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Design of Game-Based Virtual Forests for Psychological Stress Therapy

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Abstract: Numerous studies have reported the beneficial effects of natural environments on human health and wellbeing. Virtual games may offer a practical approach to experience the illusion of being in a natural setting for those with limited access to nature. This study presents an evaluation of a nature-based virtual environment application to modulate the participant's affective and psychological state. We developed a game-based virtual therapy using the Unity 3D game engine by implementing forest therapy activities and designing the forest environment like a real-life forest. Eight healthy adults participated in this study and were observed remotely. The participants' mood states before and after the game were evaluated using the Profile of Mood States (POMS). In addition, the satisfaction and usability of the game-based virtual forest were assessed using the Game-User Experience Satisfaction Scale and System Usability Scale, respectively. The results revealed that participants experienced significantly improved moods ($p < 0.05$) and decreased stress levels ($p < 0.05$) after playing the game. Moreover, the results indicated multiple positive correlations between the game experience and immersion subscales, revealing that audio and visual aesthetics offered an environment for users to feel more immersed. The study suggests using virtual forest games to promote positive mood and mental health.

Keywords: forest therapy; VR; mood modulation; psychological stress; mental health

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1. Introduction

Recent research has revealed that exposure to nature can boost people's physical and mental wellbeing [1]. Numerous studies on forests as representative natural habitats have been conducted [2], suggesting that exposure to the forest environment might benefit human health, possibly alleviating stress [3,4]. Stress has become an issue for society and organizations and has been implicated in numerous studies as a factor affecting health [5,6]. Long-term stress has been found to have a detrimental effect on people's health [7], with several mental illnesses and cardiovascular ailments being inextricably linked to it [8]. A study by [9] suggested a stress-relief theory based on evolutionary psychology, claiming that exposure to nature can relieve stress and directly influence cognitive recovery. Exposure to a natural landscape, whether real or simulated, can help a person's psychology and physiology recover from the stress by strengthening pleasant emotions and decreasing negative ones, such as fear or rage [10]. According to [11], nature enhances health in four ways: improved air quality, increased physical activity, social cohesion, and stress reduction.

Forest therapy refers to visiting or engaging in various therapeutic activities in forest environments to improve one's health, well-being, and emotions [12]. The term "forest therapy" was taken from "Shinrin-yoku" ("forest bathing"), which means taking in the atmosphere of the forest environment, and highlights the medically proven effects of exposure to forests [13]. The primary focus of forest therapy is to promote stress recovery, increased positive effects, and induced levels of restoration through nature exposure [13]. Forest therapy can reduce and improve stress-related diseases and mental health in adults, such as elevated blood pressure, anxiety, hypertension, cancer, and mental disorders [13,14].

Despite the benefits of forest exposure, people do not spend time in nature places or public parks to relieve stress due to a lack of time and mobility issues. Therefore, virtual reality (VR) can serve as an alternative way to access nature environments for restoration [15,16]. VR is commonly used in healthcare and utilized for motor treatment [17], post-stroke hand rehabilitation [18], and autism treatment [19]. It mainly consists of a simulated environment, sensory and perceptive capabilities, natural skills, and sensing devices. VR has numerous applications in various disciplines, including medicine, education, the arts, entertainment, and the military [20]. Recent research has explored the potential of game-based virtual forests for psychological stress therapy. It was found that nature-based therapeutics may be beneficial for pediatric patients with total pancreatectomy and islet auto-transplant, potentially improving their quality of life [21]. A study conducted by [22] examined the effects of 2D forest video viewing and virtual reality forest video viewing on stress reduction in adults. The effects were measured by heart rate, skin conductance, and salivary cortisol levels, suggesting that both types of video viewing can activate the parasympathetic nervous system and lead to a decrease in stress levels. In contrast, exposure to a 3D natural environment in virtual reality results in better recovery effects than the 2D natural environment. Moreover, based on the objective measurement and subjective evaluation by [23], the 3D natural environment can also effectively reduce stress, anxiety, and negative emotions. Additionally, a study by [24] examined the physiological and psychological restorative effects of a digital forest bathing environment. The results indicate that the virtual environment significantly decreased the negative affect (negative emotions, stress etc.) and provided relaxation which is a similar restorative trait as a real-life forest environment. Moreover, exposure to the natural light of the forest environment also influenced stress recovery [25]. The study assigned participants to watch one of six virtual forest scenes for 6 min, ranging from lightest to darkest light via VR simulation software. The result shows the natural light scene with moderate brightness of the forest environment can elicit stress relief. Therefore, it should be noted that the elements inside the virtual environment could also contribute to stress relief and restoration.

Furthermore, virtual reality platforms can also be used as an alternative way of nature walks for those who have mobility issues. A study by [16] developed a virtual reality nature walks application named Nat(UR)e with an ultra-reality forest environment where participants were placed inside a multisensory booth where all of the participants' senses (smell, vibration, etc.) were enhanced. The result shows significant improvement in relaxation, and a reduction in stress and anxiety were found. Additionally, there is a study conducted by [26] that examined the effects of viewing seven different forest environment types by combining several wood, plants, and platform. The result shows that environments with a lot of green vegetation have positive effects on stress relief and relaxation. However, virtual forest therapy can be enhanced by including different types of activities (meditation, walking, etc.) since incorporating these activities could also affect stress relief [26].

