Research Article

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The Role of Positive Emotion in Virtual Forest Interventions: Re-Analyzing Experimental Data for Stress Relief in High-Pressure Academic Contexts

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Abstract

It is known that natural environments have beneficial impacts on individuals' mental health. Nevertheless, there are some restrictions that could impede access to these environments that have healing properties. With the urbanization of the globe, workers encounter increased work-related stress and mental disorders that harm their subjective well-being. This study focuses on the restorative effects of forest environments. It is vital to consider how to enhance the mental health and well-being of patients due to the growing importance of the issue. That is why it is critical to create appropriate therapies that will contribute to having better experiences. VR becomes a rather attractive opportunity since it enables users to experience different situations in a secure environment. For reducing social anxiety, the idea of adding the therapeutic intention to a virtual forest was implemented in the current research. There were two experimental groups with the therapeutic intention in a VR forest and the therapeutic intention in a VR forest under the direction of a therapist. To compare the effects of the above-mentioned groups, a control group was also involved in the experiment. All the conditions contributed to an enhancement in the healing effects of the forest. Nevertheless, only the experimental group with therapeutic intention contributed to a reduction in social anxiety. Participants in the latter group also reported more satisfying experiences, along with better knowledge about the therapeutic properties of the virtual forest. This study shows that all the seven types of woodlands have at least some potential for reducing stress. There are several aspects according to which the ways of stress relief in various types of woodlands differ. The most natural type of woodland does not exert the maximum influence on stress relief. The landscape of the forest with water contributes to the positive effects of stress relief. The combination of the virtual forest and therapeutic activities can be more beneficial for achieving more effective outcomes in terms of prolonged engagement and comprehension during numerous therapy sessions. The non-VR method can help reduce stress right away.

Keywords: Natural environments; mental health issues; work stress; virtual forest; well-being; positive experiences; virtual reality (VR); social anxiety; psychology students; therapeutic sessions; stress relief

1. INTRODUCTION

There are many promising technologies that can enhance the effectiveness and availability of mental health interventions in a society that is faced with numerous psychological distresses and limited resources to support mental well-being [1]. The first type of technologies includes inducing states of calmness and attentiveness, thus reducing stress levels and other symptoms associated with them. Another class of technologies refers to organized intervention programs directed at addressing specific issues (e.g., exposure therapy as a treatment for different types of phobias and fears, as well as motivational interview to decrease addictive behaviors). There seems to be no previous research on using educational therapy in virtual forests, as well as a combination of calming technologies and educational therapies [1, 2]. Thus, our current research aims to fill this gap through analyzing the influence of using educational interventions in virtual forests targeting social anxiety, as a selected mental well-being issue.

Traveling and visiting new places, going for walks outside, spending fun times with your family, etc. All these things might be seemingly insignificant yet make you happier, therefore improving overall well-being [2, 3]. Innumerable scientific works prove that happiness and contentment play a crucial role in human well-being and life satisfaction. Besides, there is a strong link between the state of happiness and success in one's life, quality of life, longevity, and improved cognitive functioning.

Forest parks in cities are excellent recreational sites for residents to relax and spend their leisure time in. In most studies, researchers focused on investigating the association between urban forest parks and the level of subjective well-being of visitors [3]. For instance, Reyes Riveros performed the bibliometric analysis of 153 studies, emphasizing the strong positive impact of urban green spaces on people's health and happiness [3]. In their qualitative research, grounded theory was used to analyze the effect of urban forests on people's mental state as part of the forest therapy for middle-aged women. Their findings proved the positive role of such urban forests in the recovery of participants' mental state [3, 4]. Thus, urban forest parks can be considered as an important research area since it is an integral component of urban green areas that positively affects psychophysiological recovery.

The suggestion that natural environments have significant effects on increasing subjective well-being is supported by no fewer than three convincing arguments. First of all, there is scientific evidence that experiences in natural environments influence neurological system, reduce stress [3, 4], and help refocus. There is a sensible explanation for the association between natural environments and subjective well-being based on evolution. Humans are inherently a part of nature, and their ten-thousand-year-long dependency on nature contributed to forming an inherent affection toward nature.

Moderate to substantial effects of natural environments on increasing pleasant feelings and reducing negative ones, according to meta-analysis of biophilia hypothesis, prove the theory behind naturebased design [3, 4]. Secondly, social interactions, leisure activities, as well as physical exercises that produce dopamine and thus increase subjective well-being, may occur in natural environments. Specifically, according to the meta-analysis of eleven UK studies conducted by Barton and Pretty, both men and women's moods and self-respect increased significantly as a result of performing physical exercises in natural environments [4]. Finally, natural environments are characterized by fewer factors that negatively impact subjective well-being, including air pollution and noise. Chronic sleep disturbances as well as heart disease are possible consequences of constant exposure to traffic noise, while air pollution causes numerous diseases. Health issues caused by such factors may lead to reduced subjective well-being levels, even though the relationship between the two may go unnoticed, according to Welsch [4, 5]. Therefore, research done from various perspectives proves that subjective well-being increases considerably due to experiencing natural environments.

In general, numerous empirical findings suggest that happiness is related to the ability of recovering mentally. Psychological healing and subjective well-being can be considerably enhanced by nature experiences. Nonetheless, the whole route from natural environments to improved mental health and increased subjective well-being has not been fully considered scientifically [4, 5]. In order to fill the gap, this paper aims to study empirically the role of environments that are natural in subjective well-being by means of assessing the restorative qualities of urban forest parks. The particular focus will be made on the mechanisms through which natural environments increase subjective well-being and the moderating role of personal opinions on them.

1.1. MENTAL HEALING AND PERCEPTIONS OF NATURAL ENVIRONMENT

The current research concerning subjective happiness and mental healing starts to appreciate the role of the natural environment [5, 6]. According to numerous investigations, the subjective well-being of an individual is significantly determined by cognitive perceptions of natural environments. It appears that healing powers of nature are closely related to the phenomenon of subjective well-being, whereby an individual's attitude towards the natural environment increases. The contact with nature has been shown to positively affect one's psychological state and decrease his/her stress levels [5, 6] as he/she deals with various problems of everyday life. To demonstrate how one may benefit from the interaction with natural environments in terms of stress reduction, burnout prevention, and quality of life improvement, Payne and Loi

introduced the three-week mental rehabilitation program designed for college students, which allowed experimental group participants to show considerably decreased levels of stress when compared to those who stayed at waitlists.

