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Review

The Impact of Virtual Nature Therapy on Stress Responses: A Systematic Qualitative Review

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Abstract: This study aims to review the key findings of past studies that assessed the impact of virtual environments, such as nature and forests for stress therapy. Previous research has found that virtual reality (VR) experiences affect socio-affective behavior, indicating the potential of using VR for cognitive and psychological stress therapy. However, evidence for the impacts of virtual forest therapy as a stress-reduction technique is lacking, and the usefulness of these techniques has yet to be determined. This review was carried out following the preferred reporting items for meta-analyses and systematic reviews. It summarized the literature and provided evidence on virtual forest therapy (VFT) effectiveness in stress relief. We conducted a literature search considering VR-related studies published from 2013 until June 2021 for different databases, including Embase, Medline/PubMed, Hindawi, ScienceDirect, Scopus, Web of Science, Taylor & Francis, and the Cochrane Library, to see how effective VFT reduces stress levels and improves mental well-being. According to the set inclusion criteria, eighteen relevant papers detailing original research were eligible for inclusion. This overview suggests that VR provides benefits for assessing and reducing stress levels. While real natural environments effectively promote recovery from stress, virtual exposure to nature also positively affects stress. Thus, VR could be an effective technique for promoting relaxation, particularly during the COVID-19 pandemic, where stress levels rise globally. However, more in-depth studies are required to substantiate this potential field of VR relaxation.

Keywords: virtual reality (VR); virtual forest therapy (VFT); virtual nature; stress; psychology



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1. Introduction

Nature has played an essential role in people's lives [1,2]. Today, however, our ties to mother nature are tenuous at best. People can boost sensory awareness and balance their lives by taking soothing and meditative walks in nature. Nature walks are based on a Japanese technique known as "shinrin-yoku", which translates to "forest bathing" and is sometimes referred to as "forest therapy" [3]. This technique was first developed in the early 1980s by Tomohide Akiyama, director of the Japanese Forestry Agency [4], based on the idea that cultivating a love relationship with nature can help preventative healthcare, well-being, and healing. In addition to Japan, several other developed countries in Europe and North America have practiced these natures' walk methods to reduce stress levels in patients [5].

Consequently, the impacts of forests and nature on human well-being and health have piqued researchers' interest in recent years. Forest therapy is a therapeutic, immersive environmental experience that promotes well-being [6]. It also has been shown to have

a beneficial influence on the health of the human body and mind. According to previous studies, intensive involvement with nature, such as “shinrin-yoku”, can be helpful to health. This claim has been supported by numerous studies in the medical field [7–10]. A study by [6] found that, compared to an urban environment, two days of forest bathing could increase the number of natural killer cells in the immune system, significantly increase parasympathetic nervous activity, and suppress substantially sympathetic activity in the participants. Another study revealed that looking out a hospital window at trees helped patients recover faster after surgery, implying that a visual component alone can improve human health [11]. It showed that visual aspects, such as merely viewing the green forest environment, may be a source of positive benefits and apparently reflect on people’s psychological state throughout their time in the forest. Today, people are occupied with everyday life, and most reside in cities where noise pollution, air pollution, water pollution, work pressure, and lack of green environments are available. These conditions lead to stress symptoms in a large portion of the urban population [12]. Stress levels will increase in the following 30 years due to an increase in development [13–16]. Other than that, lack of time because of work makes it difficult for people to spend time going to places that can relieve stress. However, instead of stepping outside, new technology based on virtual reality (VR) has been introduced to allow us to bring forest, park, or nature into the house.

VR can be defined as a class of computer-controlled multisensory communication technology that enables more natural interaction with data and engages the human senses in new ways [17]. Another definition of VR is a computer-created environment in which the user feels existent [18]. The modern technological advances in VR have become a useful supporting tool in several environments, such as disorder therapies [19–21], rehabilitation processes [22–24], marketing [25–27], industry [28,29], or safety and industrial training [30,31]. VR systems are also increasing promptly, with countless new applications in the ranges of healthcare and psychology [32]. Researchers may fine-tune the design and elaboration of environmental settings using VR, bypassing the limits of field studies, which cannot account for a wide range of potentially confounding elements (e.g., temperature, crowd, traffic).

Furthermore, VR can develop a strong sense of presence, defined as the personal sensation of being there in a virtual environment [33]. It simulates experimental scenarios where comparable real-life situations are unavailable (e.g., forest with or without river). VR can be executed by using a flat-screen display [34], a projection-based cube room known as a computer-automated virtual environment [35], or a head-mounted display [36]. The use of flat-screen displays and the other two visualization technologies offer an immersive experience in which the user is entirely encircled by the virtual environment, generating a more real-life experience.

Nowadays, people spend more time indoors than outdoors, especially during the period of the COVID-19 pandemic. This tendency has caused individuals to be isolated from contact with nature, negatively influencing their mental and physical health. The human mind has become stressed and depressed owing to various problems such as self-harm and eventually suicide. Therefore, human beings need to find something to be free from stress and lead to a healthy lifestyle.

Many studies have been using stress as a health-related variable, revealing that prolonged stress can affect health and have a negative effect on a person [37,38]. It has been shown that stress is linked to various cardiovascular diseases and mental disorders [12,39,40]. In 1991, the theory of stress relief was proposed by [41] to improve psychology, which states that acquaintance with the natural environment can decrease stress and directly affect mental recovery. In other words, exposure to nature views or simulations of nature may help individuals recover from psychological and physiological-related stress. Psychotherapists consider VR therapy (VRT) one of the most promising psychiatric interventions in the future decades to treat mental stress through virtual forest therapy (VFT) that restricts the user’s interaction with various virtual nature environments and stimuli. Nature scenery exposure could increase positive effects and reduce negative emotions, such as fear or

anger [42]. A further study by [43] found that nature could improve health in four ways: air quality, physical activity, social interconnection, and stress reduction. Though, a lack of understanding of the relationship between physiological mechanisms and the quality of urban green spaces, making stress problems challenging to curb. In today's technologically advanced world, where time is a valuable element, green spaces can be brought into the home using virtual application technology.