Inspired by related research, we developed a gamified, nature-based virtual environment application that affects users' mood changes and psychological stress. We merged our knowledge of the effects of virtual nature, games, and stress therapy to create a VR game that promotes subjective well-being. The decision to design the VR game was motivated by two factors: (1) engagement with the virtual game context to affect participants' moods, and (2) determination of the correlation between user experience factors (e.g., virtual and audio aesthetics) and immersion. The purpose of the study is to evaluate the effects of gamified, nature-based VR therapy in reducing stress and improving moods. We hypothesize that this could induce high spatial presence that can serve as an effective environment. The usability, user experience, and immersion of the developed VR application were then assessed. We also looked at the designed VR application's capacity to improve the participants' moods using the Profile of Mood States (POMS) questionnaire.

2. Game Contents Design

2.1. Development Method

The present study used the Game Development Life Cycle (GDLC) methodology for developing a nature-based virtual reality therapy application [27]. This methodology consists of six phases: initiation, pre-production, production, testing, beta, and release. Our study utilized four phases: initiation, pre-production, production, and testing.

2.1.1. Phase 1: Initiation

We initially gathered relevant information and sketched out the game's concept in this phase. This phase involved deliberating and finalizing the project's concept and idea. Rough sketches of the forest environments were created and reviewed multiple times before proceeding to the next phase, pre-production (refer to Figure 1). Additionally, detailed information on forest therapy was collected, focusing on the definition of forest therapy, its effectiveness for stress relief, and the activities involved. The author shaped the terrain using images and videos of existing forests for stress-relieving forest bathing. The terrain mainly included oak trees, ferns, mosses, mountains, and waterfalls. This mixture of forest vegetation creates an aesthetically pleasing green forest environment for the user, and the addition of small plants such as ferns and mosses are expected to amplify the effect of nature's pleasant green space exposure. The green space has a balancing effect on the viewer due to its soothing effect on emotions [28]. For added realism and immersion, sounds of nature (e.g., waterfall, river, wind, and birds chirping) were incorporated into the environment, which was associated with stress in previous studies [29].

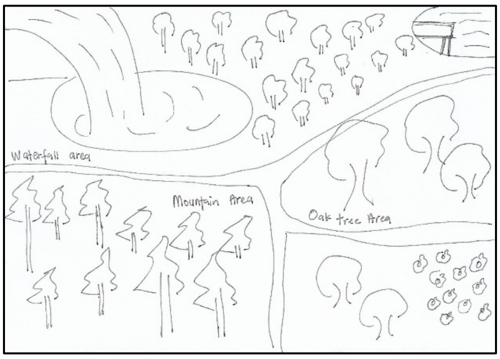

Figure 1. Rough sketch of the map of the in-game forest.

2.1.2. Phase 2: Pre-Production

This phase included developing the game's characters and iteratively modifying the game's design. Game design focused on creating the gameplay, finalizing the game genre, game mechanics, and creating the storyline, characters, challenges, and more. As references, the proposed game design was documented in a game design document (GDD). The application game flow was finalized after discussions and brainstorming, as illustrated in Figure 2. The game begins by directing the user to the game's Start Menu before accessing the game. The game has two modes: free mode and checkpoint mode. Users can freely explore the forest in free mode while accomplishing checkpoint activities in checkpoint mode. After a user completes each checkpoint action, the game ends, and the user is redirected to the Start Menu. The game's activities include photographing, collecting items, performing a simple fitness program, and taking a deep breath while admiring the surroundings. The implemented activities were narrowed down after researching the activities used for forest therapy. Table 1 details the routine tasks that occur during forest therapy, along with their descriptions and purpose. The activities were implemented as forest therapy activities, including viewing nature, nearby nature, and active participation and involvement with nature [14].

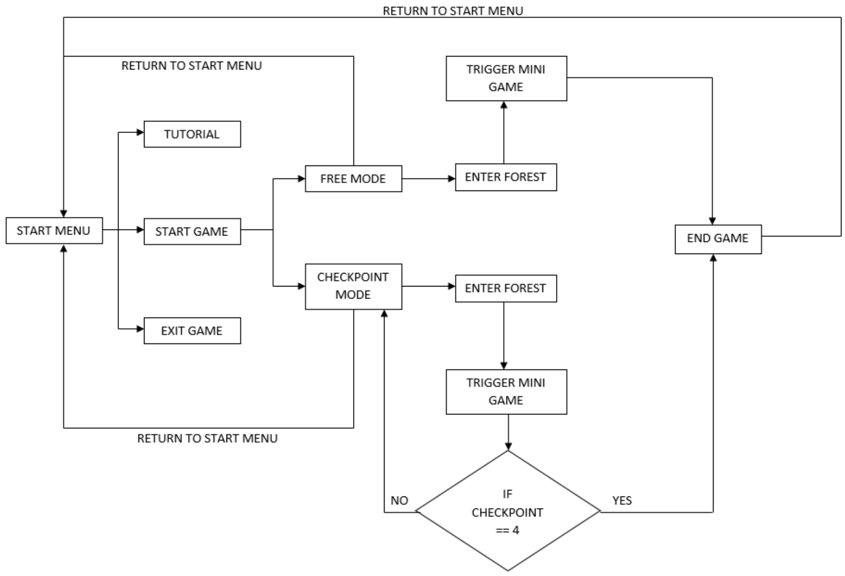

Figure 2. Detailed flowchart of the application.