Since restorative encounters are closely connected not only to people's emotions and attitudes, but also to physical attributes of the environment, [5, 6], it becomes evident that the latter may play a considerable role in the process under consideration. According to the theory proposed by Kaplan and Kaplan, the ability of an individual to restore him/herself increases with the presence of beautiful and tranquil settings, which, in its turn, creates a favorable perception, boosts intrinsic motivation and supports psychological recuperation [6, 4]. Research suggests that people's beliefs about the restorative powers of nature are positively influenced by natural qualities like comfort and absorption [4, 7]. These concepts are directly related to one's interaction with the natural world; people experience psychological stress alleviation and healing process facilitation when they are emotionally connected to their environment.

The sense of a restorative environment is currently gaining more and more importance in the sphere of mental healing and subjective well-being. By definition provided by environmental psychology, the notion includes the subjective perception and experience of certain settings like comfort, emotional attachment and absorption—the factors that contribute to the process of psychological rehabilitation. Numerous studies suggest that the calming and aesthetic qualities of a healing environment are crucial for improving people's emotional condition [6, 8]. Moreover, the exposure to natural environments had beneficial effects on physical and mental well-being, where restorative features become more pronounced along with the extraordinary attributes of natural landscapes. Additionally, restorative perception can promote the process of psychological recuperation and recovery by increasing positive mood and self-efficacy of people [5, 6].

The notion of mental healing has been extensively investigated in psychology, which resulted in growing attention to the interconnection between this concept and subjective well-being. Mental recuperation denotes the process through which a person restores himself/herself after experiencing stress or exhaustion [6]. Apart from cognitive recovery and physiological improvements, it also includes emotional restoration of an individual. Numerous studies show that the process of mental healing is helpful to improve individuals' subjective well-being and help eliminate depressive and anxiety symptoms.

The impression of restorative environment turns out to be one of the most significant mediating variables while investigating the connection between subjective well-being and perception of natural settings. Kaplan proposes the idea according to which the restorative features of an environment might be beneficial to people's mental healing processes and subjectively perceived well-being [9]. Moreover, the theory on cognitive levels states that a good environmental context is able to increase people's intrinsic motivations, which affects their emotions and behavior [1]. In addition, a comprehensive meta-analysis of the effect of direct contact with natural environments on stress [7, 10]. According to results, the exposure to such settings helps people significantly decrease stress levels and improves their ability to heal mentally.

1.2. THE INFLUENCE OF GOOD EMOTION IN MODERATING

There is plenty of research suggesting that the restorative benefit of a place depends on a good mood. The stimulation offered by natural environments is sufficient to produce positive moods that, in turn, could influence the mental healing process [10, 11]. This statement supports the "Emotion-Environment Interaction" hypothesis and suggests that positive emotions contribute to perceiving one's surroundings in a more pleasant way, thus increasing their subjective well-being [11, 12].

According to multiple sources, people's perception of the restorative effects of natural spaces is positively affected by their good mood. This could be explained by the fact that good mood helps people focus again and perceive good information from the environment as a result. Moreover, there is scientific evidence to suggest that a good emotion acts as a mediator between the sense of the natural environment and healing [12]. Based on Fredrickson's Broaden-and-Build theory, positive emotions enable people to perceive the surrounding environment in a broader manner, creating a wider variety of positive experiences and cognitions.

Positive emotions not only enable people to better handle the stress but also help them to heal mentally. One should note the link between improvement in mental healing and subjective well-being. Multiple research suggests that improved mental healing results in people feeling happier in life [13]. In the process of mental healing, positive emotion plays a vital role since it influences people's perception of their surroundings while also boosting intrinsic motivation and happiness. Finally, one should consider the importance of linking positive feelings with healing environment experience [14].

Positive emotions often accompany people's perceptions of the restorative characteristics of their environment, [13], contributing to improved mental healing and the perception of their surroundings.

The positive impact that nature has on emotional and affective processes is widely known [13]. The concept of the natural environment is not precisely defined and has several facets in scholarly research. Any environment might be viewed as natural when it includes specific natural elements. There are several types of natural environments. They can be divided into two major categories: green and blue ones.

Although the body of research on the positive effect that natural settings have on people's health keeps growing, little attention is payed to the potential health benefits of different natural spaces. White spaces that are snowy landscapes, [15],

might be viewed as one of such potentially beneficial areas. Moreover, there are recent ideas about the notion of "red nature" that comprises volcanoes and "brown space" of deserts.

Apart from the different types of natural environments, various natural environments' attributes may be influential regarding their benefits. Some characteristics could strengthen the effects of the interactions, offering opportunities for activities. The affordances concept is applicable in this case. Attributes of surroundings determine their applications and usage by humans.

Historically, the scientific study of positive emotions, wellbeing, and their relations lagged behind the examination of negative emotions and disease [17]. Recently, great effort has been made to define and characterize positive emotions that prove that they are much more than mere joy and happiness. Thus, the broaden-and-build theory allows comprehending the connection among positive emotions, wellbeing, and cognition. According to this theory, positive emotions make one's mind broaden, while negative emotions make it narrow.

It is generally acknowledged that the natural environment is a healing place that offers a wide range of benefits for humans' performance, health, and wellbeing. The benefits include a wide variety of characteristics: physiological, physical, emotional, cognitive, and social, [18, 17]. Physiologically, nature reduces muscle tension, decreases cortisol, [14], regulates blood pressure and heart rates. It is linked with reduced mortality from cardiovascular, respiratory diseases, and natural causes and type 2 diabetes. Cognitively, nature boosts memory, executive function, and concentration. Nature also increases social support perceptions and reduces perceptions of loneliness and isolation. Nature usually boosts positive feelings and wellbeing, reducing stress, [12], depression, anxiety, rumination, and negative emotions. Such effects might be long-lasting.

Experimental investigations showed a direct impact of the exposure to nature on emotional processes through boosting positive feelings and reducing negative ones. Indirectly, nature is helpful to emotional processes by providing the restoration of attentional resources which boosts self-regulation and executive functioning [13]. Therefore, one's exposure to natural stimulus positively impacts emotional states and mechanisms of regulation of emotions.

Most of the evidence regarding nature's restorative properties has been obtained with the use of digital surrogates even if personal experience does not yield the same results as exposure to real environments, [15]. For instance, for the last thirty years, movies featuring nature have proven helpful to facilitate recovery from physiological and psychological stress symptoms. Even viewing pictures showing natural environments boosts people's mood, restores attentional capacity, improves executive attention and reduces impulsivity.

Technological progress in the virtual reality area provides a way to bypass some of the problems and enables immersion in artificial nature environments. VR is a computer-generated, [16], three- dimensional simulation that provides a person with interactive, immersive, and navigational experience of another world. HMDs (head- mounted displays) that exclude or reduce other sensory stimulation allow for immersion in an immersive picture of a virtual world. Otherwise, viewers might stay in a room where there will be pictures of nature covering all viewable surfaces [13].

