the user's HoloLens2 headset position is calculated to determine whether or not a collision occurs with the obstacle. A jump is considered a jump if the headset rises more than 15 cm from the headset position in a vertical position. There is a scoreboard in front that is a little higher than the line of sight, which shows the total score, time elapsed, continuous success (COMBO), total success, and failure, as shown below in Figure 5.

Figure 5. This is a figure of the first scene in the AR Earthman Game when a player is wearing Hololens2.

We designed this application and added the interaction between the created objects and implementations using research funds. This software is owned by the University and Sports Convergence Research Institute and is available for use in research.

4. Results

Repeated measures analysis of variance (RM ANOVA) was conducted to compare changes in mood state and immersion experience, heart rate, and perceived exercise level between the groups according to participation in the physical activity program. Regardless of RM ANOVA, Box's equality of variances was tested (F = 1.220, $p = 0.301$), and Levene's equality of variances and Shapiro–Wilk's qualification test all made the basic assumption ($p > 0.05$). Statistical analyses were performed using SPSS software (version 28.0; IBM Corp, Armonk, NY, USA).

Differences between experimental and control groups are typically determined using an independent samples *t*-test. However, if the number of samples is small (less than 30), it is difficult to draw accurate conclusions using the difference in means. Methods used in statistical analyses when samples are small are called nonparametric methods, such as the classic Mann–Whitney U-test.

The Man–Whitney U-test uses a rank sum test to compare differences between two groups. It was used to determine whether there was a statistical difference between offline exercise (comparison group) and AR exercise (control group).

According to test statistics, the Mann–Whitney U-Test showed that there was a significant difference in the average heart rate during exercise (0.043) < 0.05, but in the remaining items, there was no significant difference with *p*-value > 0.05 between the two groups. In other words, there was no difference between the two exercises.

4.1. Statistical Analysis

4.1.1. Internet Game Addiction and Over-Engagement Scale (IGAOS)

The average score of the experimental group was 55.7 points, and the average score of the comparison group was 65.5. The plot graph showing the average score of the IGAOS survey results for both groups is provided in Figure 6. In order to compare and analyze the means between the experimental group and the control group, we conducted an independent samples *t*-test to verify the difference in the means of the other two groups. Using Levene's test for equal variances, the significance probability was 0.28, so equal variances were assumed. In other words, the average difference between the AR and offline exercise methods of the two groups was not significant.

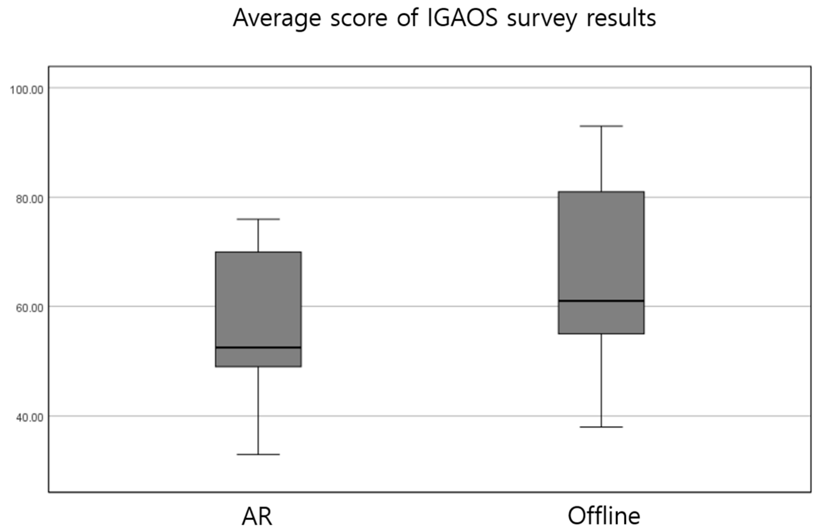

Figure 6. This graph represents the average score of the IGAOS survey results of the experimental and control groups.

4.1.2. RM ANOVA on the Mood State (K–POMS–B)

As a result of the RM ANOVA, the normality test of mood was satisfied ($p < 0.05$). Both the AR and offline groups were found to have significant differences according to the pre-test and post-test. There was a statistically significant decrease in all negative mood factors in both groups. In the control group, scores for anger, anxiety, despair, depression, and recovery were higher than before, and the scores increased due to positive factors. The scores of the AR group were similar to those of the offline group, but the scores of positive factors were not very large.