Table 1. The details of forest therapy activities implemented in the application during the prototype stage.

Activity	Description	Purpose
Collecting items	The items collected during this activity are red balls. Participants need to collect four balls scattered in the forest, encouraging participants to explore the forest.	Sense of enjoyment and reduce stress.
Take a breather	In this activity, participants were encouraged to stop and take a breath of the fresh air while immersing themselves in the forest's sound.	Provide relaxation as well as improve moods and relieve stress.
Simple exercise	The simple exercise was implemented to encourage participants to move their bodies while doing a simple exercise routine after sitting for a long time.	Reduce the stress that has accumulated inside our bodies since exercise is also known as a "stress-relieving activity".
Taking photos	This activity added an element of fun in taking pictures while exploring the virtual forest.	Relieve stress through photo healing

2.1.3. Phase 3: Production

Production is an essential process that entails the creation of assets, source code, and the integration of both into the game. The related prototypes in this phase were formalized with details and refinement [27], and the forest environment was designed based on the rough sketch and several photo references. The proposed forest landscapes in the game/application are depicted in Figure 3a. The natural elements drawn in the initiation phase were precisely reflected in the production phase. The forest design was created to give the participant the sense of embarking on a real-world adventure. A past study has proven that experiential realism is a core determinant of the efficacy of virtual forest therapy [30]. The assets for the virtual environments were compiled using Visual Studio in the Unity engine. The application was developed as a desktop Virtual Reality (VR) and does not require the use of a VR headset. Desktop VR has a similar design to other VR applications, with the interface design of the applications in a first-person point of view. Participants will need to use the keyboard and mouse for navigating inside the application.

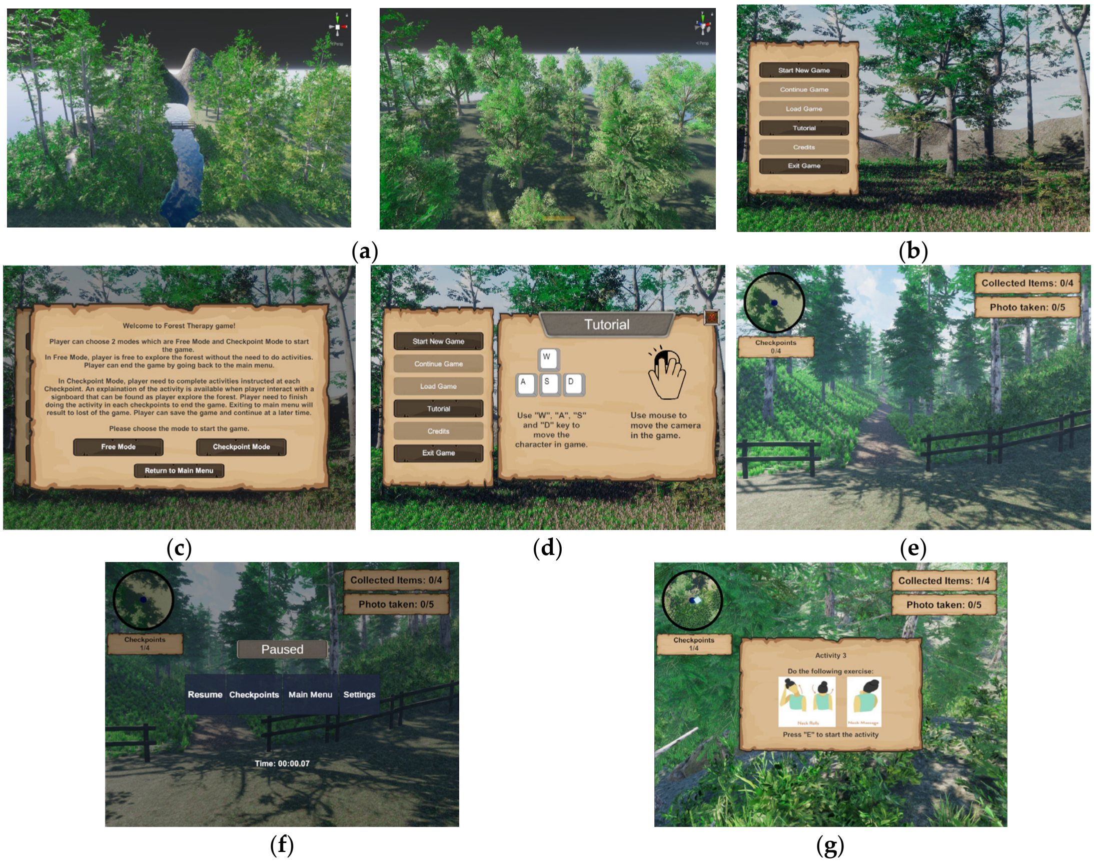

Figure 3. The game interface designs include (**a**) the forest environment, (**b**) the start menu interface, (**c**) the mode selection interface, (**d**) the application tutorial, (**e**) the in-game interface, (**f**) the pause menu interface, and (**g**) the triggered activity dialogue interface.