1.3. STRESS, FORESTS, AND WELLNESS

It is said that the natural environment can enhance individuals' physical and psychological health through recent researches. Many studies have been carried out on this topic in relation to forests as natural environments. It is evident that forests can improve individuals' health, and it may even do so by reducing stress.

There has been an abundance of research using stress as an indicator of health. It is known that prolonged stress can cause negative health effects. There are close links between stress and many cardiovascular and mental diseases. According to the hypothesis of stress reduction put forward by Ulrich from the viewpoint of evolutionary psychology, being in the natural environment can relieve stress and positively impact cognitive restoration. It is possible to recover from physiological and psychological stress by exposing oneself to natural environment either real or simulated, leading to increased positive feelings and decreased negative feelings such as fear and anger. According to one research, nature offers four main health benefits: a reduction in stress, physical exercise, social cohesion, and air quality.

Many studies have found that forests benefit health. It has been established through research that forests have positive psychological effect and reduce stress and depression. According to previous studies concerning physiological effects of relaxing in forest conditions, it has been proven that resting in forests can decrease blood pressure and heart rate, increase parasympathetic activity, inhibit the activity of sympathetic nerves, [12], reduce saliva cortisol stress hormone concentration, reduce cerebral blood flow in the prefrontal cortex, as well as stimulate natural killer cells and antitumor proteins' activities thus improving immune function.

Most of the current research concerning the beneficial effect of forests on individuals' physical and psychological wellness compare cities and forests environments [19]. Little research has examined the effect of diverse green features or environments on recovery. According to one research, the studies took into account the openness level of the forest environment, presence of water, and comparisons with golf courses and more [16]. When examining the density and accessibility of forest landscapes, the researchers found no discernable differences in terms of the level of satisfaction.

The comparison between city and forest environments with different levels of openness has been performed in surveys and interviews. It was discovered that whereas low openness created anxious sensations among participants, high openness allowed people to feel peace in forests but not in cities [15]. Studies comparing parks-like forests both with and without creeks did not discover any difference between these two habitats. Different elements of forest environments have also been studied. Among them are the effects of different forest types, their density, and plant species.

Some of the studies dealing with the effects of forest environments on health showed divergent results because of the different perceived sensory dimensions (PSDs) of surroundings [14]. One of the studies claims that the PSDs with the highest recovery value include calmness, species abundance, refuge, and nature, while space plays a crucial role too. Another study concerning patients with stress-related mental disorders found that social silence is crucial, while perceived sensory dimensions played equally vital roles. However, recent research done in China concluded that multilayered forests combined with water, calmness, nature, restricted opportunities, absence of civilization and a social component would serve as the ideal place for stress relief [9].

Health benefits associated with forests have led to forest therapy. Forest therapy, also known as "shinrinyoku" in Japan, is becoming popular rapidly in China. This approach aims at improving health and is based on the forest environment and its activities, such as rest and stroll. Various medical studies confirm the benefits of forest therapy for health.

The most essential element of forest therapy is forest rest. A walk around in a forest bath is similar to a procedure called "forest rest" that involves relaxation in a certain place within the forest. Meditation, body scan [20], and relaxation exercises are commonly practiced during the forest rest. Previous studies of forest rest have involved lying down, resting, deep and abdominal breathing. Another type of forest rest that is often considered in studies of forest treatment is sitting and enjoying the scenery.

1.4. APPLICATIONS OF VIRTUAL REALITY (VR) PERTAINING TO HEALTH AND ENVIRONMENT

The concepts of "presence" and "telepresence," describing the feeling of being present in the environment created by the use of natural or mediated techniques, form the basis of VR [21]. Sensory devices, natural ability, perception and experience, and the environment of the simulation are among the key elements. Multiple industries, including healthcare, education, the arts, entertainment, and military can benefit from VR.

In the healthcare sector, virtual reality is widely utilized. Some of the disorders which VR was used for include treatment of autism, rehabilitation of hands after stroke [14], motor rehabilitation, and recovery of function after a stroke.

Social anxiety disorder (SAD), frequently mistreated for shyness and introversion, is an invisible disease that takes much longer to heal. Due to the constant fear of critique and unfavorable judgment, those afflicted with SAD shy away from participating in conversations in public forums and expressing themselves freely [22]. There is a high correlation between SAD and the probability of experiencing depression in the future and early-school dropouts.

There is a variety of factors including genetic, temperamental psychological, and environmental influences, like early experiences or interactions with peers, that lead to development and continuation of SAD [23]. Early adverse experiences, like child abuse, are known to cause dysfunction of the HPA axis, thus increasing the person's cortisol responsiveness and making them more susceptible to SAD. SAD has a strong link to poor emotion regulation capabilities, which makes it even harder for those affected by it to deal with stress and the environment. It was found that SAD patients had enhanced neural reactivity in the brain regions involved in emotion regulation, namely anterior cingulate cortex (activated by disgusting expressions) and insular cortex (activated by angry expressions) [22]. Such hypersensitivity patterns may serve as a biomarker for SAD, as this disorder entails extreme sensitivity to social rejection cues.

Cognitive behavioral therapy (CBT) along with its various manifestations, cognitive restructuring, social skills training, and relaxation techniques, are considered traditional treatments for SAD. Applied relaxation is based on progressive muscle relaxation and is easy for patients with SAD to perform on their own [12]. In social skills instruction, the patient gets help through behavioral rehearsal, corrective feedback, and positive reinforcement to help him develop his interpersonal skills [18]. Cognitive restructuring involves the collaborative effort between the therapist and the patient aimed at identifying and disproving the negative, often erroneous beliefs and thoughts generated by SAD.

Another method of tackling SAD are mindfulness-based interventions, or MBIs. These interventions are varied and rely on practicing meditation and developing present-focused and non-judgmental awareness. They aid patients with overcoming safety behaviors and cognitive distortions through [11] increasing attention focussing, self-compassion, and attention shifting.

Out of the 56 participants in the study with anxiety or depression, only 40% took any medication or psychotherapy, even though 22.4% got diagnosed with SAD by physicians. Another study revealed that more than 80% of those suffering from SAD did not seek any treatment, with some only seeking it after 15-20 years since the appearance of the first symptoms [11, 9]. Lack of accessibility, anxiety of social contact, stigma, low awareness, embarrassment, and cost of

therapy can serve as possible obstacles [9]. In addition, long waiting times and low availability make treatment even more inaccessible. There is a negative correlation between age and treatment obstacles, suggesting that younger people have more problems with getting appropriate care [21]. Teachers are not necessarily skilled at detecting and treating SAD and children/adolescents with this disorder may become the target of bullying and taunting at school.