This systematic review aims to evaluate the impacts of nature and forest environments using VR in reducing stress levels. To this end, the proposed systematic review is conducted to answer the following questions:

1. Is VR effective enough to be employed for mental illness therapy?
2. Are VR environments, including nature and forests, able to mitigate stress levels in patients? Is there an advantage of using VR technology over nature walks methods?

2. Methods

2.1. Protocol and Registration

This review was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline [44], but the review protocol was not registered in the Prospective Register of Systematic Reviews Platform (PROSPERO).

2.2. Data Sources and Search Strategy

This review was conducted by querying various databases, including Embase, Medline/PubMed, Hindawi, ScienceDirect, IEEE, Scopus, Web of Science, and Taylor & Francis. The screening of titles and abstracts was employed in the first phase to determine the relevant articles for this research. Obtained articles were screened again in the second phase to categorize qualified articles. The following keywords used are as follows. Apart from using the term "forest", another term used in the literature searching correlated to (1) visual effects (2) nature, and (3) psychological effects. The keywords correlated to (1) visual effects were "view", "visual", and "virtual"; the keywords correlated to (2) nature were "scenery", "forest", "urban park", "flower", and "environment"; and the keywords correlated to (3) psychological effects were "physiological", "stress", "heart rate", and "blood pressure". A search range was set within the titles and abstracts and search articles about the human species to get specifically related literature from the database. The recent update to the search was conducted in June 2021.

2.3. Eligibility Criteria

Studies in the collected articles involved participants of various ages ranging from 0 to more than 65. Studies conducted based on less than three participants were excluded, owing to its irrelevant in the study. VR studies that used the nature of forest therapy or natural environments were included, while studies that used other types of therapy were excluded. Additionally, articles that have been published as literature reviews or in other languages than English were eliminated. The searching for the paper on the databases began with matching words of "virtual forest", "virtual scenery", "virtual urban park", "virtual nature", "virtual plant", "virtual environment", "physiological", "stress", and "blood pressure", which were formed in query strings such as ("virtual forest" and "stress") OR ("virtual nature" AND "stress").

2.4. Study Selection

As shown in Figure 1, 398 papers were found with a duplication of 155 articles. After screening, 110 articles were excluded because they did not meet the inclusion criteria, did not use VR devices, or were not published in the last decade from 2013 to June 2021. After reviewing the titles, 48 related articles remained. After reviewing the abstracts, the full text of 30 articles was taken for review. After reviewing full-texts, 18 articles matched the selection criteria. These articles were selected published between 2013 and June 2021 focused on reducing stress using virtual forests.

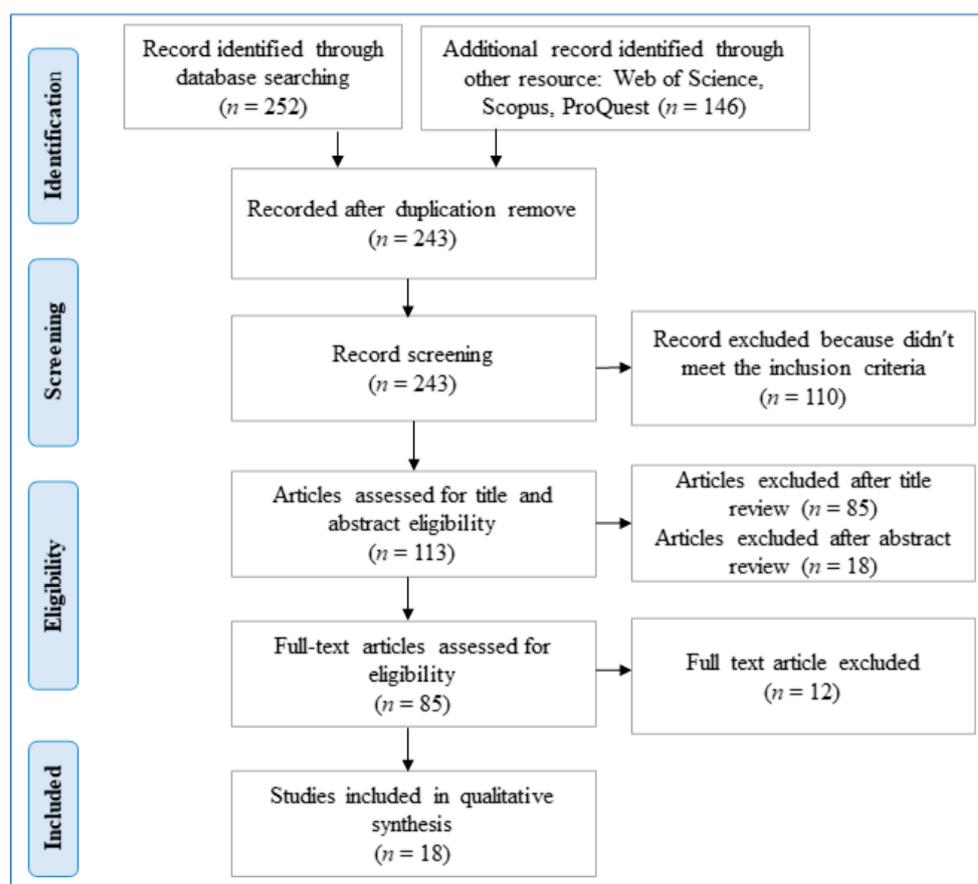


Figure 1. Systematic review flow diagram based on the PRISMA.

2.5. Data Extraction

Two independent researchers conducted the search process to ensure a precise and unbiased process. The following data were retrieved from each study: author (publication year); country; research design; measurement indicators; outcome variables; and significant findings.

