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Article

A Study of the Emotional and Cognitive Effects of Long-Term Exposure to Nature Virtual Reality (VR) Videos on Mobile Terminals

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Abstract: Research Highlights: This study examined the emotional and cognitive health benefits of nature in comparison with working memory training. It considered the long-term effects, the application of mobile terminal technology, and routine-based approaches with the aim of integrating nature's health benefits into people's daily lives. Background and Objectives: Infectious diseases and aging may limit people's activities indoors; the recovery effect of nature has been widely recognized, and terminal technology is developing rapidly. In this context, we want to explore the emotional and cognitive effects of viewing nature (VR) videos on mobile devices for a long time. Materials and Methods: The experiment employed a between-subjects design, with participants being randomly assigned to one of four groups: a forest VR video group, a water VR group, a working memory training group, and a control group. The participants watched the video three times a week for 20 min each for four weeks. The number of valid participants for compliance, preference, and willingness was 136, and the number of valid participants for the study of emotional and cognitive effects was 62. Brief Profile of Mood States (BPOMS) scales, running memory accuracy, shifting cost, etc., were used as indicators to reflect emotions and cognition. A repeated measures analysis of variance was performed on these indicators at four groups × two time points (pretest/post-test). Results: ① There were no significant differences in the participants' adherence, preferences, and willingness to watch different natural videos and perform working memory training. ② Long-term home training (e.g., watching VR nature videos or working memory training) may have had a minimal effect on emotional responses to mobile terminals. However, home training may be more conducive to the stabilization of anger. ③ Watching forest VR videos had a positive effect on the updating function of the brain; watching water VR videos was beneficial for the shifting function and automatic processing speed; and working memory training had a positive effect on the updating and shifting functions. Conclusions: There were no significant differences in adherence, preference, willingness, and effects on emotion and cognition between long-term forest VR video viewing, water VR video viewing, and working memory training on mobile terminals. All three types of home training may be beneficial for the stabilization of emotion (especially anger), and all can have some positive effects on cognition.

Keywords: natural intervention; mobile terminal; emotion and cognition; home training; working memory training

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1. Introduction

Emotion and cognition are considered important psychological functions that are closely related to an individual's normal life, work, and adaptation to society. Nature-based interventions can affect human emotions and cognition. However, individuals who are isolated during epidemics, elderly people with limited access, hospital patients, prison inmates, people with disabilities, and so forth, are particularly vulnerable due to a limited access to nature. In contrast, the individuals are so immersed in their screens that they have mobility but lack natural contact [1]. These situations require the development of technologies to facilitate nature exposure. Advances in mobile devices and virtual reality (VR) technology have made it possible to perform mobile device-based emotional and cognitive interventions on a daily basis. VR nature videos are a potential alternative to nature-based interventions. It has been demonstrated by studies that working memory training can influence human mood and cognition, too. And much of the existing research that focuses on the health effects of natural interventions involves short-term studies. Thus, studying the effects of the long-term viewing of VR nature videos on human emotions and cognition at mobile terminals and their differences compared to working memory training is a scientific question worth exploring.

1.1. Natural Intervention and Working Memory Training

It has been demonstrated that natural interventions and working memory training may have positive impacts on emotion and cognition. Both of these approaches have the potential to be incorporated into daily home training programs.

Nature's influence on human emotions and cognition is significant, with several theories explaining these effects. Kaplan and Kaplan's Attention Restoration Theory (ART) suggests that natural environments have a restorative effect on cognitive functions, particularly replenishing directed attention capabilities, due to the inherent fascination they provoke [2]. Another pivotal concept is Ulrich's Stress Recovery Theory (SRT), which posits that exposure to natural settings accelerates stress recovery, decreases negative emotions, and enhances positive feelings, primarily through physiological responses to natural stimuli [3]. Additionally, Wilson's Biophilia hypothesis argues that humans have an innate affinity towards nature, which can improve emotional well-being and cognitive performance, driven by evolutionary predispositions [4]. These theories collectively underscore nature's vital role in enhancing emotional stability and cognitive functions.

Forests, as the epitome of the natural environment, are believed to have a positive effect on mood, cognitive abilities, sense of well-being, and physical health [5–11]. Forests have been shown to assist in stress reduction, enhance mood, and support attention restoration [12–14].

Numerous studies have shown that exposure to nature can boost one's mood and cognition in many ways. Nature has a positive impact on people's mental health and cognitive abilities [15]. The natural environment is recognized as an important public health resource for stress recovery and overall well-being [16,17]. The video of natural surroundings was rated by participants as the most relaxing [18], and it has been demonstrated that exposure to natural environments produces alpha waves, which can be restorative [3]. During the COVID-19 pandemic, it was shown that having relatively abundant greenery visible in the vicinity of the residence reduced depressive or anxiety states [19]. A study showed that the effects of exposure to nature (trees, grass, flowers, bushes, water, etc.), but not to daylight, were more pronounced for those with affective problems [20]. When children are exposed to natural environments, there are potential benefits in terms of attention, mood, and memory [21], not only for learning, but also for better math, reading, writing, and critical thinking and problem solving skills [22].

Working memory training has been studied and was found to have a positive effect on executive function and memory capacity enhancement. In a pilot study in which patients with chronic schizophrenia were trained for 4 weeks on visual–spatial working memory tasks and verbal working memory tasks, improvements in verbal working memory (d = 1.04) produced statistically significant and large effects [23]. It has been proposed that working memory training may be an effective preventive and therapeutic approach against cognitive decline in individuals with Parkinson's disease [24]. In addition, studies have demonstrated that working memory updating training has the potential to reduce susceptibility to episodes of repetitive negative thinking (RNT) states [25] and may even exert a distant transfer effect with the potential to affect fluid intelligence, emotional regulation [26], and other abilities. A review of studies covering healthy populations, populations with anxiety, post-traumatic stress disorder (PTSD), and eating disorders using standardized working memory training found that it had mood-regulating effects [27]. In addition, studies have shown that working memory training is effective in enhancing episodic emotional regulation [28]. One study found that working memory training had a transfer effect on short-term memory and cognitive inhibition measures and reduced depression and anxiety scores in older adults who underwent major surgery [29]. In experiments investigating the neural mechanisms by which working memory training improves emotional regulation, it was found that working memory training also improves cognitive reappraisal and can be a potential intervention to promote emotional regulation in individuals with high trait anxiety [30].

1.2. Mobile Technology Application and Virtual Reality Nature Intervention

The advent of mobile devices and related technologies has facilitated the implementation of interventions targeting everyday emotions and cognitions on mobile devices. In particular, the use of virtual reality technology has been shown to have great potential for emotional and cognitive interventions.