However, the partial eta squared value in effect size was higher than (ES > 0.14) on average. Tension was 0.301, anger was 0.347, fatigue was 0.328, depression was 0.415, and confusion was 0.331, which were significantly higher than ($\eta_p^2 > 0.14$). In other words, it can be seen that the effect of each variable on the dependent variable increased. Vigor was 0.135, which is close to 0.14, so it can be considered large. It was confirmed that AR-based physical activity games can reduce negative psychological factors such as anxiety, anger, depression, confusion, and fatigue at a similar level to offline physical activity, as shown in Table 3.

4.1.3. *t*-Test on Heart Rate

We performed an independent samples *t*-test on the variables including resting heart rate, average heart rate during exercise, maximum heart rate, and perceived exercise. The offline group showed a higher average heart rate during exercise than the AR group, and there was no difference between the groups in resting heart rate and maximum heart rate. There was no difference between the groups in terms of perceived exercise, and both groups perceived the physical activity program as being at a medium- to high-intensity level, which is equivalent to 'slightly difficult'.

Table 3. The results of the RM ANOVA for mood states.

Variable	Group	N	Pre	Post	Source	*F*	*p*	ES (η_p^2)
Tension	AR	10	9.3 ± 2.98	7.4 ± 2.45	Time (T)	7.744	0.012	0.301
					Group (G)	1.034	0.323	0.054
	Offline	10	8.5 ± 3.68	6.2 ± 1.47	TxG	0.070	0.794	0.004
Anger	AR	10	7.2 ± 1.93	5.8 ± 1.54	Time (T)	9.578	0.006	0.347
					Group (G)	0.232	0.636	0.013
	Offline	10	6.8 ± 2.69	5.5 ± 0.97	TxG	0.013	0.910	0.001
Fatigue	AR	10	10.9 ± 3.07	9.1 ± 2.28	Time (T)	8.769	0.008	0.328
					Group (G)	1.560	0.228	0.080
	Offline	10	9.3 ± 4.57	7.4 ± 2.67	TxG	0.006	0.937	0.000
Depression	AR	10	6.8 ± 1.03	5.0 ± 0.00	Time (T)	12.789	0.002	0.415
					Group (G)	0.272	0.609	0.015
	Offline	10	7.2 ± 3.85	5.4 ± 0.96	TxG	0.000	1.000	0.000
Vigor	AR	10	14.8 ± 3.79	15.5 ± 4.30	Time (T)	2.805	0.111	0.135
					Group (G)	0.321	0.578	0.018
	Offline	10	14.9 ± 5.21	17.4 ± 4.52	TxG	0.887	0.359	0.047
Confusion	AR	10	10.4 ± 2.17	8.8 ± 1.61	Time (T)	8.926	0.008	0.331
					Group (G)	1.960	0.179	0.098
	Offline	10	9.3 ± 2.83	7.8 ± 1.13	TxG	0.009	0.924	0.001

Table 4 shows the heart rate and RPE results. The average resting heart rate of the experimental group was 75.2 beats per minute (bpm), and the resting heart rate of stable adults over 20 years of age is usually 60 bpm to 100 bpm. The average resting heart rate of the comparison group was 79.7 bpm, which was higher than that of the experimental group. There was no gender difference between the two groups. The average heart rate during exercise of the experimental group was 113.25 bpm, which was slightly lower than the comparison group at 128.8 bpm. The maximum heart rate during exercise was 150.4 bpm in the experimental group, and in the comparison group, it was 154.6 bpm.

Table 4. The results of the independence samples *t*-test for heart rate and RPE.

Variable	Group	N	M ± SD	T	*p*
Resting heart rate	AR Offline	10 10	75.2 ± 7.55 79.7 ± 9.11	−1.202	0.245
Heart rate during exercise	AR Offline	10 10	113.2 ± 15.03 128.8 ± 16.23	−2.222	0.039 *
Maximal heart rate	AR Offline	10 10	150.4 ± 16.58 154.6 ± 15.55	−0.584	0.566
Rating of perceived exertion	AR Offline	10 10	12.9 ± 1.37 12.8 ± 1.81	0.139	0.891

* $p < 0.05$.

For people in their 20s, the maximum heart rate is 200 beats, and an exercise that makes you slightly out of breath is 60% of the maximum heart rate or 120 beats. Moderate intensity is 64–76% of the maximum heart rate, and the average age of participants was 19.5 years old, similar to a 20-year-old. Based on the maximum heart rate of 200 bpm during exercise, the maximum heart rate of the experimental group was 150.4 bpm (75.2%), which corresponds to moderate-intensity exercise. The average maximum heart rate of the comparison group was 154.6 bpm, which is 77.3% of the maximum heart rate, corresponding to hard activity exercise. This is 1.3% higher than the medium intensity standard of 76%. And p value of heart rate during exercise is ($p < 0.05$).