3. Results

3.1. Search Results

Figure 1 illustrates the flow chart of the systematic review. We collected 398 relevant papers from the literature containing the above-listed keywords in the titles and abstracts. A total of 243 publications were found after duplication screening. After title and abstracts reading, 30 articles were considered eligible. Finally, 18 articles were obtained after a full-text reading. These articles presented evidence on the impact of forest therapy based on VR on stressed patients. A paper count was performed to determine the number of countries with publications concerning nature forest therapy using VR. Figure 2 shows studies by countries on nature forest therapy using VR. As indicated in Figure 2, China, Australia, Germany, Sweden, USA, and Japan have the highest publications (two articles) in the designated journals. Taiwan, Lebanon, Singapore, Korea, Malaysia, and Poland have published one article.

According to the search results between 2013 and 2016 (four years), only two publications were made on the nature of forest therapy based on VR. These studies were solely in 2013 and 2014, while no studies were published in 2015 and 2016. This implies that the concept of using forest therapy based on VR was still in its infancy during these years. However, since 2017, articles have gradually increased, reaching three articles in 2019, six in 2020, and three in the first half of 2021. These statistics in Figure 3 are not unexpected, given

that VR has lately been widely used in research, particularly in therapy. Additionally, more research is required to improve people's well-being and mental health in the workplace and everyday situations.

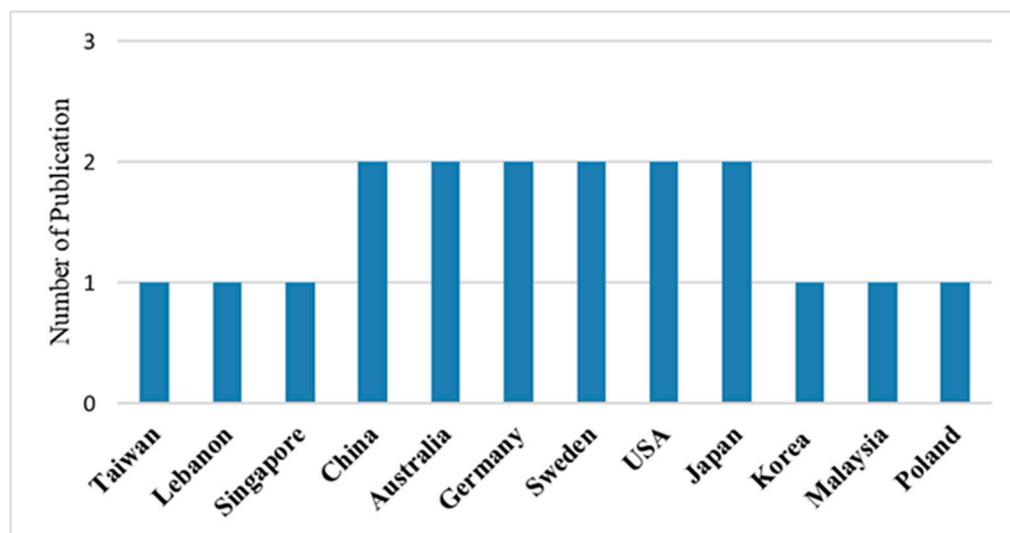


Figure 2. The publications of the nature of forest therapy based on VR by country focus.

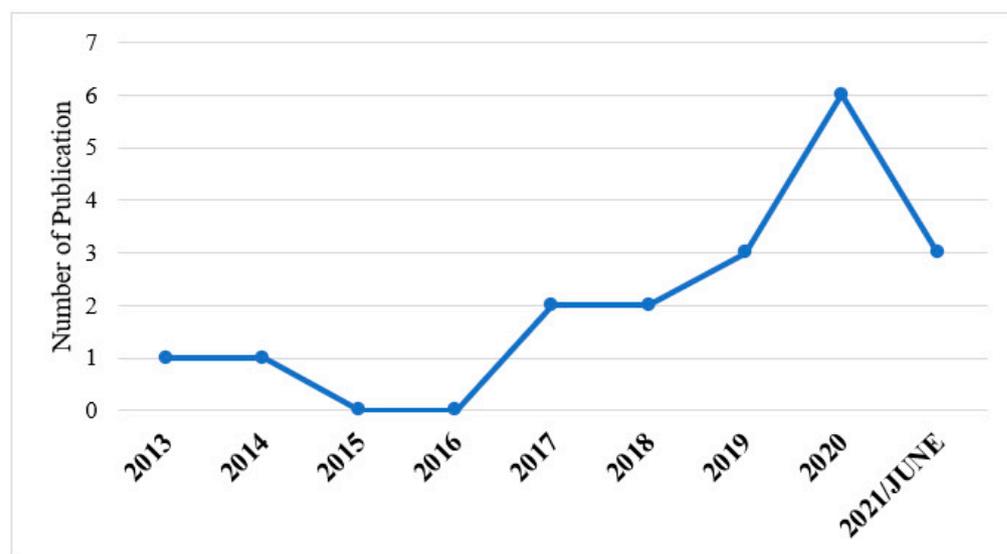


Figure 3. The annual number of publications on the nature of forest therapy based on VR from 2013 to June 2021.

3.2. Psychosocial and Physiological Effects of Forest Therapy

Recent studies focused on investigating the combined effect of psychological or physiological variables and the external environment on physical and mental health. Earlier studies on forest therapy concentrated on psychosocial and physiological factors, often enhancing an individual's moods (Table 1). Most studies on the psychosocial impacts of forest therapy used self-report surveys to assess participants' mood states and overall mental health. Among the most employed methods were the Profile of Mood States (POMS), positive and negative affect scale (PANAS), visual analogue scales (VAS), standard stress scale (SSS), perceived stress scale (PSS), and state and trait anxiety inventory (STAI-S). Along with psychosocial impacts assessment, twelve studies [35,36,45–54] examined the effects of forest therapy on physiological health by evaluating heart rate (HR), heart rate variability (HRV), systolic blood pressure (SBP), diastolic blood pressure (DBP), salivary

amylase (SA), the standard deviation of R-R intervals (SDRR), blood volume pulse (BVP), and skin conductance levels (SCL).