Previous studies in the literature have documented that mobile application utilization increased exponentially throughout the ongoing COVID-19 epidemic [31]. A study that conducted a search of the European Google Play Store and Apple App Store found that there were 121 stress management apps (SMAs) [32]. Web or mobile applications for cognitive interventions, such as Lumosity, are also becoming more widespread. A retrospective cohort study about using a behavioral health app for digital intervention revealed a significant decrease in stress symptoms during a period of 1–6 weeks of app use that was maintained during a period of 6–10 weeks [33].

Virtual reality (VR) is a broad concept including screen-based virtual reality, virtual worlds, and immersive virtual reality environments. VR was defined as "inducing targeted behavior in an organism using artificial sensory stimulation, while the organism has little or no awareness of interference" [34]. Sometimes, VR is simply used to refer to the physical equipment, i.e., the hardware (e.g., head-mounted displays [HMDs]), which enable the viewing of virtual worlds. The present study employed a virtual reality (VR) headset to present three-dimensional (3D) nature videos to participants. A study showed that real-life and VR height exposures using 3D 360° videos are mostly indistinguishable on a psychophysiological level (EEG and HRV), while both differ from a conventional 2D laboratory setting [35]. VR is also becoming more and more popular in mobile applications. It can provide an alternative to actual outdoor immersion through 3D images that realistically simulate real scenes, giving people a feeling of immersion (e.g., positive effects on cognition [36] and stress relief [37]). The application of virtual technology to promote relaxation and to benefit attentional resources, cognitive performance, and pain experience is being supported by more research [38]. VR physical activity (VR-PE) has demonstrated considerable efficacy in enhancing cognitive function among the elderly, suggesting its potential as an effective approach for cognitive improvement in this population [39].

Research shows that natural alternatives (photos and videos) can approximate real nature, making the body relaxed and restored [40]. The forest environments presented via a head-mounted display had a positive effect on the participants' cognition [36]. Studies have demonstrated that virtual exposure to a forest environment is effective in reducing stress and anxiety caused by confinement in a limited space [37,41]. A study with an intervention duration of 6 min found that both real nature exposure and VR nature exposure increased physiological arousal, enhanced positive mood levels, and were restorative compared to indoor environments without nature [42]. There have also been studies showing that exposure to virtual natural environments led to improvements in mood states and reduced fatigue and depression in people of all ages [43,44]. A study has demonstrated that a virtual reality nature condition provides significantly superior directed attention restoration and higher presence ratings [45]. A study showed that, in comparison to a control environment, exposure to virtual nature resulted in significantly higher cognitive performance, higher perceived restorativeness, a higher positive affect, a higher sense of presence, lower perceived stress, and lower simulator sickness [36].

1.3. Problem Formulation and Research Hypothesis

The objective of this study is to introduce nature interventions into the everyday lives of individuals using mobile devices. The goal is to provide opportunities for individuals who experience limitations in their behavioral activities to engage in the well-being of nature. In addition, this study seeks to examine the emotional and cognitive effects of watching forest VR videos, water VR videos, and performing working memory training on mobile devices over prolonged periods. In this study, the home training regimen included viewing the forest VR video, the water VR video, or the working memory training.

1.3.1. Problem Formulation

- The comparison of working memory training with natural interventions deserves more research. Both naturalistic interventions and working memory training have been shown to have some effect on mood and cognition. However, there may be differences between the two in terms of preference and adherence as well as effects on mood and cognition. These differences warrant further research.
- The emotional and cognitive effects of different types of nature and long-term nature interventions need further research. Natural interventions can alleviate a wide range of negative emotions and promote cognitive function, and whether there are differences in the effects of interventions between different types of natural environments (for example, a forest environment and a water environment) needs to be studied in more detail.
- More evidence is needed to support the impact of mobile device-based daily interventions on mood and cognition. Mobile devices and virtual reality technologies offer possibilities for family self-intervention, and how to best utilize these mobile devices is a topic worth exploring.

1.3.2. Research Hypothesis

Based on the above considerations, this experimental study will analyze the differences in adherence, preferences, and future participation willingness of different home training methods (forest VR intervention, water VR intervention, and working memory training) on mobile devices, and it will investigate their effects on individual emotions and cognition.

The following hypotheses were raised in this study:

H1. *There may be differences in adherence, preference, and willingness to participate when watching forest VR videos, water VR videos, or performing working memory training for long periods of time on mobile terminals.*

H2. *There may be differences in the emotional impact of watching forest VR videos, water VR videos, or performing working memory training for long periods of time on mobile terminals.*

H3. *There may be differences in the cognitive impact of watching forest VR videos, water VR videos, or performing working memory training for long periods of time on mobile terminals.*

2. Materials and Methods

2.1. Participants

A total of 136 participants were recruited through online posting and WeChat recruitment. Inclusion and screening criteria for participants included the following: no history of alcohol abuse, acute/chronic medical conditions, or drug dependence; recent good health, no psychiatric treatment or psychological counseling, and no specific medications; right-handedness as the dominant hand, normal or corrected vision, and no psychiatric disorders, stress disorders, abnormal organic lesions, traumatic brain injuries, or endocrine disorders.

The number of valid participants for adherence, preference, and willingness was 136, of which 61 were male and 75 were female. The age of all participants was 20.36 ± 1.703 years; the participants ranged between the ages of 18 and 25 years, and they were mainly college and graduate students. Demographic indicators of the participants in each group are shown in Table 1. Age and gender did not conform to a normal distribution, and the Kruskal–Wallis H(K) nonparametric test was used, which showed that there were no significant differences between the groups in terms of the age (H(K) = 0.2420, df = 3, p = 0.490) and gender (H(K) = 0.625, df = 3, p = 0.891) of the participants.

Table 1. Demographic indicators for each group of participants.

	Daily Training Group	Average Age	Number of Participants	Age Criteria Deviation
Valid participants for adherence, preference, and willingness	Forest VR intervention	20.15	33	1.349
	Water VR intervention	20.08	26	1.547
	Working memory training	20.39	36	2.032
	Control group	20.68	41	1.738
	Total	20.36	136	1.703
Valid participants for emotional and cognitive interventions	Forest VR intervention	20.26	19	1.759
	Water VR intervention	20.07	15	1.58
	Working memory training	20.2	15	2.042
	Control group	20.31	13	1.601
	Total	20.21	62	1.719

Participants who watched nature videos or performed working memory training with 7 or more actual completions and complete data were considered valid participants for the emotional and cognitive impact study. There were 62 valid participants for the emotional and cognitive interventions, of whom 26 were male and 36 were female. Among them, 15 were in the working memory training group, 19 were in the forest VR intervention group, 15 were in the water VR intervention group, and 13 were in the control group.

This study was approved by the Ethics Committee of the North China University of Technology. All participants received RMB 50 compensation for participating in the study.