4.1.4. The Rating of Perceived Exertion Index (RPE)

A one-way analysis of variance was performed to compare the AR and offline groups. The null hypothesis is that both AR and offline scores are similar. If the significance confirmation rate is $p > 0.05$, the variance is equal. However, there are items with $p < 0.05$, so it can be assumed that the effects of AR and offline exercise are the same. Figure 7 shows a graph comparing the RPE scores of the two groups. The average RPE score of the AR group was 12.9 points, and the average RPE score of the offline group was 12.8 points. However, the differences were 1.37 and 1.81, respectively. In the case of the AR group, the standard deviation was small, so the accuracy of the values can be considered higher.

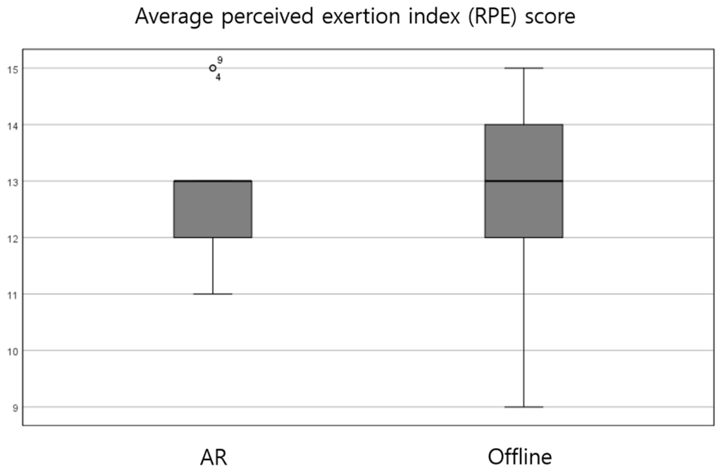

Figure 7. This graph shows the average score of the RPE of the experimental (AR) and control (offline) groups.

4.1.5. Degree of Activation of the Prefrontal Cortex

The NIRSIT instrument was used to determine the level of activation in the prefrontal cortex. Figure 8 shows the average blood flow change before and after cerebral blood flow measurements for all participants [37].

Blood flow changes from blue to yellow to red, and the more the prefrontal cortex is activated, the closer it turns to red, as shown in Figure 8. Functional brain magnetic resonance imaging (fMRI) is increasingly being used because it has good spatial resolution, has no risk of radiation, and has the advantage of being able to obtain images repeatedly. fMRI refers to imaging activated parts of the brain using the blood oxygen level-dependent (BOLD) method. It is based on local hemodynamic changes that occur following neural activation in a region of the brain.

Functional brain imaging research methods, including fMRI, have made it possible to visualize the brain neural network responsible for high-level cognitive functions such as language, memory, and concentration. Most researchers use this method to identify neural regions that act on emotion and motivation. Cerebral blood flow becomes increasingly active in the following order: dark blue, light blue, yellow, orange, and red. For example, blood flow in the prefrontal lobe becomes more vivid red.

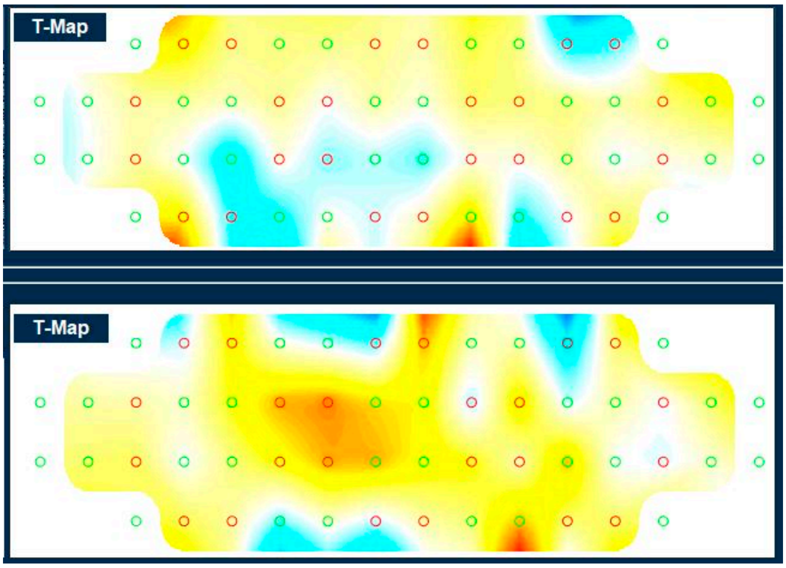

Figure 8. The data expressed in infographics by measuring blood flow in the prefrontal cortex. Top: pre-test. Bottom: post-test. Comparing the top and bottom, the entire brain area is activated, and more areas turn red at the post-test.