Four of these studies used POMS and HR/HRV to evaluate the psychological and physiological responses [46–49]. Tsutsumi, Nogaki, Shimizu, Stone, and Kobayashi [46] conducted a study to see if stimulation from watching one's favorite video of the sea or the forest affected relaxing. Participants were instructed to watch DVDs for sea and forest with natural sounds for 90 min. The POMS scores were collected on every session, and Bispectral Index System value and HRV were monitored by the Bispectral Index System and MemCalc system. Each indication was compared between the two groups of six participants based on their sea or forest scenery choice. The heart rate, persistent arousal, and high frequency changed significantly as watching the favorite video. These findings suggested that the viewer's favorite movie of the sea or forest had a calming impact. Yu, Lee, and Luo [47] investigated the physiological and psychological reactions to virtual reality forests and urban environments. This study used a cross-over and pretest-posttest approach to assess the VR environment's impact on forests and urban restoration. The researchers gathered both physiological and psychological responses (POMS). The findings revealed that the subjects' systolic blood pressure and heart rate reduced over time, regardless of contextual variables. In simulated urban contexts, an increased degree of weariness and a decreased level of self-esteem was observed as psychological responses. However, in simulated forest conditions, vigor levels increased, and negative feelings, such as perplexity, tiredness, anger-hostility, tension, and despair, decreased. Overall, the benefits of immersing in a forest environment have proved to be more significant. Another study was carried out by Hong, Joung, Lee, Kim, Kim, and Park [48] to examine the influence of VR forest video on adult stress relief using POMS, HRV, and HR measurements. Arithmetic tasks (1-digit by 2-digit numbers multiplication) were used to induce stress in participants before giving them five minutes to watch a virtual reality forests (VRF) video. This study revealed that stress index and HR decreased, confirming that VRF reduces stress in adults, stabilizes physiological state, and improves psychological state. Wang, Shi, Zhang, and Chiang [49] presented seven exemplary forest rest areas discovered during fieldwork in Beijing to participants using VR. Blood pressure, heart rate, salivary amylase, and the Brief POMS were physiological and psychological indicators, with stress level as the dependent variable. Each environment type was randomly allocated to 96 participants, and only a kind of forest resting setting was observed. According to this study, all seven forest rest environments may reduce stress effects to some level. The impact of different types of forest resting environments on stress relief is distinct, with the most natural settings having the greatest impact on stress relief.

Two studies [35,36] used STAI-S as a psychological indicator and HR/HRV or SCL as physiological indicators. For example, [35] studied the effect of natural noises and stress recovery in natural surroundings. The study investigated subjective stress (STAI-S) and physiological recovery (HR) in two virtual natural environments—(1) with exposure to natural sounds and (2) without exposure to natural sounds—and one control condition after producing stress with a virtual stress test. The results revealed parasympathetic activation in the group exposed to natural sounds in a simulated natural environment, implying increased stress recovery in such settings. The control group and the group that recovered in virtual nature without sound showed neither autonomic activation nor inactivation. The findings imply a possible mechanistic relationship between nature, natural sounds, and stress recovery, indicating the potential use of VR as a viable method to manage stress. Li, Sun, Sun, Yuan, and Li [36] investigated the influence of brightness levels on stress retrieval when watching VRF with simulated natural light. This study used pre-test and post-test strategies to examine the effect of different brightness levels on stress recovery using a virtual forest environment. A total of 120 participants were recruited to watch stimuli from six immersive virtual environments (IVEs) through a head-mounted display. The physiological and psychological responses, as well as perceived

environmental characteristics, were assessed. This study showed that VRF scenes of bright sunlight reduced stress more effectively than scenes from the dark night.

In two more studies, HR was used with VAS [54] and PANAS [50] to evaluate the effectiveness of VR in reducing stress. Schebella, Weber, Schultz, and Weinstein [54] use IVEs comprised of visual, auditory, and olfactory stimuli to examine the impacts of biodiversity on stress recovery. Their study employed three natural and one urban environment (none, low, moderate, and high). A further IVE with high biodiversity was also added, but no auditory or olfactory stimulation. The study reported consistent reactions to well-being using physiological and self-reported measurements. However, biodiversity has been shown to have a non-linear effect on stress recovery, and is most effective in urban settings and most influential in moderately diverse environments. It was stated that multisensory (visual, auditory, and olfactory) stimulation improved stress recovery and did not impact the immersion sense of the participants when compared to visual-only encounters. In [50], the impact of VR technology on reducing stress and enhancing individuals' moods was investigated using a pulse-oximeter and the PANAS. This study was conducted on 36 women with substance use disorder (SUD) for the first 10 min of their daily programs in a residential treatment program for four weeks, including two activities. A cross-over design was employed to compare seeing natural environments and performing mindfulness-based activities. As a result, there were statistically significant reductions in mean negative affect ratings and heart rate after seeing a nature scene and conducting mindfulness-based exercises. Additionally, general mood significantly improved for participants in both circumstances.

The other four studies used other psychological and physiological indicators, such as EDA and MRJPQ in [45]; GHQ12 and GSR in [51]; POMS, PSS, and GSR in [52]; and PANAS and SDRR in [53]. For instance, Anderson, Mayer, Fellows, Cowan, Hegel, and Buckey [45] used VR technology with immersive natural scenery to reduce stress levels and improve participants' moods. They recruited 18 participants (9 men and 9 women), aged 32 to 44. The participants were required to watch three 360° views of an indoor control, rural Ireland, and remote beaches for 15 min. Before the scenes, the subjects were psychologically stressed with arithmetic tasks. Psychophysiological arousal was measured using EDA and heart rate variability. The mood and scene qualities were assessed using the positive and negative affect schedule and the 15-question MRJPQ. When comparing the natural sceneries to the control scenario, the reductions in EDA from baseline were larger at the end of the natural scenes. The natural settings reduced negative influence from baseline, whereas the control scene did not. The control scene had lower scores of MRJPQ than natural situations. The preferred scene in the two natural sceneries reduced the negative effect and increased MRJPQ scores than the second-choice scene. Their study revealed that natural VR could produce relaxation with the right selection of scenery, owing to its impact on assessing the mood and quality of the scenery. In [51], VR was integrated with bilateral stimulation for stress relief to evaluate EMDR. The authors conducted three relaxation training sessions on 28 healthy office workers who recorded their subjective stress (GHQ12), HR, mood, GSR, and muscle response prior to the session. The study revealed a significant reduction in stress levels and improved participant mood using VR based on their findings. Mostajeran, Krzikawski, Steinicke, and Kühn [52] studied the effects of exposure to a forest and an urban virtual environment on mood, stress, physiological responses, and cognition. The environments were shown as either traditional photo slideshows or 360-degree films on a head-mounted display. Their findings revealed that the forest environment had a favorable effect on cognition while the urban environment disrupted mood. Furthermore, images of an urban or forest setting could lower physiological stimulation than immersive 360-degree movies. A more recent study by [53], with 111 subjects recruited, highlighted the impact of buildings with vertical greenery on negative psychophysiological stress responses using VR technology. The vertical greenery covered the balconies, walls, and pillars of buildings in the plant state. The plants were replaced with equivalent hues of green in the color