2.1.4. Phase 4: Testing

This phase was conducted to test the game's usability and playability. The testing method was different for each prototype stage. The testing output was a bug report, change request, and a development decision. The outcome determined whether to advance to the next step (Beta) or remain in the production phase [27]. During this phase, participants were invited to fill out several questionnaire surveys to assess the usability and playability of the developed game.

2.2. Game User Interface

At the start of the game, the user is presented with the start menu, which includes numerous options, as illustrated in Figure 3b. Three buttons are available on the start menu: Start New Game, Tutorial, and Exit Game. The design of the Start Menu is geared toward creating a relaxing and calming atmosphere. The user is given two modes to choose from during the mode selection: Free Mode and Checkpoints Mode (Figure 3c). Instructions explaining the available modes are shown for the user to understand them better. The tutorial button provides a simple tutorial on the character's control and buttons used in the game, as shown in Figure 3d.

Figure 3e depicts the game's interface after selecting the Checkpoints Mode. The interface displays the total number of checkpoints completed, the number of items collected, the number of photos taken, and a simple mini-map to help the player understand the character's site. The pause menu interface provides access to various options, including resuming the game, viewing activity details for each available checkpoint, returning to the main menu interface, and adjusting the game's settings (Figure 3f). The playing duration is also included in the pause menu interface to allow participants to keep track of how long they have played the game. Figure 3g depicts the triggered activity dialogue interface when participants enter the activity area. The dialogue provides participants with additional instructions on how to begin the activity. Each activity requires participants to experience it for no more than one minute.

3. Materials and Methods

3.1. Participants

A total of eight healthy adults ranging from students to full-time employees participated in the testing. Before the testing, participants were given a short introduction about the study and its purpose. The participants consisted of 4 males (50%), 3 females (37%), and 1 participant who preferred not to disclose their gender (13%). The age of participants ranged from 16 to 30 years old (62%) and 31 to 45 years old (38%). Half of the participants were full-time employees, while the other half were students, as illustrated in Table 2.

Table 2. Participants' demographics.

Parameters	Percentages	
Gender	Males	50%
	Females	37%
	Prefer not to say	13%
Age	16–30 years old	62%
	31–45 years old	38%
Employment status	Full-time	50%
	Seeking opportunities	37%
	Student	13%

The participants voluntarily participated in this study. We ensured that the participants received full information about the study and the nature of their participation. We obtained verbal consent from all participants before the intervention. During the verbal consent process, we explained the purpose of the study, the potential risks and benefits, and that participants could withdraw from the study at any time. Before the participants verbally agreed, we addressed any concerns they may have had.

3.2. Psychological Parameters

The participants' psychological and mood states were assessed using the Profile of Mood States (POMS) questionnaire before and after playing the developed virtual game. The POMS questionnaire is widely used to track participants' mood changes, mainly their psychological stress [31,32]. Numerous studies have proved that the POMS is a reliable self-report questionnaire in clinical psychology, psychotherapy, and medicine to measure emotional and perceived stress [15,33].

This scale contains forty variables that define subjective experiences associated with six distinct mood states (T: tension, D: depression, A: anger, F: fatigue, C: confusion, and V: vigor). Each item was evaluated using a five-point Likert scale ranging from 0 (Not at all) to 4 (Extremely). The higher the score, the more intense the feeling felt by the person. Participants were instructed to fill out the scale according to their emotional states following the experiment. Total mood disturbance (TMD) is calculated as follows:

$$\mathrm{TMD} = (\mathrm{T} + \mathrm{D} + \mathrm{A} + \mathrm{F} + \mathrm{C}) - \mathrm{V} \quad (1)$$

A rise in the average value of TMD indicates a decrease in the participants' mood.

3.3. System Usability Scale

The System Usability Scale (SUS) was used to assess the usability and playability of the developed gamified nature-based virtual application [34]. The SUS required users to respond to 10 separate statements with 5 multiple choices ranging from "Strongly Disagree" to "Strongly Agree". The 10-item scale evaluates the efficacy, efficiency, and satisfaction of computer applications. According to the SUS's developers, a score of 68 is considered average. Scores above 68 are above average, while scores below 68 are below average.