As the development of virtual reality (VR) becomes increasingly advanced, scientists try to determine how similar the therapeutic potential of VR environment experience would be to natural environment experience, particularly helpful for city inhabitants with no access to nature environments [22, 24]. Biophilic theory suggests that humans are biologically connected with nature and interaction with nature improves emotional well-being. Nature environment provides for better affective experiences, causing higher levels of pleasant emotions and lowering negative feelings [25].

Such an experience can be replicated through the virtual environment, thus providing similar benefits to those who cannot access real-world nature. The research demonstrates that virtual nature exposure can enhance psychological states of vitality and relaxation as well as decreasing tension, anxiety, and negative emotions [14, 20]. According to comprehensive analysis of 21 scientific works on the psychological effects of virtual nature experience, [14, 20], the consistent recovery of emotions was demonstrated, as well as the superiority of virtual nature in reducing negative emotions rather than enhancing positive ones. The effects of everyday exposure to virtual nature on university students was researched as well. The 3-4 week-long exposure resulted in a decrease in anxious arousal (panic) and anxious apprehension (worry) [21].

Interaction with the natural environment in forest bathing, without formal teaching, was proven beneficial for body and mind, and this practice evolved into forest therapy over time with professional conduct of organized walks combined with meditation and CBT [18, 17]. Researchers are trying to find the most well- studied mechanisms for enhancing benefits for both physical and psychological health, and support both scheduled and unscheduled approaches to forest therapy [26].

Adding interactive components to VR natural environment can enhance mental health. The impact of the environment on participants of participatory activities (kite flying, fishing, watering plants, and scenery appreciation) in both urban and park setting was studied by Wang et al. This study recruited 195 subjects with mild to severe depression and anxiety symptoms, with one session a week repeated four times [27]. There was a reduction in anxiety and depression in both groups of participants.

With the aim of closing this gap in research, we decided to conduct a study on the effects of a VR program using evidence-based techniques in a forest environment on moderate social anxiety treatment. Using VR forest, we guided participants in learning coping mechanisms to deal with their social anxiety through various combinations of cognitive behavioral therapy, mindfulness techniques, and meditation [28]. While a virtual therapist was guiding them, users would tour the forest to enhance relaxation. People wary of in-person counseling were our intended audience for the application [21].

1.5. RESEARCH QUESTIONS AND HYPOTHESES

- As opposed to the use of therapeutic teaching without virtual forest therapy, will the use of a virtual forest environment (or therapeutic teaching without or in combination with the virtual forest environment) reduce social anxiety and increase self-rated restoration?
- Will social anxiety be lower and self-rated restoration higher through the use of therapeutic teaching and virtual forest therapy as opposed to just virtual forest therapy without therapeutic teaching?
- Would users find virtual forest less attractive compared to when it was not used with therapeutic teaching because of its interface, immersion, and positive sentiment?

2. METHOD AND MATERIALS

The sample size consisted of 54 participants aged between 18 and 25, comprising 34 females and 20 males, who were students enrolled in a first-year psychology class at the University of China and volunteered for the experiment. In return for participating in the study, students were provided with course credit [28]. Pre-assessment of initial anxiety level and virtual reality experience was not carried out; rather, subjects were randomly allocated into three experimental conditions [27, 29]: Condition A, which had the VR forest only; Condition B, which comprised the VR forest and therapy exercises; and the Non-VR condition, which had therapy exercises only. According to Table 1, 9 participants out of the 40 students in the two experimental conditions conducted a follow-up session. These participants were aged between 18 and 19; there were 5 females and 4 males; 5 participants were in Condition B, while 4 belonged to the Non-VR condition.

The material and equipment employed for this study include the following:

(1) self-administered surveys to measure immersiveness [26, 30], usefulness, restorative effects, and social anxiety;

(2) Meta Oculus Quest 2 VR headset and applications with virtual forests; and

Table 1. *Number of participants for each session and condition*

Session	A	B	Non-VR
1	17	21	17
2		7	3

(3) therapy instructions.

For the measurement of the degree of stress that is experienced when engaging in social activities, the 20-item Social Interaction Anxiety Scale (SIAS), which is a self-administered survey tool, was employed. It uses a five-point Likert scale to record the participant's responses.

To evaluate the quality of the VR software in regard to its user interface, in-game support [24, 28], and VR-induced symptoms and effects, the Virtual Reality Neuroscience Questionnaire (VRNQ) was utilized.

For the purpose of interacting with the virtual forest, the participants were provided with the Meta Oculus Quest 2 VR headset. The virtual forest application was developed and designed by programmers at the Interaction Media Lab of the Chinese Academy of Sciences through Unity 2020.3.26f1 [21, 31]. As for the assets used for the creation of the application, they were downloaded from Unity Asset Store. Nature Manufacture, WDALLGRAPHICS, and PROTOFACTOR INC. provided the woodland, wildlife, and architectural assets, respectively [19, 26].

Figure 1. *Participants followed the red trail on the virtual forest map, which included eight checkpoints indicated in yellow; forest modelling images are also shown.*

As explained earlier, at each stage, the participants in Condition B and Non-VR group were required to concentrate on the guidelines issued by the virtual therapist [28]. In addition, psychoeducation, mediation practices, and quizzes that tested the participants' learning were part of the therapy.

This study was posted on the participant database for the first-year psychology class participants in University of China during the winter term of 2024 [23, 26]. Only individuals aged 18 and above who do not have a diagnosis of social anxiety disorder could participate in the research. This study was carried out face-to-face in Interaction Multimedia Laboratory at University of China.

For the evaluation of the influence of the experimental conditions on users' social anxiety, quiz performance, user interface experiences, and restorations [30, 32], the following tools were used in data analysis: R Version 4.2.1, R Studio Version 2023.06.0+421, and Python Version 3.12.

3. RESULTS

Factor analysis was performed on the Social Interaction Anxiety Scale (SIAS), which consists of 20 items [24, 33]. With KMO of 0.87, the sample was found to be appropriate. The result of Bartlett's Test of Sphericity showed that the matrix can be factorized since it was significant ($\chi^2(187) = 549.89$, $p < 0.001$). Based on the scree plot in Figure 2, the number of factors was one. Factorization was done using Varimax Rotation, thereby making it clear. In Table 2, Item 14 "I have trouble talking to people I'm attracted to" had the smallest loading of 0.184 out of the 20 items, making it the least contributory to the factor [25, 33].