condition. The study suggested that vertical greenery prevented stress from increasing, as indicated by heart rate variability.

Two studies measured only physiological responses, such as SCL in [55], and NIRS, HRV, and SD in [56]. The effects of visual stimuli (virtual 360-degree images of forests, urban areas, and parks) on recovery from physiological stress have been compared by [55] to the effect of congruent olfactory stimuli (natural and urban smells) and acoustic stimuli (birdsong and noise). In their study, a total of 154 participants were randomly assigned to one of the three situations, urban area, forest, or park, and were then exposed to stress (operationalized by skin conductance levels). This study showed a significant reduction in stress in parks and forests but not in cities. Igarashi, Yamamoto, Lee, Song, Ikei, and Miyazaki [56] investigated the physiological effects on relaxation of 3D floral pictures compared to 2D images upon prefrontal cortex and autonomic nerve activity. Ninety male university students, aged 22 to 23, were given 90 s to see the water lily picture in 3D and 2D images. Their study detected prefrontal cortex (PFC) activity using near-infrared spectroscopy, whereas autonomic nerve activity was quantified using HRV. Besides, a modified SD approach was used to determine psychological impacts. The 3D visual stimulation, compared to 2D visual stimulation, resulted in significantly decreased hemoglobin concentration in the right PFC. Additionally, it caused lower sympathetic activity as measured by the low- and high-frequency ratio of the HRV component and substantially more realistic feeling, as evidenced by higher SD ratings.

The four final research used psychological indicators based on questionnaires and observations. Moyle, Jones, Dwan, and Petrovich [34] used the observed emotion rating scale (OERS) to assess the impacts of VRF on dementia patients' engagement, apathy, and mood states, and learn more about staff, patients, and their families' perspectives. Their study was conducted by the mixed method, consisting of ten individuals with dementia, ten family members, and nine care professionals from two residential aged care facilities by one care provider. Residents took part in a VRF session that was facilitated. The results showed that residents, family members, and staff agreed that the VRF had a favorable impact. Residents reported significantly higher levels of pleasure and attentiveness during the VRF session. They also felt more fear and anxiety during the forest encounter than the comparative normative sample. The VRF was considered to have a favorable impact on dementia patients, although a larger level of fear and anxiety has been observed during the VRF than the normative sample. Besides, Reese, et al. [57] used SSS and PANAS to evaluate participants' condition following the VR experience irrespective of the control. This study recruited 64 participants who navigated by an experimenter or navigated across a VR environment. They claimed that lower stress could be experienced through a VR environment than actively navigating through it.

Scates et al. [58] used a Likert-type scale questionnaire to observe whether a VR nature could alleviate stress and discomfort in cancer patients in a treatment center. The authors recruited 50 patients having their regular chemotherapy treatment sessions. These patients were evaluated for two visits for stress and pain during their intravenous (IV). They watched a naturally inspired VR simulation during the second visit while getting their IV. The study found that cancer patients viewing naturally inspired VR were significantly less frustrated, more relaxed, and had peaceful feelings and positive distractions. Besides, Rozmi, et al. [59] highlighted several design aspects in terms of visual realism, navigation methods, and aids for users to be fully immersed in the virtual forest environment, thus reducing their stress levels. The design was based on a game concept and received positive feedback from users, and the study suggested using elements of nature, such as vegetation, natural habitat, and forests.

Table 1. Characteristics of included studies.

References	Country	Group Interventions	Sex (M:F), Age	Recovery Duration	Aim	Outcome	Measurement Technique	Results
[35]	Sweden	EG: VR with nature sounds CG: VR without nature sounds or No VR treatment	EG: 10 (10:0), age 28.2 ± 10.3 . CG: 10 (10:0), age 28.1 ± 4.4 ; 10 (10:0), age 26.7 ± 3.4 .	40 min	Explore physiological recovery in two distinct virtual natural settings, with and without interaction with natural sounds.	The findings imply a possible mechanistic relationship between nature, natural sounds, and stress recovery.	STAI-S, HRV, HR, TWA	After the intervention, significant differences were discovered between groups (HR, $p = 0.007$; TWA, $p < 0.001$).
[56]	Japan	EG: 3D flower images CG: 2D flower image	EG & CG: 19 (19:0), age 22.2 ± 0.6 .	90 s	Evaluate physiological relaxation effects on autonomic nerve activity by viewing 3D versus 3D flower images.	The study found that realistic 3D floral images boost physiological relaxation more effectively than 2D floral images.	NIRS, HRV, SD	Significant differences were found (NIRS, $p < 0.01$; HRV, $p < 0.05$; SD, $p < 0.01$) between the two groups.
[45]	Lebanon	EG: natural scenes (rural Ireland and remote beaches), and indoor control. CG: -	18 (9:9), age 32 ± 12 .	15 min	Promote nature exposure for those living in isolated, restricted settings.	VR nature produced relaxation, and scene selection had a substantial impact on both mood and visual perception.	EDA, MRJPQ	Significant differences were found (EDA, $p = 0.002$; MRJPQ, $p < 0.014$) between the natural scenes and indoor control.
[46]	Japan	EG: nature scene of sea or forest, and baseline CG: -	12 (12:0), age 22.2 ± 1.7 .	90 min	Evaluate the influence on people's relaxation while viewing a video of the sea or a forest.	The viewer's favorite movie of the sea or forest had a calming impact. The findings also imply that watching a favorite scene of a natural setting could help to relieve stress and exhaustion.	POMS, HR, low frequency, high frequency, BIS	Significant stress reduction was found (POMS, $p < 0.05$) between the nature scenes (sea and forest) and their baselines.