2.2. Experimental Design and Procedures

This experiment used an independent group design, referred to as a between-sub jects design. Participants were randomly assigned to the forest VR intervention group, the water VR intervention group, the working memory training group, and the control group. Each participant underwent the experiment individually without interference from other participants.

During the experiment, the participant entered the laboratory, and the experimenter introduced to the participant the purpose of the experiment, the experimental procedure, the experimental method, the risks of the experiment, the discomfort of the experiment, and the confidentiality issues. After formal entry into the experiment, the participant filled out the Brief Profile of Mood States (BPOMS) scale and performed cognitive index tests. The above were used as pretesting data for the experiment, reflecting the baseline levels of the participants when they were untrained. The main examiner explained the corresponding task requirements to each group, and the whole process took about 30–40 min. After the presentation, all participants were asked to undergo a month-long home training session.

Participants in the working memory training group were asked to perform a dual dimensional n-back working memory training task for one month, taking approximately 20 min per task, three times per week, for a total of twelve sessions over four weeks. The experimenter installed the dual dimensional n-back app in the participants' cell phones and taught the participants how to use it. The experiment required the participants to send the training results (score of each index of working memory) in the form of a numerical string to the experimenter via WeChat after each training session was completed.

In the forest VR intervention group and the water VR intervention group, the experimenter gave the VR glasses (Thousand Mirage Magic Mirror G03A) to the participants and shared the VR videos prepared in advance to the participants, who downloaded the videos to their cell phones. After the experimenter taught the participants how to play and watch videos using the VR glasses, the participants were asked to operate and experience them at the site to ensure that each participant could watch the videos using the VR glasses. The forest VR intervention group and the water VR intervention group were trained for approximately 20 min per experiment, three times per week, for a total of twelve times over four weeks. After each training session, participants were asked to report the completion of the training via WeChat.

In the control group, participants did not carry out any training, and they were asked to follow a WeChat Official Account and read the content. The experimenter tweeted the article on the public website three times a week for a total of twelve times over four weeks. Participants were asked to report to the experimenter after they completed reading the article.

Participants in each group re-entered the laboratory after one month to fill in the BPOMS scale, and a second test of cognitive indicators was performed. The above were used as experimental post-testing data, reflecting the conditions of the participants after the training intervention.

At the end of the training intervention, participants were asked to fill out questionnaires on adherence, preferences, and willingness to participate in the future. The experiment was completed when the questionnaire was completed. The experimental flow chart is shown in Figure 1.

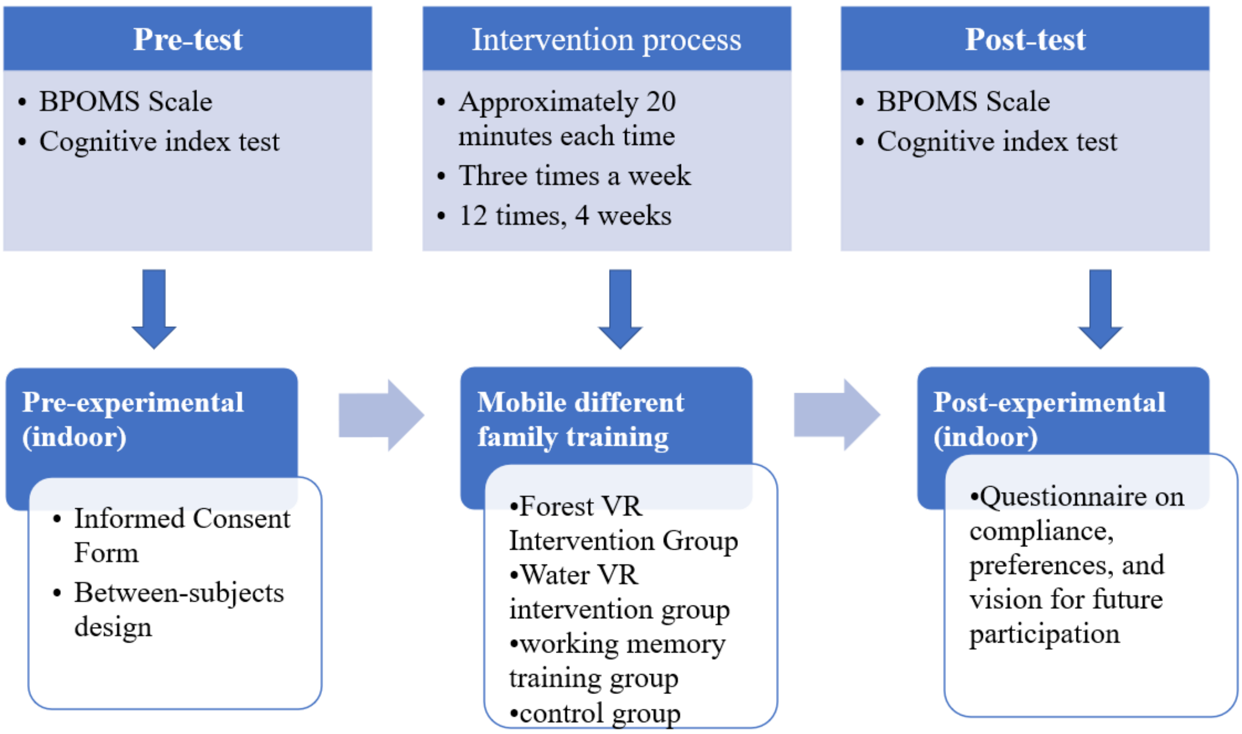

Figure 1. Experimental flow chart.

2.3. Experimental Materials

(1) Dual dimensional n-back working memory training app

The working memory training group used a mobile dual dimensional n-back working memory training app. The n-back task is a frequently used paradigm in working memory training. In the n-back task, the participant needs to determine whether the material of the current trial is consistent with the material of the nth previous trial. The memorized material was presented sequentially, and the information stored by the participants needed to be constantly updated. As the value of the return number n increases, the amount of information that the participants need to save increases, and the difficulty also rises.

The dual dimensional n-back task is a variant of the n-back task and contains two simultaneous tasks. The two tasks are independent of each other and require dual executive control. The two tasks can be dual sensory channels, such as a standard auditory task and a standard visual task. The two tasks can also be different attributes of a stimulus, such as shape, color, location, etc. The dual dimensional n-back task is not conducive to the development of strategies and automated processing that satisfy independent attention and task integration, and it can characterize different subsystems of working memory.