Five additional items were added as a result, namely Items 7, 12, 15, 17, and 19. Strong internal consistency was shown by this 5-item scale [27, 26], as indicated by Cronbach's alpha values of 0.87 for pre-session data and 0.93 for post-session statistics, as shown in Table 3.

The five categories were averaged to create a social anxiety score [28, 30]. The variations in social anxiety among the three situations in Session 1 are then shown in the Cumming plot in Figure 3, after we deducted the post-session social anxiety from the pre-session social anxiety.

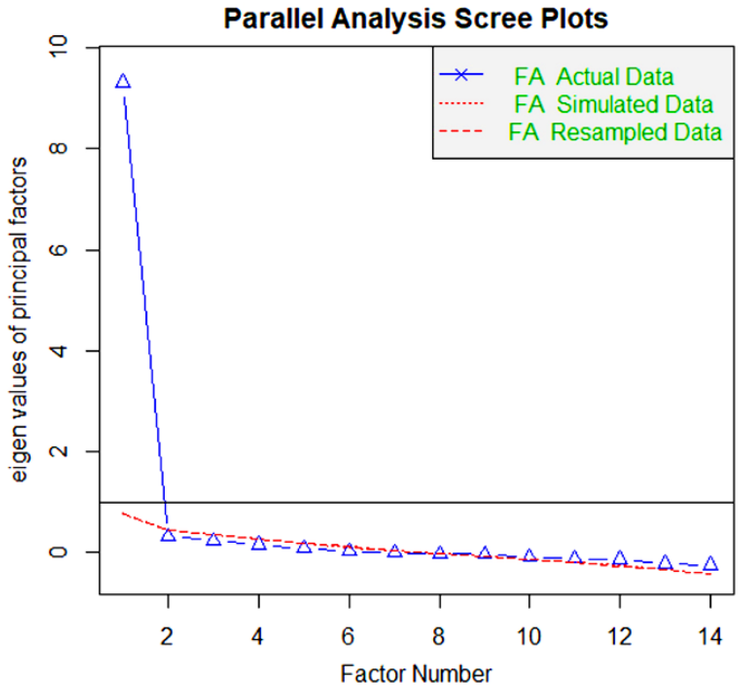

Figure 2. *Factor analysis of the 20 Social Interaction Anxiety Scale (SIAS) sections in a visualization plot*

Table 2. *Social Interaction Anxiety Scale (SIAS) 20 component loadings of factors*

Social Interaction Anxiety Scale (SIAS)	Factor Loading
Speaking with a teacher, employer, or other authoritative figure makes me anxious.	0.695
I have trouble looking people in the eye.	0.508
Talking about myself or my emotions makes me nervous.	0.418
I have trouble getting along with the folks I work with.	0.809
Making pals my own age is hard for me.	0.395
If I run into someone I know on the street, I become anxious.	0.648
I feel uneasy in social situations.	0.795
If there is just one other person around, I become nervous.	0.359
Meeting people at events like parties is hard for me.	0.348
I find it hard to communicate with other people.	0.798
I have a hard time coming up with topics to discuss.	0.548
I'm afraid I'll come out as odd if I explain myself.	0.418
I have a hard time disagreeing with other people's opinions.	0.528
Talking to someone I'm attracted to is hard for me.	0.988
I fear that I won't know how to respond in social settings.	0.488
Mixing with folks I don't know well makes me anxious.	0.364
I'm afraid I'll say something awkward when I speak.	0.418
I fear that I will be overlooked when I mingle with other people in a group.	0.982
In a group setting, I am tense.	0.147
I'm not sure whether I should greet someone I know just a little.	0.689

Table 3. *Five-item Scale Retained Following Analysis of Item Reliability*

Phase and Alpha Cronbach's	Social Interaction Anxiety Scale (SIAS) Items
S1 Pre =0.89	I feel uneasy in social situations.
	I fear that if I express myself, I may come out as uncomfortable.
S2 Post= 0.98	I fear that I won't know how to respond in social settings.
	I'm afraid I'll say something awkward when I speak.
	In a group setting, I am tense.

We used Fisher's exact test to compare the performance of participants in Condition B with the Non-VR condition at the three checkpoints in the first sessions, as shown in Table 4 [30, 31]. The first two checkpoints demonstrated no disparity in the results between the two circumstances, with Checkpoint 1 having p = 1 and Checkpoint 2 having p = 1.

The user experience ratings were higher among participants in the VR conditions, suggesting that VR scenarios were preferred compared to the non-VR scenario [34]. The overall rating of quality of user experience differed significantly

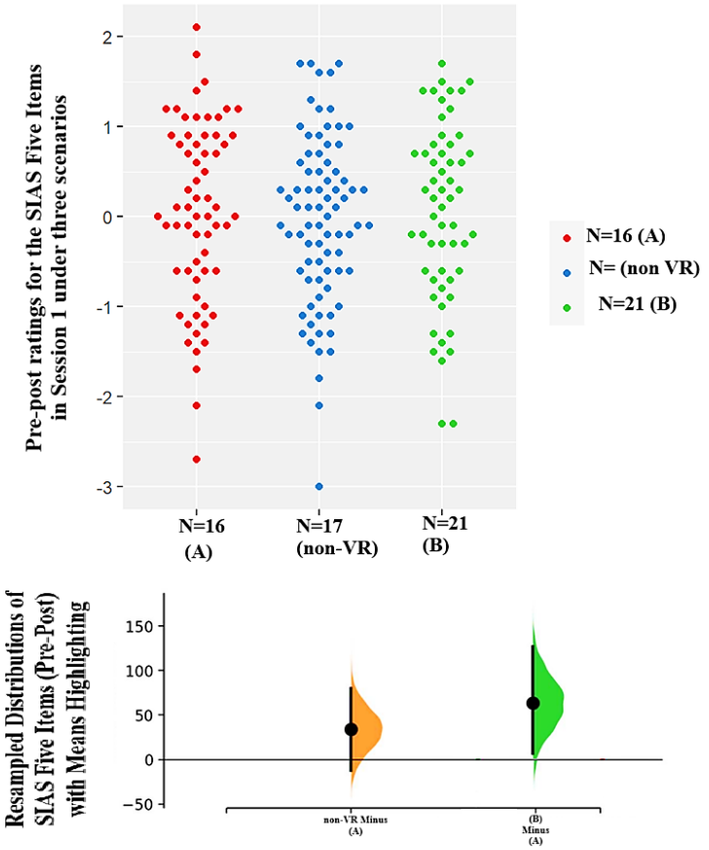

Figure 3. *Cumming plot on the decrease in social anxiety (pre-post) in three circumstances (a): virtual forest alone as a control condition; non-VR (Green): therapies solely; and b): therapy and virtual forest together) in Session 1*