Table 1. Cont.

References	Country	Group Interventions	Sex (M:F), Age	Recovery Duration	Aim	Outcome	Measurement Technique	Results
[34]	Australia	EG: virtual reality forest CG: -	Residents with dementia: 10 (3:7), age = 89 ± 4.7 ; Family members: 10; Care staff: 9.	15 min	Assess the apathy, engagement, and mood of dementia patients and to examine employees, dementia patients, and family experiences.	The VRF positively affected dementia patients despite a higher level of fear/anxiety during the VRF compared to the normative group.	OERS	Residents reported higher levels of happiness ($p = 0.008$), attentiveness ($p = 0.001$), and anxiety/fear ($p = 0.16$).
[47]	Taiwan	Cross-over study: forest and urban VR environments.	30 (13:17), age 20–29.	9 min and 30 s	Evaluate the effects of virtual forests on boosting people's psychological well-being.	Immersing in forests could provide benefits such as reduced negative emotions and enhanced vigor as compared to urban environments that lower self-esteem and raise fatigue levels.	PASAT, POMS, BP, HRV	Significant decrease in negative emotions (tension, $p = 0$, depression, $p < 0.017$) observed in forest environments.
[55]	Sweden	Pseudo-randomised study: VR forest, park and urban environments.	Forest: 52 (24:28), age 27; park: 52 (26:22), age 28; park: 50 (22:28), age 27.	3 min	Assess the potential for stress recovery using three different environments: urban areas, parks, and forests.	According to the study, residing in an urban environment with no green space, traffic noise, and tar and diesel odors can expose people to a certain amount of stress compared to natural environments such as gardens and forests.	SCL	Significant differences were found between urban areas and both forest ($p = 0.003$) and park ($p < 0.001$), while no significant differences ($p = 0.39$) between forest and park.

Table 1. Cont.

References	Country	Group Interventions	Sex (M:F), Age	Recovery Duration	Aim	Outcome	Measurement Technique	Results
[48]	Korea	EG: VR forest, baseline CG: -	40 (23:17), age 24.4 ± 2.8 .	5 min	Evaluate viewing forest videos in reducing stress in adults.	The study revealed that watching videos of VR forests could affect individuals' stress levels, regulate physiological conditions, and positively affect their mental conditions.	HRV, HR, SI, POMS, SD, PANAS	Significant decrease in stress was found (SI, $p < 0.01$; HRV, $p < 0.05$; HR, $p < 0.01$; SD, $p < 0.01$; POMS-TMD, $p < 0.01$).
[49]	China	Independent group design: Pre and post-VR forests.	96 (33:63), age 24.03 ± 5.29 .	5 min	Evaluate stress recovery after viewing VR videos of seven forest environments: (1) structure, (2) wood, (3) wood with bench, (4) wood with platform and bench, (5) platform with trees, (6) waterfall with trees, and (7) pool with plants.	The study investigated seven forest resting environments. These environments showed a distinct impact on stress relief and proved to reduce stress to some level.	SBP, DBP, HR, SA, POMS	Significant differences were found in various environments with greatest impact in type 6: (SBP, $p < 0.01$; DBP, $p < 0.05$; HR, $p < 0.05$; SA, $p < 0.05$; POMS-TMD, $p < 0.01$).
[36]	China	Independent group design: six immersive virtual environments (IVE) (lightest to darkest).	120 (27:93), age 19.79 ± 1.90 ; 20 for each scene.	6 min	Investigate how varied natural light brightness levels affect people's stress recovery effects in the forest and provide some proof for stress reduction's mental well-being benefits.	This study confirmed that bright sunlight scenes (i.e., the lightest, lightest, lightest) in the virtual forest ease tension more effectively than the darkest night sceneries. Another discovery indicated that dark settings, such as sunrise without sunlight but with a hint of brightness, had the same effect.	SCL, BVP, STAI-S	Significant differences were found in natural light brightness ($p < 0.001$; SCL, $p < 0.001$; BVP, $p < 0.001$; STAI-S, $p < 0.01$).

Table 1. Cont.

References	Country	Group Interventions	Sex (M:F), Age	Recovery Duration	Aim	Outcome	Measurement Technique	Results
[54]	Australia	Independent group design: four levels of biodiversity (urban IVE, none; natural IVE, low, moderate, and high).	52 (24:28), age 37.6 ± 10.6 . Not stated the number of participants for each scene.	5 min	Evaluate the effects of biodiversity IVEs on recovery from induced stress.	The findings revealed similar well-being responses across self-reported and physiological measurements, implying that biodiversity had an impact on human happiness. In the urban IVE, stress recovery was the least effective for most well-being metrics.	VAS, HR	Significant differences in stress recovery for subjective stress, anxiety, and happiness were found between urban and low biodiversity IVEs ($p < 0.05$). For HR, no significant differences were found between the urban and either biodiversity IVEs.
[58]	USA	Repeated measures design: cancer patients with/without viewing VR during the intravenous procedure (IV).	50 (15:35), age > 65 (n = 29).	During IV procedure for 30 consecutive days	Investigate VR during IV procedures on reducing stress and pain among cancer patients.	The participants felt significantly less frustrated and more relaxed while watching VR nature scenes throughout intravenous chemotherapy.	Likert-type scale questionnaire	Significant increases were found in positive distractions ($p < 0.0001$), relaxation ($p < 0.05$), feelings of peace ($p < 0.01$).
[50]	USA	Cross-over study: nature scene versus practicing mindfulness-based activities.	36 (0:36), age ≥ 18 .	4 Weeks, 10 min daily	Evaluate the effectiveness of VR in reducing stress among people with SUD.	This study provided preliminary evidence that nature-viewing had similar benefits as a mindfulness therapy for treating stress and low mood associated with recovery from SUD.	PANAS, HR	Significant decreases in mean negative affect scores ($p = 0.001$) and heart rate ($p \leq 0.001$) were found while viewing nature scenes and practicing mindfulness-based activities.
[59]	Malaysia	Observational study.	Public respondents.	-	Use VR nature therapy as an alternative tool for stress relief.	An early study found that VR had potential as an aid in therapy, with positive outcomes from users.	Users' feedback	-

Table 1. Cont.