3.4. User Satisfaction and Immersion

The Game User Experience Satisfaction Scale (GUESS) is a psychometrically validated scale that has been created to evaluate and measure the user's experience satisfaction [35]. The GUESS includes nine factors that all contribute to video game satisfaction, such as Usability/Playability, Narratives, Play Engrossment, Enjoyment, Creative Freedom, Audio Aesthetics, Personal Gratification, Social Connectivity, and Visual Aesthetics. Audio Aesthetics and Visual Aesthetics were chosen for this study to evaluate the auditory and graphics aspects of the application, to see how the auditory of the application can enrich the participants' experiences, and how attractive the application's visual appearance is to the participants.

The user's immersion or sense of being in the designed virtual environment was also evaluated using Jennett's Likert survey [36], which includes questions such as: "To what extent did you feel that you were interacting with the game environment?", "To what extent did you feel as though you were separated from your real-world environment?" and "To what extent was your sense of being in the game environment stronger than your sense of being in the real world?". The questionnaire could elicit concentration, dissociation, complexity, emotional engagement, and enjoyment in response to various displays.

3.5. Procedure

The application testing was conducted remotely due to the COVID-19 restrictions. Participants were sent a link to a short video of the gamified application's gameplay, features, and environment, as well as the PC version of the gamified nature-based application for usability testing and playtesting, via email. Participants were given an introduction to the project and the purpose of the testing, as well as instructions remotely from the application's creator. Participants were instructed to view the video and playtest the application using headphones for clear audio in an enclosed room. Participants were given approximately 15 min to view the short video and playtest the application.

Participants were allowed to ask questions about the project and the game during testing. Participants filled out a set of POMS questionnaires before and after playing the game, and their responses were recorded and monitored using Google Forms. Participants were required to inform the team once they had completed the testing via email. However, the time when the participants viewed the short video or playtested the PC version of the application was not recorded.

3.6. Statistical Analysis

Statistical analyses were conducted using JASP statistical software (version 0.15.0, University of Amsterdam) and the Statistical Package for Social Sciences (SPSS) version 25.0 (SPSS Inc., Chicago, IL, USA). Data were assessed for normality using Shapiro–Wilk tests and presented as mean (M) and standard deviation (SD). Data of POMS subscales were analyzed based on a nonparametric method, Wilcoxon Signed-Rank Test. In contrast, a paired t-test was performed on the TMD data after confirming its normal distribution and variance homogeneity. The effect size (Cohen's d) was also assessed to determine the degree of the difference between pre- and post-game moods. Additionally, Pearson's Correlation Coefficients were computed to evaluate the relationship among GUESS factors. Statistical significance was established at $p < 0.05$.

4. Results

4.1. Results of Psychological Evaluations Using POMS

The POMS scores for all subscales, except vigor, were considerably lower in the post-condition of the virtual forest game than in the pre-condition. Figure 4 shows the results of six POMS subscales, while Table 3 summarizes the statistical results of the analysis. The Wilcoxon Signed-Rank Test revealed that the tension (*T*), fatigue (*F*), and confusion (*C*) decreased by 4.88, 2.38, and 3.63 points, respectively, with statistically significant positive impacts (*T*, $Z = -2.10$, $p = 0.035$; *F*, $Z = -2.12$, $p = 0.034$; *C*, $Z = -2.12$, $p = 0.034$) and large effect sizes (*T*, r = 0.74; *F*, r = 0.75; *T*, r = 0.75). Although anger (*A*) and depression (*D*) were also decreased during the post-conditions, no significant differences were found with the pre-conditions (*A*, $Z = -1.83$, $p = 0.068$; *D*, $Z = -1.84$, $p = 0.066$). In contrast, vigor slightly increased by 0.88 points, showing no significant differences between the pre- and post-conditions ($p = 0.624$).

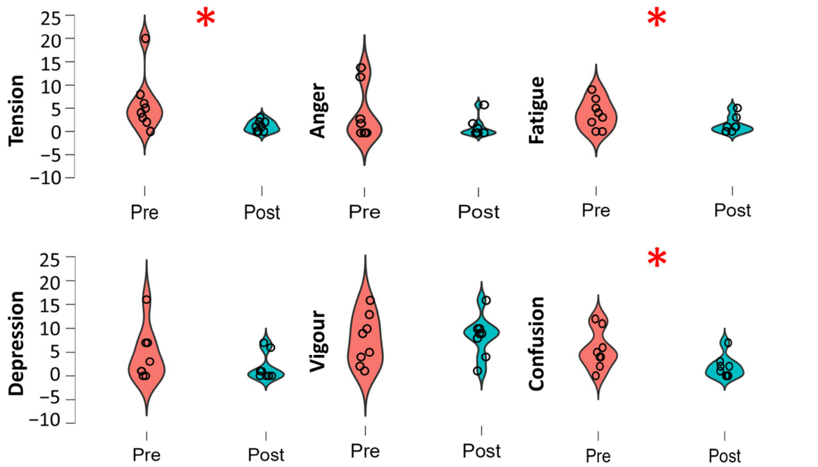

Figure 4. A comparison of the POMS subscales pre and post of the designed virtual game. * $p < 0.05$.

Table 3. Statistical results for changes in POMS scores pre and post playing the virtual forest game.