Table 4. *Participate accuracy contingency table for the three Checkpoints*

Checkpoints	Conditions	Correct	Incorrect
1	B Non-VR	44 36	1 1
2	B Non-VR	18 16	2 1
3	B Non-VR	39 14	2 17

between conditions, as per the results of the one-way ANOVA on the Session 1 data ($F(2, 56) = 5.48$, $p < 0.01$, $\eta^2 = 0.16$) [35]. As shown in Figure 4a, post hoc Tukey analysis indicated that Condition Non-VR ($M = 4.98$, $SD = 1.48$) received significantly lower scores for overall satisfaction in comparison with Conditions A ($M = 5.95$, $SD = 1.49$, $p < 0.05$, Cohen's $d = 0.79$, 95% CI [0.79, 1.49]) and B ($M = 6.00$, $SD = 1.08$, $p < 0.05$, Cohen's $d = 0.86$, 95% CI [0.26, 1.78]). For Session 1, there were no differences between the three conditions regarding sound, visuals, immersion, and pleasure evaluation [36, 37].

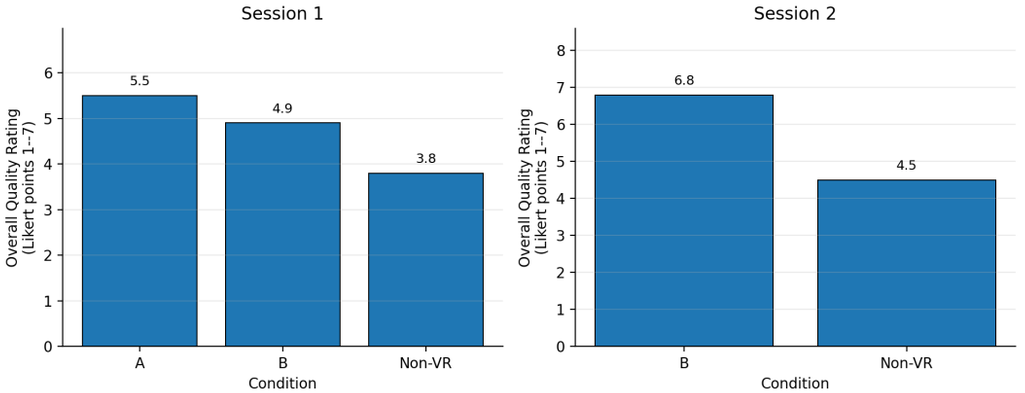

Figure 4. *(a) Average Ratings for overall quality in session 1 under three situations; (b) average ratings for pleasure in session 2 under two conditions*

It would be interesting to investigate how emotions would be impacted by VR presence [38]. Will the participants find the VR forest experience more attractive than without VR? To test how both VR and non-VR influenced the sentiment scores of respondents' comments in the first experiment, an independent sample t-test was employed.

Respondents may have felt that the VR experience was much more exciting, fascinating, or satisfying compared to Condition Non-VR. As shown in Figure 5 and Table 5, the sentiment score for positive experiences was marginally greater in the VR conditions than in the non-VR condition [9, 34].

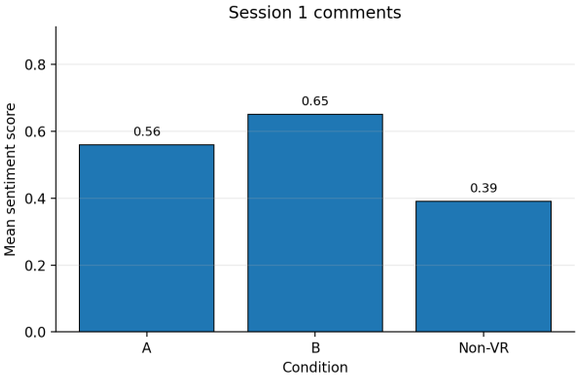

Figure 5. *A bar graph representing the average sentiment rating with one standard error for participant remarks in session 1 under three different settings. Condition A: SD=0.78, M=0.75. Conditions Non-VR: M=0.38, SD=0.47; Condition B: M=0.67, SD=0.34*

Table 5. *Comments on the top and worst sentiment scores*

Condition	Comments	Sentiment Score
Remarks that received the greatest sentiment ratings under each of the three scenarios.		
A	The soothing visuals and music were a huge stress reliever for me. It was also simple for me to lose myself in it and have a deep feeling of peace. Because they were all unique and evoked awe and curiosity, the constructions were pleasant. I had a great time with it.	0.97
B	Although I appreciate that there are adorable animals there, it would be preferable if they could all be pushed (I'm not sure why pushing animals is so pleasant). I'm also a little disappointed since I was hoping to see anything under the surface of the river, like fish, but there isn't any. However, the forest is lovely, the sound effect is really genuine, and the experience is nice altogether. If I have time, I'll return. I appreciate the experiment.	0.85
Non-VR	The courses were enjoyable and extremely beneficial. Thank you.	0.84
Among the three situations, the comments with the lowest sentiment scores		
A	I like the atmosphere the headset generated and was completely absorbed in the virtual reality world; however, the one thing that bothered me and made me dislike the experience was the nausea I had.	-0.49
B	Although I like some of the pictures, such as the flowers, river, and clouds, I also thought they were a little distracting since I felt like I was in a fake virtual world. Additionally, it made me sick, which interfered with my ability to focus.	0.89
Non-VR	Excellent experience, although I think I may have lost concentration on Module 4 since I found it to be quite lengthy and dull.	-0.76

A one-way ANOVA was used in Session 1 for testing the existence of variations in the frequency of word occurrences between conditions ($F(2,69) = 7.65$, $p < 0.05$, $\eta^2 = 0.75$; see Figure 6) [24, 28]. The amount of immersiveness linguistics in Condition A ($M = 0.67$, $SD = 0.84$) was significantly larger than in Condition Non-VR ($M = 0.19$, $SD = 0.69$) as tested using post hoc Chinese test ($p < 0.05$, Cohen's $d = 0.87$, 95% CI). [0.87, 1.87].

ANOVA analysis on the combined data for Session 1 was conducted to study the effects of circumstances and phases on restoration rating [23, 32]. Phase effect on restoration rating was significant, $F(1, 108) = 27.49$, $p < 0.0001$, $\eta^2 = 0.67$, see Figure 7.