The working memory training group in this experiment used the n-back task of non-emotional material in the dual dimensional n-back working memory training app developed independently by Li Xuebing's group [34]. The length of the task is about 20 min. Dual tasks have different properties with the same stimulus: color and position. This dual-channel task is easy to manipulate on a mobile device. The main interface of the task is a 3 × 3 nine-box grid with different color blocks appearing in different squares, and the participants need to judge the colors and positions of the blocks at the same time. The app enables adaptive cognitive training, and if an individual scores over 80 in two consecutive sets, they can move to the next level. In other words, if the original level is level one, they can enter the level two next; if the original level is level two, they can enter the level three next. Likewise, if the participant obtains two consecutive scores less than 25, they will be dropped from the class. That is, if the original rank is rank two, then they recede to rank one; if the original rank is rank three, then they recede to rank two. This is depicted in Figure 2.

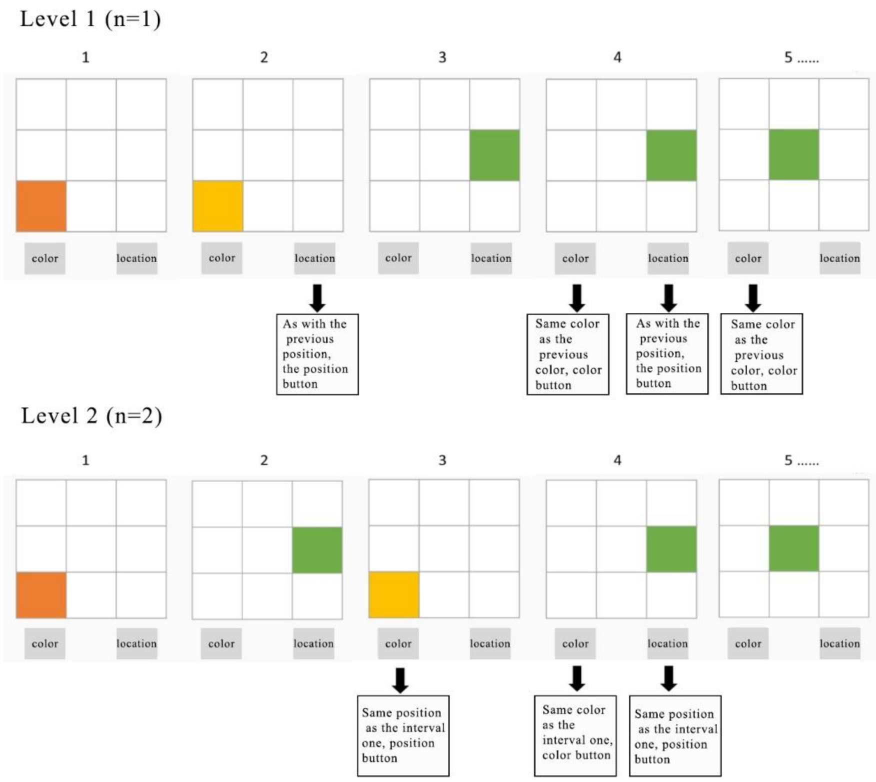

Figure 2. Schematic diagram of dual-dimensional n-back task.

(2) VR natural environment video of forest and water

The VR video of a forest and water was filmed from 23 September to 28 September 2019 from 10:00 to 16:00 on sunny days. The video was shot through a UCVR EYE VR camera (Changzhou Pingang Intelligent Company, Changzhou, China), which captured the forest and water in the same way. The shooting height was 1.4 m, the shooting angle was 150°, and the duration was 20 min [35]. The original video was shot for a total of 75 min. Among them, forest VR video involved plant-based scenes in five parks in Beijing, namely Beigong Forest Park, Lianshi Lake Park, Green Bank Park, Century Forest Park, and Yongding River Recreational Forest Park. This is depicted in Figure 3. The water VR video is a water scenery-based scene, shot in Beijing's Lian Shi Lake Park, Greenbank Park, Century Forest Park, and Yudong Country Park. This is depicted in Figure 4. The original video was edited using the LoveClip v17.1 software in which the images of people and animals were deleted. Both the forest VR video and the water VR video appeared in seven scenes, each for 180 s, with a total length of 21 min each. Participants viewed the scenes in 360° modes on a cell phone using UtoVR's app in dual lens. For the case of UtoVR flashback on a participant's phone, the participant could use the VR player with the same mode for full-screen viewing. There is no difference between the two viewing methods.

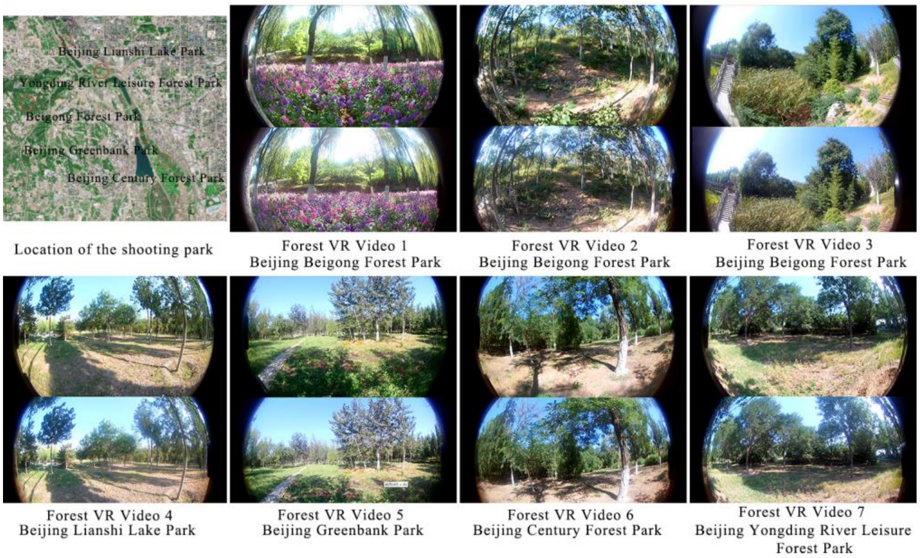

Figure 3. Forest VR natural environment video.

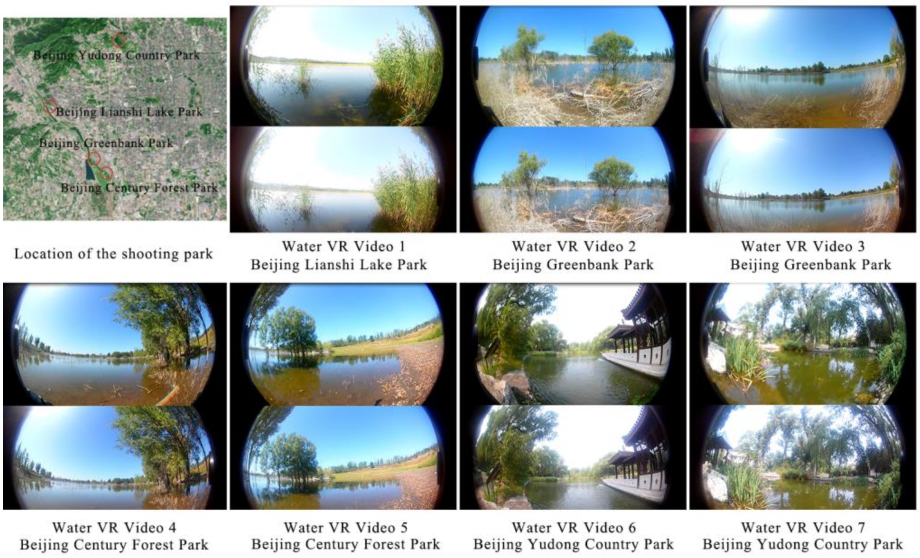

Figure 4. Water VR natural environment video.