5. Discussion

In this study, we developed an augmented reality-based aerobic gamification physical activity program with gamification functions for college students who are excessively immersed in games. This research was evaluated using tools that allowed us to observe psychological and physical changes in users.

The subjects were college students who liked games and were selected in order of game addiction and over-immersion scale scores. Augmented reality-based physical activity programs were found to effectively reduce negative emotions in college students with high game addiction and over-immersion scores. Scores in the areas of tension, depression, anger, fatigue, and confusion decreased, and scores in the vitality area increased, showing a decrease in the overall mood disorder score. Physical activity has long been known to be helpful for mental health. In particular, research results show that aerobic exercise reduces game addiction tendencies, aggression, hostility, and anxiety in game addicts and overindulgent subjects.

More than half of the study participants responded that 'I play games every day' (40%), 'I log in 4–6 times a week' (20%), and 'Playing games makes me feel better' (75%). They also said they played games for significantly longer periods of time (80%).

It is known that the gaming-addicted group has lower school adjustment scores than the general group and that gaming addiction has a negative impact on participation in sports-related activities. In order to improve game over-immersion and change tolerance and dependence on games in a positive direction, intervention using appropriate physical activity is necessary. In this study, we applied the concept of gamification to motivate people to engage in physical activity.

Due to the nature of the game, there are strong motivating factors such as records, competition with opponents, and visual elements. To induce user immersion, we implemented an augmented reality-based physical activity program equipped with gamification functions.

The offline group had a higher average heart rate during exercise compared with the AR group, with no differences in maximum heart rate or perceived exercise awareness. In terms of exercise intensity, both groups perceived it as medium- to high-intensity. In summary, the AR-based physical activity program was found to improve the emotions of game-addicted and over-immersed college students and to have a similar level of exercise effect as offline physical activity. This is similar to the results of a study that confirmed improvement in positive emotions and reduction in fatigue with an exercise program combining augmented reality technology and moderate-intensity physical activity. The depression scores significantly decreased from 40% to 60%.

6. Conclusions

In this study, we conducted an augmented reality-based physical activity program for college students with high game addiction. We measured over-immersion scores to investigate changes in mood state and the level of immersion experience and analyzed differences in heart rate and the perceived amount of exercise. The AR group ran the software with the HoloLens2 equipment worn on their heads. While the offline group ran the indoor gym by imitating the movements of the 'pacemaker' who ran in front of them. Average heart rate and maximum heart rate during exercise were measured by wearing a polar device on the chest. The perceived degree of movement was measured immediately after the end of the program.

The augmented reality-based physical activity program reduced the total mood disorder score by lowering the scores of the negative emotional tension, depression, fatigue, confusion, and anger factors of the mood state. Although there was a change in the vitality factor score, positive emotions were not statistically significant. AR Earthman was recognized as a medium- to high-intensity exercise and showed similar exercise effects to offline exercise.

As a result of the above research, our AR-based physical activity program equipped with a gamification function confirmed its potential as content that can improve and resolve game addiction and over-immersion by providing users with an optimal immersive experience. AR content is designed to verify the usability of exercise and augmented-reality technology and to activate augmented-reality physical activity content. In addition, designs for producing AR software (09.12.2022, Ver 1.0) which we made, applying the gamification concept were also created. The results of this study confirmed the need to consider building a gamified AR exercise environment.

For generalization purposes, it appears that it would be more effective to expand this research to include various variables, such as conducting future research with teenagers younger than those in their 20s. Additionally, if we expand the experimental subjects, we expect to be able to draw generalized conclusions and meaningful implications. One of the things that did not proceed smoothly during the experiment was related to the limitations of AR technology. There was a 10% probability that we had to reset and restart HoloLens2. To prevent this problem, we were prepared to reset the anchor or adjust the illuminance. Therefore, although it did not have a significant impact on the experiment, there was a delay in the experiment schedule of about 1 to 2 minutes. The coordinates of the location where the object is created are fixed with the Anchor setting. However, there is a problem with the coordinates moving automatically due to the effects of lighting and the limitations of holographic technology. Because of this, we experienced problems with the AR technology on the coordinates of the floor or the location where the object was created changed.

The future goal is to develop a physical activity program based on augmented reality technology and build a complete environment through the process of applying it. At the same, IT technology to implement this must also be developed. Currently, we are at a stage where experiments are possible in both VR and AR, but more accuracy and software stability are required.

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