References	Country	Group Interventions	Sex (M:F), Age	Recovery Duration	Aim	Outcome	Measurement Technique	Results
[51]	Poland	Cross-over study: VR immersion with visual, auditory, and tactile conditions.	23 (10:13), age 37.2 ± 9.7 .	6.3 min	VR combined with bilateral stimulation in EMDR as a stress-relieving tool.	According to the study's preliminary findings, VR-based bilateral stimulation may boost mood and reduce stress.	GHQ12, GSR	No significant differences were found between groups. For GSR, visual was most effective in subjective assessment of stress level (pre, 80%; post, 100%).
[52]	Germany	Cross-over study: forest and urban VR environments.	34 (23:11), age $27.26 > 2.14$.	6 min	Demonstrate the health and well-being advantages of natural environments.	The forest environment had a beneficial influence on cognition, while the urban setting had a negative effect on mood. Photos of an urban or forest scene succeeded better than 360 videos to reduce physiological arousals.	POMS, PSS, GSR	Significant differences in participants' mood (POMS, $p < 0.05$; PSS, no significant effects; GSR, $p < 0.001$)
[57]	Germany	EG: VR with active control and 30-s familiarization CG: VR with no control.	EG: 32 (8:24), age 23.31 ± 4.7 . CG: 32 (9:23), age 22.7 ± 2.85 .	5 min	Identify the impact of control on the positive effects elicited by virtual nature environments.	The study showed that participants reported reduced stress, and their positive affective states were raised following the VR experience.	PANAS, SSS	Significant positive effect was found after VR (PANAS, $p < 0.001$; SSS, $p < 0.001$)

Table 1. Cont.

References	Country	Group Interventions	Sex (M:F), Age	Recovery Duration	Aim	Outcome	Measurement Technique	Results
[53]	Singapore	Independent group design: VR based plant or color conditions.	111 (40:71), age 21.63 > 1.81.	5 min	Demonstrate the influence emotion and stress-buffering of vertical greenery outside buildings.	The study suggested that vertical greenery on city buildings could help to mitigate the negative psychophysiological effects of stress.	PANAS, SDRR	Significant decreases were observed in SDRR ($p = 0.01$) and positive affect ($p < 0.00$) in color conditions. No significant main effect of the condition was found.

M: male, F: female, EG: experimental group, CG: control group, SSS: standard stress scale, PANAS: positive and negative affect scale, SDRR: standard deviation of R-R intervals, GSR: galvanic skin response, PSS: perceived stress scale, GHQ12: general health questionnaire, HR: heart rate, HRV: heart rate variability, VAS: visual analogue scales, BVP: blood volume pulse, SA: salivary amylase, SBP: systolic blood pressure, DBP: diastolic blood pressure, SI: stress index, SCL: skin conductance levels, BP: blood pressure, PASAT: paced auditory serial addition test, STAI-S: state and trait anxiety inventory, EDA: electrodermal activity, OERS: observed emotion rating scale, MRJPQ: modified reality judgment and presence questionnaire, TWA: t-wave amplitude, NIRS: near-infrared spectroscopy, SD: semantic differential, POMS: profile of mood states, BIS: bispectral index system.

3.3. Effectiveness of VR Intervention to Relieve Stress

All eighteen studies stated in Table 1 examined the effectiveness of forest VR in treating physiological and psychological stress. These studies concluded that VR is a valuable tool for assessing and promoting relaxation among different population groups and found a statistically substantial reduction in stress levels, except for the study by [51], who evaluate VR immersion with visual, auditory, and tactile elements. According to the selected studies, realistic 3D views were found to have a more significant influence on physiological relaxation than 2D views [56]. Four studies [48,49,57,59] found that individuals exposed to forest VR experienced a more remarkable improvement in their stress levels than baseline or before the intervention. Another four studies [47,52,54,55] compared stress levels in virtual forests with urban areas following the VR intervention, revealing reduced negative emotions and stress levels in virtual forests. Even vertical greenery on urban buildings, as claimed by Chan, Qiu, Esposito, and Mai [53], might help minimize negative psychophysiological impacts of stress.

Additionally, elements of nature, such as sounds [35], were positively correlated with stress recovery after the VR intervention with sounds than without sounds. Similarly, bright sunlight scenes [36] were more effective in reducing stress than other natural light brightness levels. The effectiveness of nature was not a monopoly of forests, but beaches [45] and seas [46] provide similar positive effects to an extent. In health practice, VR has been proven to mitigate stress among patients with SUD [50], dementia [34], and cancer, during the intravenous procedure [58].

4. Discussion

This systematic review intended to synthesize existing evidence on the practicality of VR nature therapy in stress relief. In recent years there has been a growing interest in the use of VR to simulate natural environments for promoting well-being and health. Eighteen studies were included in the review. VR has been shown to be a workable and acceptable means of relieving stress, whereas virtual environments, such as nature or its elements, improved stress recovery in comparative conditions. The target population groups in the studies presented in this review covered different age ranges and involved students, cancer patients, dementia patients, people with SUD, research institute colleagues, organization workers, social workers, and public members.