(3) WeChat public tweets

Participants in the control group were asked to read tweets from a public website called WeChat. The tweets were mainly about theories and practices related to therapeutic landscape. The articles were distributed randomly, and the participants were asked to read them on their cell phones.

2.4. Experimental Indicators

2.4.1. Emotional Indicators

The Profile of Mood States (POMS) is a highly reliable and effective tool for testing the states of mind and moods of individuals [46,47]. The Brief Profile of Mood States (BPOMS) is a simplified version of the POMS, which is more convenient to use. After extensive experiments, the Brief Profile of Mood States (BPOMS) has been shown to be an efficient and convenient tool for measuring participants' moods and emotions [48–50].

The statistics of the BPOMS scale include the Total Mood Disturbance (TMD) and five dimensional factors: tension (T), anger (A), fatigue (F), vigor (V), and confusion–depression (C + D). The scale consists of 30 emotion-related adjectives, such as "nervous", "angry", "exhausted", "uplifted", "confused", etc. When each adjective is rated, a score of 1–5 represents different levels of sensation, where 1 = no such feeling at all, and 5 = a very strong such feeling. The participative effects of different training methods on mood were determined by analyzing the data on the TMD and the changes in the values of each dimension. T reflects tension–anxiety, A reflects anger–hostility, F reflects fatigue–weakness, V reflects vigor–energy, and C + D reflect confusion–depression [46]. The formula for calculating TMD is shown below.

$$TMD = T + A + F + C + D - V.$$

2.4.2. Cognitive Indicators

The working memory measurement app is used in this study. Each cognitive index was assembled into one app. The app is applicable to Android cell phones.

Working memory training has been shown to have an effect on central executive function in existing studies. The three core functions of the central executive system (updating, shifting, and inhibition) are reflected by different specific metrics. Please see Table 2 for details.

Table 2. Cognitive indicators of central executive system.

Function	Task Type	Specific Indicators
Updating	Running memory task	Running memory accuracy
	2-back task	2-back average accuracy
Shifting	Digital task shifting	Shifting cost
Inhibition	Stroop task	Stroop conflict effect Stroop baseline accuracy; Stroop conflict accuracy

1. Running memory task

The running memory reflects the updating function of the central executive system. In the task, participants were presented with 3–9 randomly appearing digits, each displayed for 1000 ms at 800 ms intervals. Participants were asked to continuously update their memories and fill out the last four digits when the numbers were presented. The task consisted of 14 attempts, with all four numbers being correct as the final correction. Running memory was used as a specific indicator in terms of the correct rate. Running memory accuracy = correct trials/total task trials × 100. When the task was finished, the participant was shown the results.

2. The 2-back task

The 2-back task was also used to reflect the updating function. Participants were presented with three randomly appearing groups of 22 letters each, with each letter appearing individually; each letter was displayed for 1000 ms at 800 ms intervals, and participants were asked to respond starting with the third letter. When the 3rd letter was the same as the 1st letter, participants had to press the button at the bottom of the screen, and if the 3rd letter was not the same as the 1st letter, they did not have to press the button. When the 4th letter was the same as the 2nd letter, the key was pressed next. That is, the participants needed to determine whether the current letter n was the same as the nth–2nd letter. During this process, participants were asked to continuously update their memories and be able to respond faster and better. When each set of tasks was finished, the participants could see the number of correct keys, the number of no keys, and the number of incorrect keys.

3. Digital shifting task

The digital shifting task reflects the shifting function of the central execution system. Participants were asked to shift between simple tasks greater than or equal to two. The task was divided into three stages, which were the judgment of the size of the number, the judgment of the parity, and the judgment of the size or parity according to the color, and 32 numbers appeared in each stage. In Phase I, random numbers from 1–9 were presented except 5. The participants had to press the left button if the numbers were bigger than 5 and press the right button if they were smaller than 5. In Phase II, random numbers from 1–9 except 5 were presented, with odd numbers allocated to the left button and even numbers allocated to the right button. In Phase III, numbers from 1–9 were presented randomly with colors except for 5. Participants were asked to judge size by seeing blue numbers, pressing the left button when they saw a number larger than 5, and pressing the right button when they saw a number smaller than 5. Participants were asked to see yellow numbers to determine parity, and they had to press the left button when they saw an odd number and press the right button when they saw an even number.

Digital task shifting uses the cost of shifting as a specific metric. In this study, the shifting cost refers to the difference between the response time of the repeated task and the shifting task [47]. The average response time of the three phases was recorded for this task. The calculation formula is as follows: Shifting cost = average reaction time in Phases III-(average reaction time of Phase I + average reaction time of Phase II)/2. The better the task is completed, the smaller the shifting cost will be.

4. Stroop task

The Stroop task is used to reflect the inhibition function of the central execution system. This study uses a numerical variant of the classical Stroop paradigm. The task is divided into two phases, and the two phases are baseline and conflict. In each stage, 40 characters or numbers appear. There are 10 separate exercises to be completed before the official task begins. In the Phase I—baseline stage, participants are presented with a series of strings such as X, XX, XXX, and XXXX on the screen and are asked to correctly determine the number of Xs as quickly as possible and then respond with a keystroke. In Phase II—conflict phase, the string is changed to a number. For example, when the numbers 2, 33, 444, 1111, etc., appear on the screen, the participant is asked to determine the number of numbers as quickly as possible and press the key to answer.

The Stroop task uses conflict effects and accuracy rates as specific metrics. The Stroop conflict effect refers to the difference in response times between a conflict situation and a congruent situation or a conflict situation and an unrelated situation. The higher the amount of conflict effect, the worse the inhibition [48]. The correct rate is divided into baseline accuracy and conflict accuracy.