POMS Subscale	Pre		Post		Wilcoxon Signed-Rank Test		
	M	SD	M	SD	*Z*-Value	*p*-Value	Effect Size
Tension	6.00	6.16	1.13	1.13	−2.10	0.035 *	0.74
Anger	3.88	5.77	1.13	2.10	−1.83	0.068	0.65
Fatigue	3.75	3.20	1.38	1.77	−2.12	0.034 *	0.75
Depression	4.38	5.50	1.88	2.90	−1.84	0.066	0.65
Vigour	6.50	5.37	7.38	4.44	−0.49	0.624	0.174
Confusion	5.50	4.14	1.88	2.36	−2.12	0.034 *	0.75

Abbreviations: M, mean; SD, standard deviation; POMS, profile of mood states; TMD, total mood disturbance; * $p < 0.05$.

The scores of the Total Mood Disturbance (TMD) subscale of the POMS are illustrated in Figure 5, and their statistical analysis results are summarized in Table 4. The results demonstrated that the TMD recorded a negative mood state at 17.0 ± 21.8 before virtual forest game playing and changed to a positive mood state at 0.00 ± 11.7 after game playing ($t = 2.75$, $p = 0.014$, d = 0.97).

Table 4. Statistical results for changes in TMD scores pre and post virtual forest game.

Pre		Post		Paired *t*-Test		
M	SD	M	SD	*t*-Value	*p*-Value	Effect Size (d)
17	21.82	0.00	11.65	2.745	0.014 *	0.970

Note. M, mean; SD, standard deviation; * $p < 0.05$.

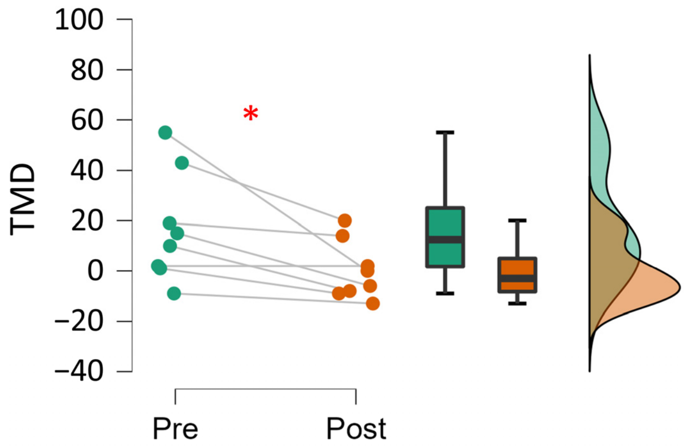

Figure 5. Changes in TMD scores by virtual forest game (pre- and post-value). * $p < 0.05$.

4.2. Results of System Usability Scale Questionnaire

Participants had varying opinions on the usability of the designed virtual game. The game obtained a total mean score of 76.88 (SD = 10.6) on the SUS, showing a significant difference ($t = 20.5$, $p < 0.001$). With 95% confidence, the population value ranges from 68.0 to 85.7, and almost 87.5% of participants rated it above 68, which the scale's developers classify as average usability. This score showed that participants found the game to be user-friendly in terms of usability and learnability, and thus, the participants could actively promote the game to others. Figure 6 illustrates more details on the SUS scale.

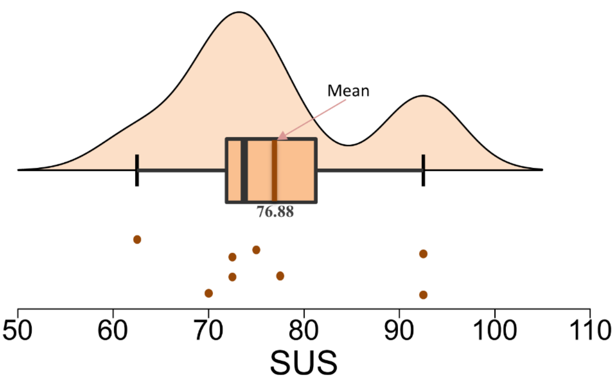

Figure 6. Participants' responses to the System Usability Scale (SUS) questionnaire.

4.3. Results of the GUESS and Immersion Questionnaire

The GUESS and Immersion questionnaires were conducted to evaluate virtual game satisfaction by looking at individuals' scores in each factor. Each item in the GUESS and Immersion questionnaires was rated on a Likert scale ranging from 1 (worst) to 5 (best). Based on the descriptive statistics in Table 5, the average scores were above the midpoint in all factors: audio aesthetics (M = 4.31, SD = 0.61), visual aesthetics (M = 4.33, SD = 0.56), and immersion (M = 3.42, SD = 0.68).

Table 5. Descriptive statistics for the GUESS and immersion factors.

Factor	M	SD
Audio aesthetics	4.31	0.61
Visual aesthetics	4.33	0.56
Immersion	3.42	0.68

Note. M, mean; SD, standard deviation.