Participants from all three conditions showed a significant increase in their restoration rating from pre-experiment value $M = 3.54$ ($SD = 0.41$) to post-experiment one $M = 4.59$ ($SD = 1.39$), Cohen's $d = 0.95$, 95% CI [0.85, 1.37], [29, 39]. These results suggest that both the virtual forest presented in the VR experiments, as well as the sounds and picture of a real forest in non-VR Condition, could induce similar increases in restoration rating (see Figure 7).

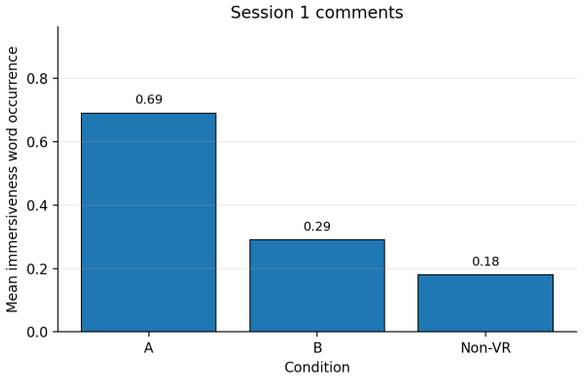

Figure 6. *Bar Plot shows the mean incidence of the phrase "incredibleness" (with one standard error bar) on the remarks of participants in session 1 under three scenario.*

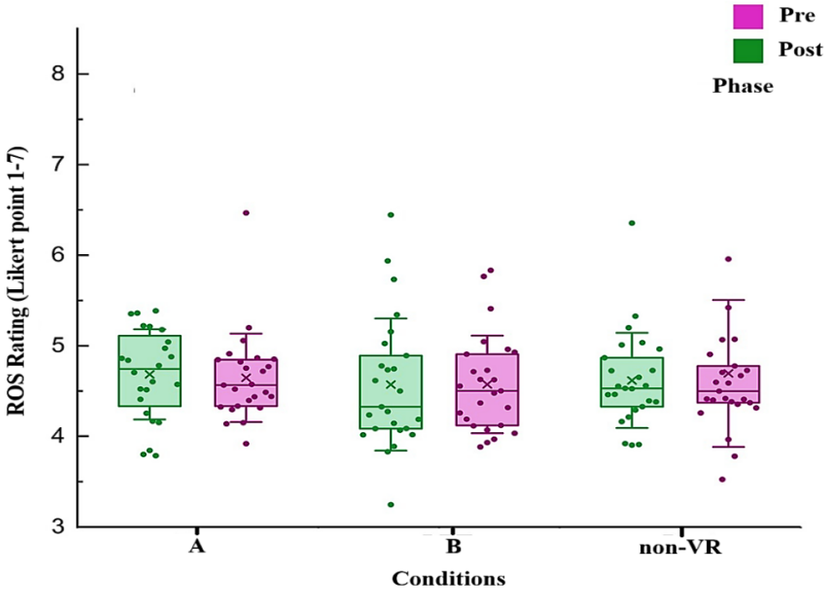

Figure 7. *Boxplot of ROS rating for three circumstances in Session 1 before (purple) and after (light green) phases*

4. DISCUSSION

Based on this research, visiting natural environments might considerably increase the level of subjective wellbeing. There are several reasons why we avoided explicitly saying that natural environments had a positive influence on subjective well-being within the proposed model [12, 14]. Firstly, there are many studies showing that contacting natural environments increases subjective wellbeing. Secondly, many visitors said that they felt subjectively better while they were visiting the place, [20], and that they felt encouraged to positively interact with life, [23].

These results coincide with the works of researchers who believe that the natural environment of urban forest parks might have a healing effect on the psychological state of residents. For example, in the research of Tsunetsugu et al., four different urban forest regions were compared with urban areas in central and western Japan. The results showed that the participants in forest zones had lower heart rates, a higher level of activity of parasympathetic nervous system, [40, 41], and lower diastolic blood pressure. Evidence of this kind proves the importance of urban forest zones in creating the conditions for people's wellbeing.

Such an objective correlates well with our initial one of presenting effective and cost-effective therapy for individuals with mental disorders. As mentioned by [4], the chain of natural environment *perception* $\rightarrow$ *mental healing* $\rightarrow$ *subjective* well-being supports the view that visiting natural zones is a key element of psychological recovery, [26], which leads to improvement of subjective well-being.

The above connection can be demonstrated through guests at urban forest park feeling relieved and refreshed after contacting the green parts of natural environment, and hence improving their subjective well-being [28]. Although most of research did not give any attention to such a mediating effect, it is consistent with the pathway of stimulus-mental-behaviour impact in the area of cognitive psychology.

Though all of the investigated studies proved the fact that virtual natural environment had a beneficial effect on

generating emotions, it should be noted that there still exists contradictory information and further research is needed [42]. It is important that though the majority of studies concluded that VR experience had a positive effect on emotional states through reducing negative emotions, the participants of some studies did not show any considerable increase in positive affect. Thus, for instance, the reduction of negative valence emotions was observed, yet no change in positive valence emotions was recorded [42]. Similarly, negative emotions were reduced whereas pleasant ones were not altered.

Nevertheless, some other research stated about non-significant decrease or increase in arousal level. Methodological difficulties can explain such surprising results. The participants were alternately seated and walking, [16], what could lead to stimulating them physically. In a similar way, playing with VR experience could activate the processes leading to increase of arousal, [28].

There is a Possibility that the non-VR (therapy only) Condition Might Reduce Social Anxiety. It appears to be the only condition having the potential to reduce the level of social anxiety [27, 28]. Contrary to the single session intervention which was provided for most of the participants in the research, the cases of social anxiety usually need several sessions over quite a long period of time because this phenomenon is typically very solid among people. Therefore, the absence of statistically significant reductions in social anxiety levels is not surprising [26]. On the contrary, there was observed a statistically significant increase in ROS scores after the intervention in all three experimental conditions.

VR Therapy Enhances Learning of Therapeutic Material and Engagement. Based on the data collected during the quiz, the participants in Condition B performed better than the subjects in Condition Non-VR at Checkpoint 3, [24, 33], which measures their comprehension of therapeutic material. This checkpoint was reached approximately after 15 minutes of interacting task. However, compared to the only treatment, sentiment was more positive in the VR conditions according to the sentiment analysis of text comments left after the session ($p = 0.067$) [30]. Although this effect was marginal, the tendency suggests that participants might perceive the virtual forest environment more positively, [35], which can play a huge role in treatment compliance and engagement.