2.4.3. Preference and Adherence Indicators

Participants' preferences and adherence were tested using a questionnaire. Participants were asked to answer three questions: (1) the number of times they actually completed the task in a month (1–3 times on a scale of 1; 4–6 times on a scale of 2; 7–9 times on a scale of 3; and 10–12 times on a scale of 4); (2) whether they liked the task (on a scale of 1–3); and (3) which daily training method they would choose if they self-selected one (1, watching forest VR videos; 2, watching water VR videos; 3, working memory training; and 4, other). Question 1 reflects adherence, question 2 reflects preference, and question 3 reflects willingness.

2.5. Data Analysis

The experimental data were organized statistically and analyzed using the software SPSS Statistics 25 and EXCEL 2021. Firstly, participants' adherence, preferences, and willingness were analyzed using the chi-square test and frequency analysis. Then, the ones with good adherence were selected for data analysis for the emotional and cognitive effects. In this study, adherence was defined as the number of times a participant performed a task as requested. Adherence was considered to be good if the participant performed the task seven or more times. A repeated measures analysis of variance (ANOVA) was performed on the data results of emotional and cognitive indicators for 4 groups (working memory training group/forest VR intervention group/water VR intervention group/control group) $\times$ 2 time points (pretest/post-test).

3. Research Results

3.1. Indicators of Adherence, Preferences, and Willingness

When the questionnaire results of 136 participants were analyzed, there were no significant differences in the results of the χ^2 test for each group in terms of training adherence (χ^2 (9, N = 136) = 10.346, p = 0.323). A trend analysis of the percentage of adherence revealed that the water VR intervention group showed a better trend of adherence, with 53.8% completing 10–12 sessions and 65.3% completing 7–12 sessions. This case is depicted in Figure 5.

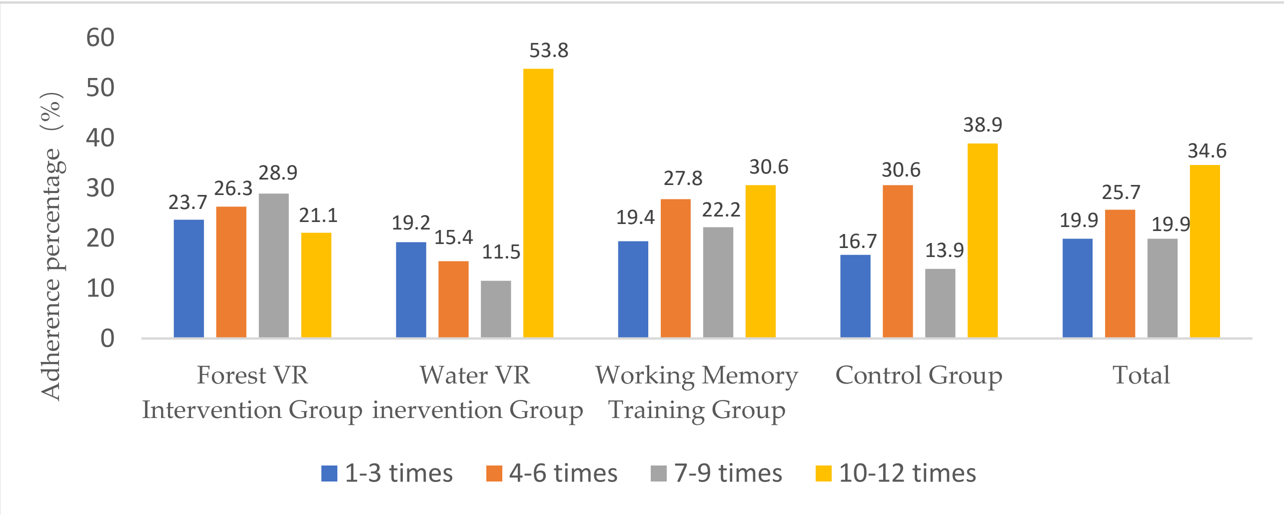

Figure 5. Trend analysis of different home training adherence graphs.

After analyzing the results of the survey regarding the preferences of the 136 participants in the training group, there were no significant differences in the results of the χ^2 test for each group (χ^2 (6, N = 136) = 2.552, p = 0.863). When observing the trend of frequency distribution of preferences in each group, it was found that the number of people who preferred the forest VR intervention and the control group accounted for a relatively large number. This case is depicted in Figure 6.

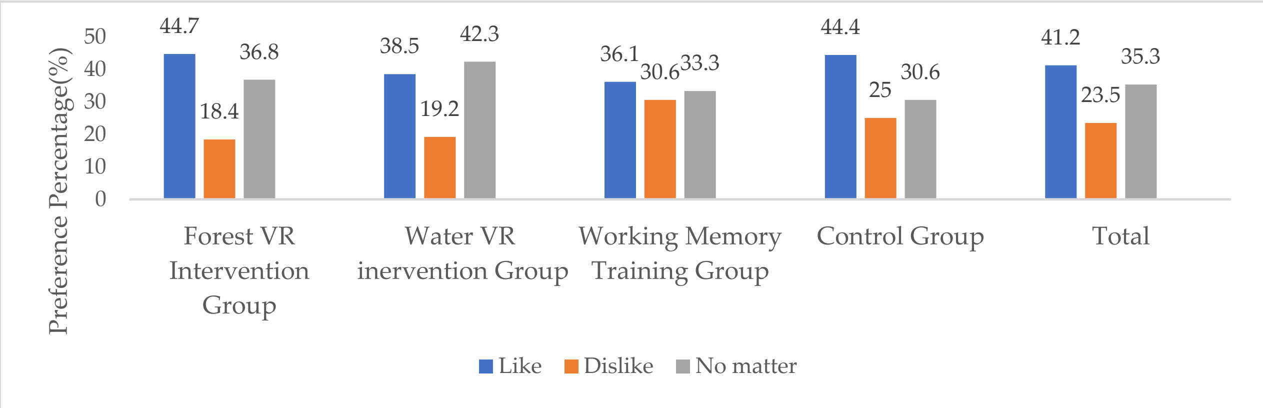

Figure 6. Trend analysis charts of different home training preferences.

After analyzing the results of the survey of 136 participants' willingness to participate in home training, there were no significant differences in the results of the χ^2 test for each group (χ^2 (9, N = 136) = 10.003, p = 0.350). The results of the χ^2 test of willingness and preference were also not significantly different and not significantly correlated. A cross-analysis of the preferences and intentions of the 136 participants revealed that those who expressed a preference were more likely to indicate an intention to participate in the future. This case is depicted in Figure 7. It is noteworthy that in the survey regarding the willingness to participate in home training, all groups of participants who participated in daily training showed a tendency to be more willing to participate in other training. This is demonstrated by the following: a trend towards a higher willingness to participate in future forest VR interventions for the participants in the group involved in working memory training and a trend towards a higher willingness to participate in future water VR interventions among the participants who participated in forest VR training. The willingness of the participants in the control group to participate in future home training was the three daily home training (forest VR, water VR and working memory training). The ranking of percentages of participants in the control group who were willing to participate in daily home training was, in descending order, water VR training, forest VR training, and working memory training. Totally, the percentage of willingness to participate in home training in the future is ranked from highest to lowest as follows: water VR, forest VR, working memory training, and other. This is depicted in Figure 8.