To better understand the relationships between the GUESS factors and the immersion factor, Pearson's correlation tests were used to determine the association between the three factors. As shown in Figure 7, the findings indicated a statistically significant positive association between all factors, indicating that these factors have some conceptual overlap. Although the relationship between audio and visual aesthetics showed the strongest positive correlation (r = 0.87, $p < 0.01$), the association of immersion with either audio (r = 0.73, $p < 0.05$) or visual (r = 0.70, $p < 0.05$) aesthetics also had a strong positive correlation. Table 6 summarizes the correlations between the factors.

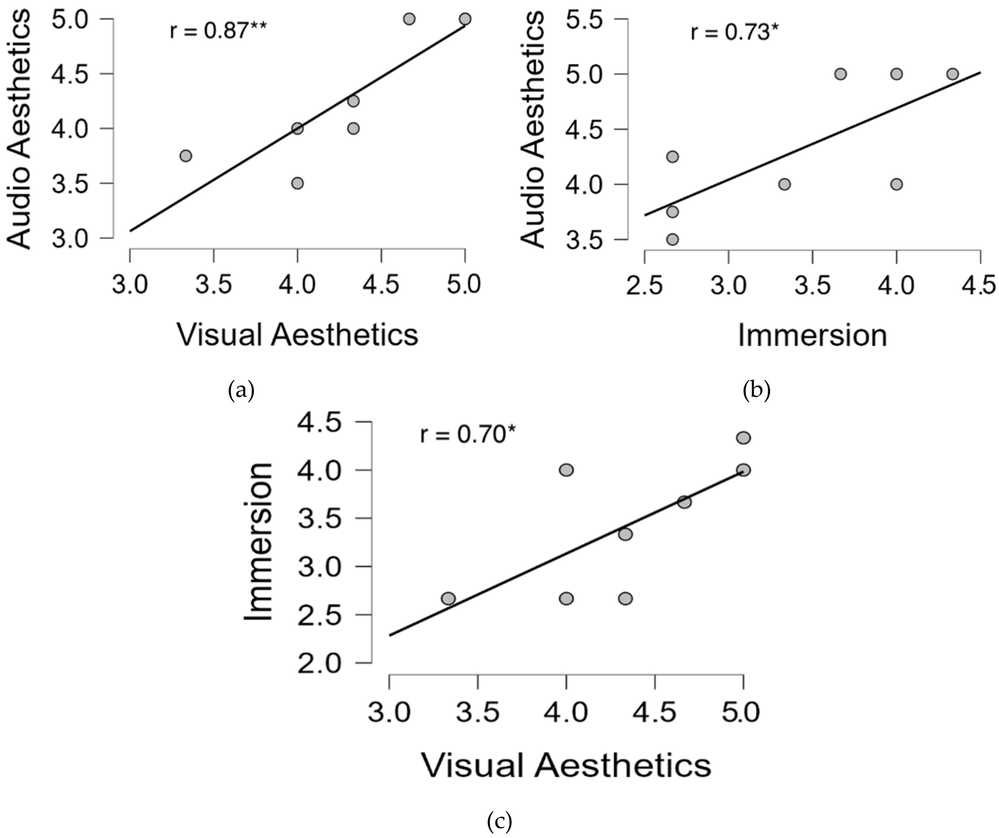

Figure 7. Correlations across three factors of the GUESS, (**a**) audio aesthetics–visual aesthetics, (**b**) aesthetics–immersion, (**c**) visual aesthetics–immersion. * $p < 0.05$, ** $p < 0.01$.

Table 6. Pearson's Correlations between GUESS factors.

Factor	Visual Aesthetics	Immersion	Audio Aesthetics
Visual aesthetics	—		
Immersion	0.70 *	—	
Audio aesthetics	0.87 **	0.73 *	—

Note. One-tailed, * $p < 0.05$, ** $p < 0.01$.

5. Discussion

We expected that the surroundings, the degree of immersion, and interplay would all affect mood and stress recovery. We anticipated that the gamified virtual forest therapy would have a significantly positive effect on users. The findings of this study provide empirical evidence for the feasibility and efficacy of a game that incorporates physiological awareness to help users change their moods and control their physiology. The decision to conduct the system's initial evaluation on a media device was motivated by two factors. We were primarily interested in determining whether or not the engagement with the virtual game context was convincing enough to affect participants' moods. If feasible, this would encourage the development of accessible applications that could enhance and support the treatment of mood disorders such as stress, depression, and anxiety. Second, we aimed to measure the game's usability, user immersion, and satisfaction with the application.

The POMS subscales and the TMD were used to assess the effect of exposure to the virtual forest-based game on users' moods. The moods of the participants changed before and after they played the game in the experimental condition. It was demonstrated that exposure to a virtual forest was a predictor of mood disturbance, as exposure to such an environment decreased mood disturbance. Evaluations of the individual POMS questionnaire factors indicated that the application substantially lowered tension, fatigue, and confusion levels. As anticipated, the factor vigor was decreased in the pre-condition compared to the post-condition, suggesting that the virtual forest game assisted individuals in reducing negative mood states and increasing the sense of energy, enthusiasm, and vitality. The overall average score of TMD of the post-condition was lower than that of the pre-condition, revealing that emotional distress in participants after viewing and playing the game-based virtual forest application was considerably decreased. The findings of this study corroborate those of previous studies involving different virtual approaches and a diverse population of participants, and conclude that forests can help reduce blood pressure, improve mood, and reduce stress, and they may even be beneficial for people with mental illnesses [37–40].