Improving Restoration by Using Forest Sound. According to the results of mixed ANOVA, the level of self-reported ROS increased after all three conditions of experiments. The same background audio–forest sounds, like singing of birds, flowing river, and wind – was used in all the experiments [38]. The majority of the participants claimed that forest sound enhanced vividness and tranquillity of the experience (Table 6) [16, 9].

Table 6. *Comments about forest noises are made by participants*

Conditions	Comments
A	"The sound was really soothing."
	"I thought the graphics and sounds were fantastic."
	"I felt at ease because the sound and visuals gave me the impression that I was truly in the forest."
	"I think my experience was close to a real-life experience because the sounds and images were realistic enough."
	"I thought the setting it created was really lovely, but what really brought it to life was the soundtrack."
B	"The sound quality—both the checkpoint narrator's voice and the background noises from the forest—was one element that really caught my attention."
	The sound quality was the feature of the program that caught my attention. The noises of the forest were quite vivid, and the male narrator's voice had excellent sound quality. It seemed to be simultaneously emanating from everywhere and nowhere.
	"The sound effect is very realistic, and the forest is lovely."
Non-VR	"I was able to picture myself in a forest thanks to the soothing background noises."
	"The sound effects were very realistic, which aided in rapid immersion."

Condition Non-VR participants were shown a screenshot of the virtual forest as the backdrop picture on the interface and invited to imagine being there [24, 26]. With the combination of sounds of the forest and the virtual forest environment, a restorative effect similar to those obtained in the VR conditions was produced. The participant in Condition Non-VR mentioned phrases such as "vibrant" and "immersive" (Table 6) [27].

5. LIMITATION AND FUTURE WORK

Even though this study shed some light on the viability and efficiency of combining therapeutic activities with virtual woods for treating social anxiety in adolescents, there are still several limitations associated with it. First of all, our sample size and high drop-out rate were considerable limitations. Only nine participants managed to complete the second session [26] although we started with fifty-eight first-year psychology students, roughly twenty individuals per condition. Our ability to make strong conclusions regarding long-term changes in the efficiency and usefulness of our therapeutic approaches is impaired by the drop-out rate.

Because of the deeply ingrained nature of social anxiety disorder, there is no reason for any participant to expect

seeing themselves having lower self-rating of anxiety in just one session or even two, spaced by two weeks. To see some significant improvements, a social anxiety treatment typically takes 14–20 weekly sessions [14]. It is clear then that due to social anxiety treatment requiring a longer time span for intervention, our intervention being brief — it took no longer than two sessions — makes our findings less generalizable [13, 9]. Long-term impact of VR therapy on social anxiety was not analyzed in this study, either. Due to the shortness of research period and low number of sessions, there is no doubt that the observed minor effect was caused by it.

There is a chance that the keyword strategy we applied theoretically to capture studies concerning immersive virtual reality experience in natural settings, unintentionally left some studies that used other terminology for the same phenomenon. For instance, names of certain natural environments ("forest," "park," "lake" and so on) or other terms related to virtual reality technology ("simulated nature") could have been missed [19]. Though our search covered a relatively high amount of relevant situations, future reviews can use broader and more detailed keyword search taking into account dynamic and multidisciplinary nature of our topic.

The design of an efficient experience in VR will definitely benefit from better understanding of influence factors on emotions in relation to usability, engagement, and satisfaction [25]. Moreover, taking into account the previously established relationship between cybersickness and virtual reality-induced stress, future studies need to focus on the issue and its effect on user experience and emotionality in the VR setting [41].

First-year psychology students comprised the majority of study participants; thus, their demographic data do not necessarily represent young people as a whole. Having a more diverse sample — for example, consisting of various age groups (18-30 years old) and educational background [23, 28] would have increased the validity of results in general. Besides, detecting any significant difference in social anxiety before and after intervention becomes rather difficult since participants' social anxiety ratings are relatively low and none of them had a clinical diagnosis of social anxiety disorder, which is one of the criteria of our ethics in this study [21, 24]. Thus, future research should include pre-testing for levels of social anxiety and have participants with different severity levels in order to balance the conditions and receive a more reliable measurement of efficiency of interventions.

Not in a way that caused them to quit the experimental session, some participants reported experiencing nausea during VR sessions. Some studies on the issue of mitigating the symptoms of VR-induced nausea proposed using movement input for that purpose [9, 26]. In the future research related to virtual forests as a means for alleviating social anxiety, it would be worth applying such an approach.

It would be interesting to further examine in future studies if the found patterns in sentiments scores persist in multiple therapy sessions and if these affective responses affect efficiency of therapy and patient's adherence to treatment [19, 28]. What is more, identifying the contribution of various elements of VR environment (exposure duration, interaction, ambient noise, dynamic vision change) will help improve VR treatment design.

6. CONCLUSION

This study considered the usefulness and efficiency of integrating therapeutic activities with the use of virtual woods for the treatment of social anxiety in young people. As compared to other conditions, it has been determined that Condition Non-VR has exhibited tendencies of decreasing social anxiety, answering our initial research question in negative (though in short-term only) and the second research question positively. It means that conventional application of therapeutic content, unburdened by immersive VR experience, is more likely to prove efficient when trying to address social anxiety disorder.

Analysis of studies on virtual nature proved useful in uncovering their efficiency and differences in elicitation of emotions. There is a significant influence of various treatments on virtual nature meeting efficacy, such as time of exposure and interaction technique.

Combination of therapeutic activities with a virtual forest (Condition B) proved to have some advantages. Not only did it produce the highest level of participants' subjective experience rating but it also yielded higher scores for quizzes — thus, participants learned the materials better. The fact that this approach is likely to retain interest in therapeutic training raises hope for the success of such therapy.

These results once again illustrate the importance of delivery mechanism in therapeutic treatment. While the use of immersion VR experience is useful in terms of long-term efficiency and engagement with the materials, it can be more effective in reducing social anxiety immediately in a shorter period of time through non-immersive methods. In future, these attributes need to be balanced out in VR therapeutic treatment for maximum efficiency of the procedure.

Use of virtual forest technology to deliver therapeutic information is a viable solution. However, to avoid distracting users, proper design would be required. The crucial element here would be gradual information delivery process.

There are numerous practical applications of virtual forest technology outside the usual therapeutic purposes. Patients confined to home or nursing care, disabled people unable to enter a real forest, leukaemia patients undergoing treatment and unable to interact with surrounding environment because of immunodeficiency, closed institution residents (rehabilitation

centers) — anyone among them could use these technologies. Virtual nature exposure is a convenient and effective way to provide psychological comfort to people who cannot access natural environment easily. Despite difficulties outlined in this study, it seems reasonable that advantages of using these technologies far exceed research efforts to design effective products.

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