The VRF is more operable in practice with better control of the independent factors and offers a more realistic experience than image or video. The VRF appeared to be used in health practice. For example, stress research on patients with dementia [34], cancer [58], and SUD [50] has been respectively conducted, which is a good initiative for further studies covering more psychological conditions.

Interaction with virtual nature elements, such as sound, lighting, and weather, can efficiently induce recovery for individuals with psychological disorders, including stress conditions. Various studies have investigated the exposure effect of these natural elements. Li, Sun, Sun, Yuan, and Li [36] used several brightness levels (i.e., the lightest, lighter, light), reporting their capability to reduce stress to a certain level. Ref. [35] found a relationship between nature sounds and stress recovery. Other factors, including weather, aquatic components, temperature, and humidity, may significantly affect physiological and psychological well-being. However, there are difficulties in knowing which elements of nature have a positive effect on people. More challenging is that individuals' differences in responding to these elements can vary depending on the environment in which each person lives. Although equitable studies are much harder, such parameters have to be controlled when designing a study.

Further, modern urban design strategies aim to emulate key forest features that are important in urban settings. Urbanization inevitably reduces the availability of green spaces, while green spaces generally improve public health and stress recovery. To study the effects of greenery factors on the psychological condition of the urban population, VR technologies have been incorporated to design such spaces. Performing a real-world study

that includes vertical greenery on the exteriors of a row of buildings is a challenging task that requires considerable effort. Field experiments should be conducted to improve the ecological validity of a study. Based on reviews, greenery factors were a viable variable for achieving healthy urban environments [53–55]. Urban green spaces can produce cognitive and psychological advantages by reducing stress [53].

Most studies included in this review confirmed that the effectiveness of VFT in overcoming methodological barriers in environmental research and demonstrated its ability to significantly improve participants' health, mood, and ability to recover from stress. The intervention duration, either short-term < 10 min [36,47–49,51–57,59] or long-term > 10 min [34,35,45,46,50,58], positively impacted indicators of perceived well-being, indicating the effectiveness of VRF treatment. According to the reviews, the combination of nature and sound features in VRF environments has been demonstrated to stimulate the parasympathetic nervous system and contribute to relaxation, stress restoration, and behavioral regulation [35]. A more immersive presentation of the VRF could result in more beneficial natural outcomes, and participants' preferred views would have the most relaxation effect [46]. Thus, experiencing natural virtual surroundings may be a viable solution to gaining the therapeutic benefits of interaction with real-world nature, particularly for individuals who are unable to visit real forests or outdoor areas.

The strength of these reviews involved controlling independent factors, enabling researchers to identify changes in results of VR-based stress therapy using physical and psychological measures. Limitations included the availability of students and young people samples, which implies that the results could not be generalized to other age ranges or those with a lower educational level. Furthermore, some studies were subject to relatively small sample sizes and various forms of bias [34,45–47,51,56]. For example, the use of self-reports may lead to a more positive assessment by respondents and the prevalence of the one-session format may contribute to bias in innovation, as positive assessment may be related to VR innovation and not to its intervene. Although most studies use both genders (males and females), few studies have restricted their studies to one gender, which could be a big limitation. For instance, refs. [35,46] have limited their studies to males only, while Reynolds et al. have recruited only female participants with SUD. Although using one group of sex may help to standardize the data and limit the generalizability of studies' results, the diversification of the research group may produce diverse outcomes.

Although the studies discussed above show that VFT holds potential for psychiatric rehabilitation, there is still a lack of standardization in VR terminology and solutions. A more consistent approach to VR software architecture would certainly simplify and accelerate the uptake of VR therapies. This issue may be rectified shortly, as manufacturers strive to provide turnkey VR solutions. The programming requirements for creating and developing virtual environments, on the other hand, may be the most significant problem. This is a significant impediment to mainstream adoption, while standardization of VR material would considerably alleviate the issue, and the situation is improving progressively.

4.1. Direction of Future Studies

Future studies should consider individual social differences and expand to standardized measures and interventions for stress therapy. Long-term studies are crucial for the efficacy and clarification of virtual environments. The optimal period of intervention exposure to guarantee the practicability of VR-based stress therapy remains undetermined, and, therefore, more robust studies are required. Future studies could examine the psychological advantages of natural virtual environments in stress therapy by considering various natural elements. The current review discovered a lack of consistency in viewers' positions (standing or sitting) in the studies reviewed, given that standardization of positions could provide a more accurate evaluation. Additionally, further controlled clinical studies using VR therapy on ambulatory people with distress, anxiety, post-traumatic stress disorder (PTSD), depression, and stress-related conditions are needed to enhance coping strategies.

4.2. Strengths and Limitations of the Current Review

This is the first review that emphasizes the efficacy and acceptability of VR for nature therapy of people with stress conditions. The used methodology included search queries on the digital academic databases and non-indexed references. This method boosted the number of articles searched and increased confidence that the review's result integrated all relevant studies. The search process, including screening, data extraction, and eligibility assessments, was conducted by two independent researchers to ensure a precise and unbiased process.

A limitation of the current review is that diversity of applications, target population, and measurement techniques restricted comparisons between studies. Another limitation is that the search strategy was confined to databases in English, which may have ruled out studies in other languages. Reviewed studies used self-report measures, as well as physiological, psychological, or physical parameters, as no stand-alone metric was used for measuring stress. Correspondingly, virtual environments aimed at promoting stress relief were diverse. Therefore, care must be taken when comparing studies and concluding that natural virtual environments effectively relieve stress.

5. Conclusions

This review provides a narrative synthesis of the literature on VR-based nature therapy for stress relief. Most studies merged virtual environments with natural elements, such as sounds, flowers, scenes, light, or vertical greenery on buildings, and all reported a significant decrease in stress levels. The current systematic review has limited the generalizability of the results, and any conclusions should be carefully derived. However, VR is a potential technology for relieving stress in people. It is a practical and affordable intervention that allows people to relax at home or work. This may be even more relevant currently, as the COVID-19 outbreak has caused an increase in stress worldwide.

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