The advantages of Investigating forest-induced moods are significant and long-lasting, as they have impacts on human health, physiological responses to stressors, mental function, and prosocial behavior. Therefore, forest therapy and the associated moods should be viewed as socially significant and worthy of public attention, especially for employees, students, and others who are struggling with various stressors, such as job demands, social challenges, and future ambiguity. A game-based forest therapy could be an efficient and cost-effective strategy for dealing with such stressors.

Positive changes in participants' mood states have consequences beyond "feeling better", as mood state affects what is attended to in the environment and thus profoundly affects subsequent cognition and behavior [41]. The mood change is associated with physiological mechanisms. Numerous studies on forest therapy [32,39,40,42] have found that mood plays a significant role in eliciting forest therapy experiences. The importance of mood was demonstrated by examining its effects on behavior, cognition, and physiology. These effects include learning, health, and socialization [43]. The benefits of improved mood associated with forest therapy experiences may provide a compelling argument for industries and universities to invest in delivering and managing workplace forests.

A comprehensive preliminary investigation into acceptability, simplicity of use, and learnability is required to maximize the potential of game-based therapies. The System Usability Scale (SUS) was initially established to assess the usability of services and products, such as software, hardware, mobile devices, and mobile applications. We selected the SUS to evaluate our designed game since it incorporated all of these elements and had been previously used in various studies [44,45]. The SUS scores in this study were 76.9% after playing the designed game-based virtual forest, indicating that the application had a positive and significant influence on usability scores. These findings imply that the game-based virtual forest is an acceptable and valuable method for improving mood.

From a gaming experience standpoint, we sought to determine whether playing the gamified virtual forest would provide participants with a considerably improved experience. Therefore, we considered users' experiences during the game playing. Interestingly, the Involvement subscale of the GUESS questionnaire appeared to be correlated with the immersion questionnaire. Overall, the analysis showed that audio aesthetics, visual aesthetics, and immersion experience were higher and shared significant correlations among them. For instance, the audio aesthetics was significantly correlated with the visual aesthetics and immersion, revealing that a higher level of audio quality is linked to a greater presence of the player and a greater spatial awareness of the environment. In contrast, immersion when playing the game-based application was highly correlated with the audio and visual aesthetics, contributing to a more immersive environment that provided better settings for users to feel more engaged. According to this reasoning, the audio and visual aesthetics can distract and remind users of their surrounding reality. Therefore, by providing a virtual forest game experience, we can increase the system's immersion and, thus, the probability of users feeling more present.

In conclusion, this research suggests that virtual forest-based games can be used to reduce negative mood states and increase positive moods, with potential implications for promoting wellbeing. Further research could explore the effects of different types of virtual forest environments on mood, as well as the long-term effects of virtual forest exposure on mental health. Additionally, the findings of this study could be used to inform the development of virtual reality applications designed to improve individuals' wellbeing and psychological health. Furthermore, game developers should take into account audio and visual aesthetics to create more immersive experiences for their users, which could be used to improve virtual environment experiences.

Limitations

Our study has some limitations. The small sample size of this study is a limitation, limiting our attempts to draw conclusions. Expanding the sample size may provide a more solid discussion and conclusion. Another drawback of our observation is that we only collected data through viewing the forest-based game's short video and playing the game without a VR headset. It would be intriguing to utilize wearable equipment to measure physiological changes continuously in a future investigation objectively. Additionally, it would be preferable to examine the long-term impact of game-based virtual forests on users and determine the acceptable optimal duration. This study also does not contain a control group that may engage in activities in a non-forest environment game. Furthermore, future studies should involve a more controlled experiment comparing different types of backgrounds or game-based forest-related activities versus non-forest-related ones. This study's participants were selected based on random sampling to avoid biased results without determining the criteria of the participants. Therefore, a definite criterion for the participants' selection needs to be considered to obtain better results for future works. Despite these limitations, this study contributed to a better understanding of the variations in attributes before and after game-based virtual forest therapy.

6. Conclusions

This study demonstrated that interaction with a game-based virtual forest therapy had substantial psychological effects. More precisely, significant improvements (TMD, $p = 0.014$) in participants' emotional states and stress responses were observed after viewing and playing the designed game. The results of this study show that game forest therapy can be used to improve the mental health of individuals, although it does not indicate a reduction in stress. Furthermore, participants were able to enrich their experience with satisfying audio and visual aesthetics of the game, which garnered their attention with the attractiveness of the in-game forest environment designs. The results also demonstrated positive correlations between certain aspects of the game experience, audio and visual aesthetics, and immersion. There is a solid case to be made for forest therapy as a supplemental therapy in today's urbanized world.

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