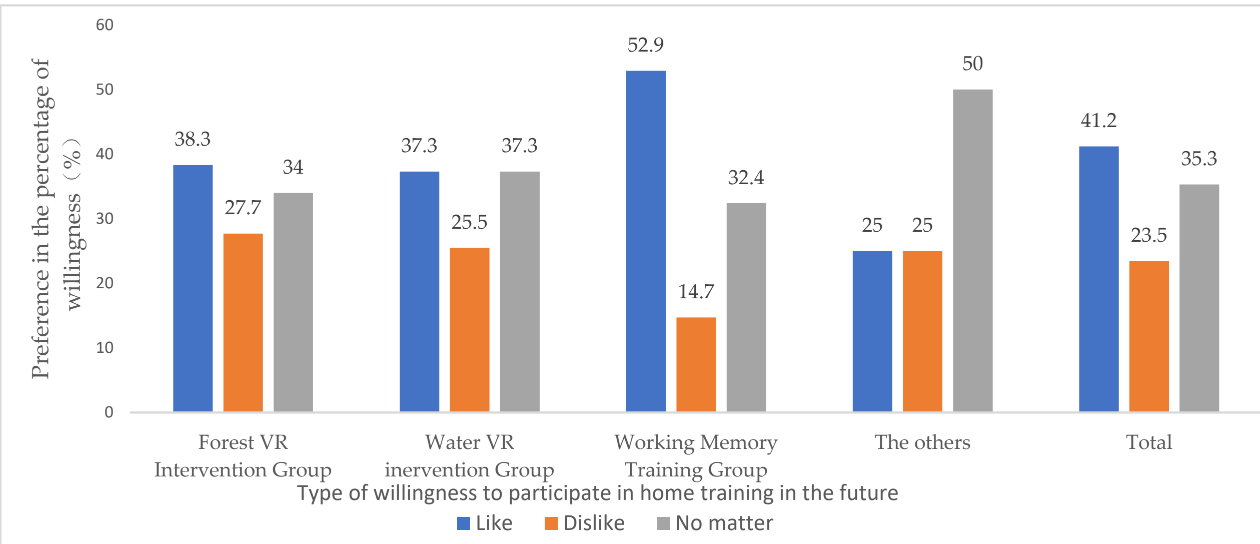

Figure 7. Analysis chart of percentage of different home training preferences and willingness.

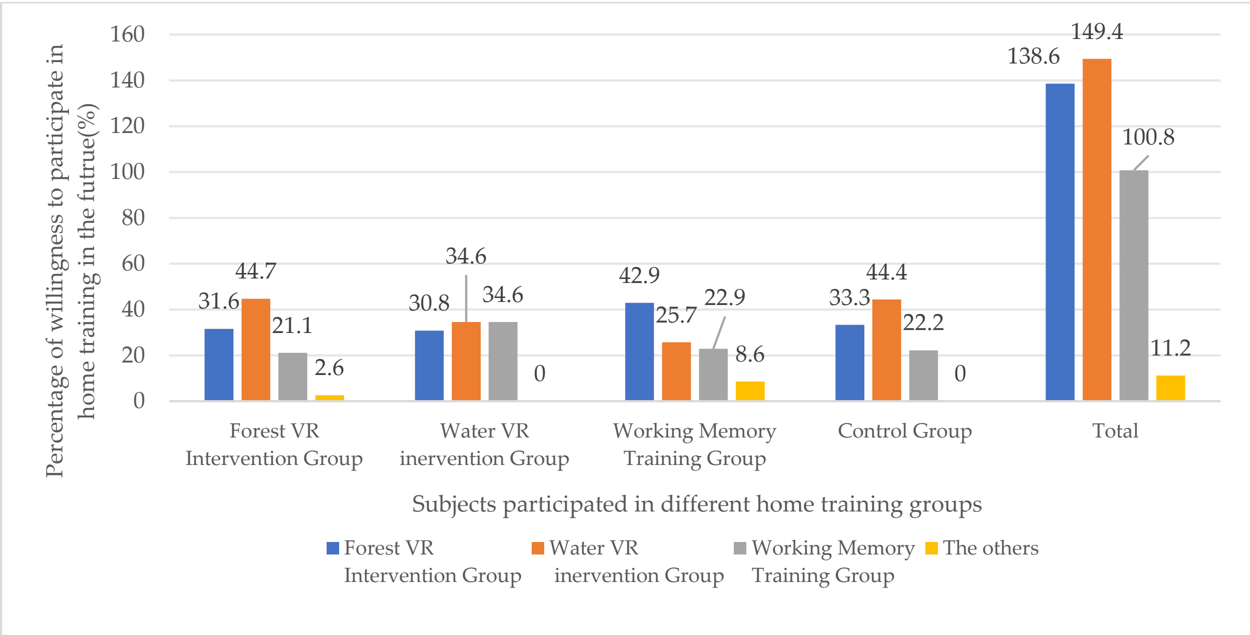

Figure 8. Analysis of percentage of willingness to participate in future home training methods within different home training groups.

3.2. Emotional Indicators

For the BPOMS scale, there were no significant differences in the time point and group main effects for the T-value, F-value, V-value, C + D-value, and TMD-value, and there were no significant differences in the time point × group interaction.

The main effect of the A-value time point was significant (F (1,58) = 10.457, $p = 0.002$, $\eta^2 = 0.153$), showing that the post-test was significantly higher than the pretest. Neither the group main effect nor the time point × group interaction was significant. Another simple effects analysis resulted in a significantly higher control post-test relative to the pretest (F (1,58) = 6.197, $p = 0.016$, $\eta^2 = 0.097$). This is depicted in Figure 9.

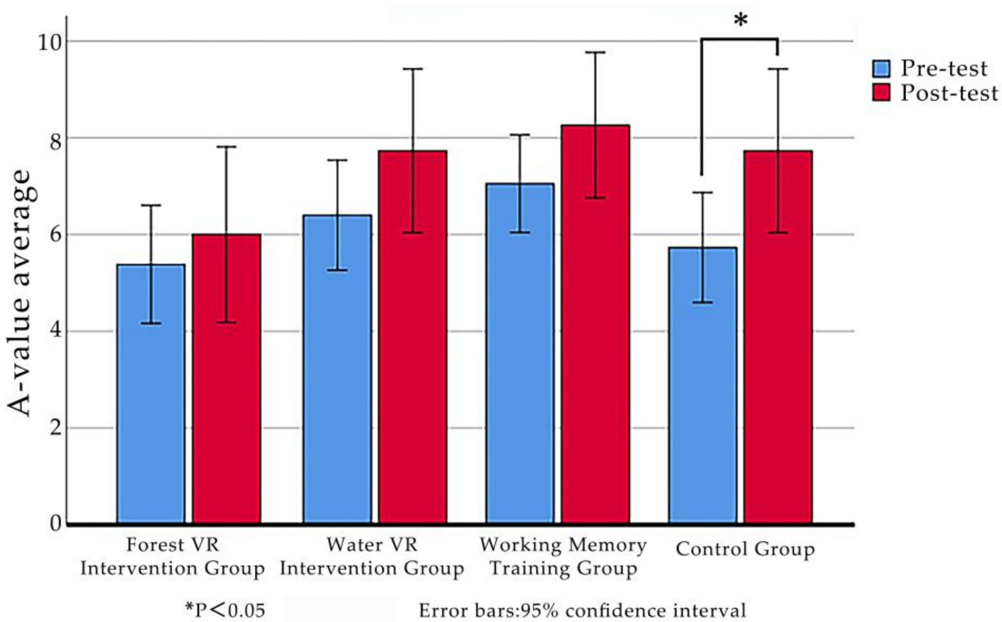

Figure 9. Pre- and post-test mean A values in BPOMS for different groups.

3.3. Cognitive Indicators

The main effect of the time point of running memory accuracy was significant (F (1,58) = 4.797, $p = 0.033$, $\eta^2 = 0.076$). Another simple effects analysis was conducted, and the results showed that the working memory training group significantly improved on the post-test relative to the pretest (F (1,58) = 5.142, $p = 0.027$, $\eta^2 = 0.081$). This is depicted in Figure 10.

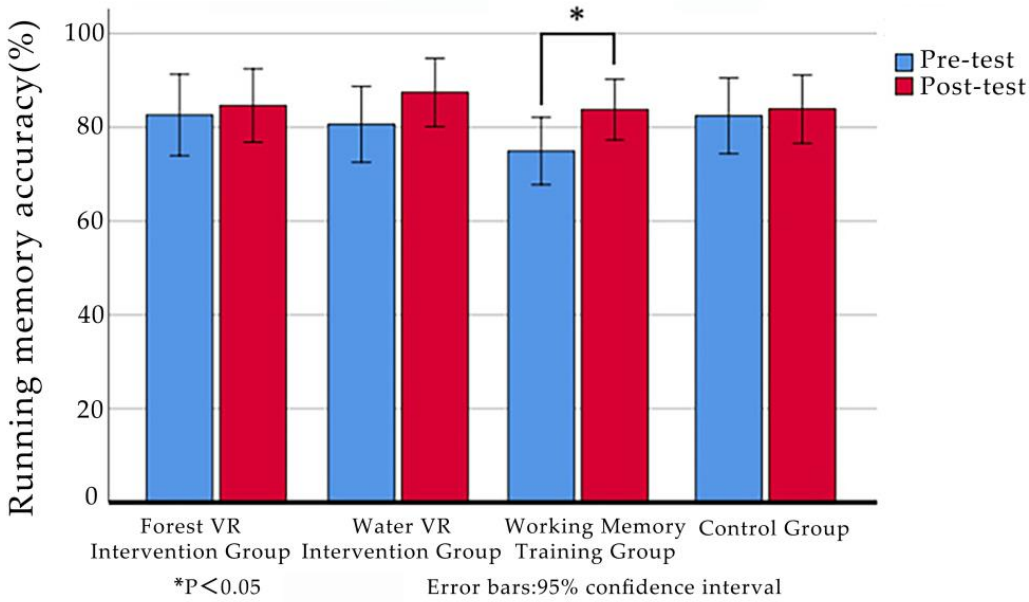

Figure 10. Pre- and post-test mean values of running memory accuracy for different groups.

The main effect of the 2-back average accuracy time point was significant (F (1,58) = 27.866, $p = 0.00$, $\eta^2 = 0.325$). Another simple effects analysis was performed, and the results show that the average accuracy on the post-test relative to the pretest was significantly higher in both the working memory training group and the forest VR intervention group. In the working memory training group, F (1,58) = 14.722, $p = 0.000$, and $\eta^2 = 0.202$. In the forest VR intervention group, F (1,58) = 13.364, $p = 0.001$, and $\eta^2 = 0.187$. These results are depicted in Figure 11.

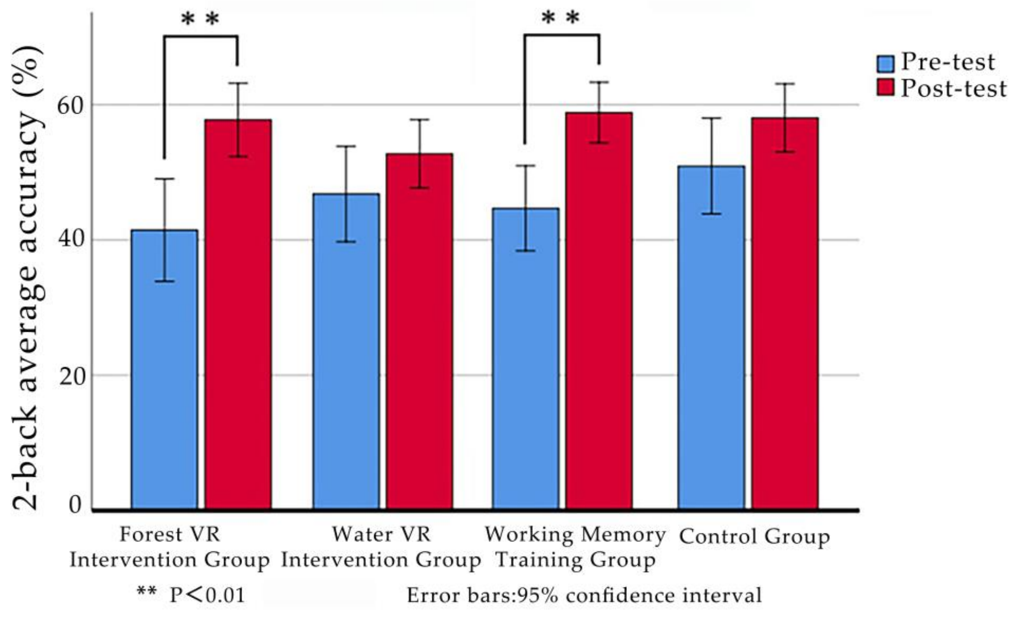

Figure 11. Pre- and post-test mean plot of 2-back average accuracy for different groups.

The main effect of the shifting cost point in time was significant (F (1,58) = 11.587, $p = 0.001$, $\eta^2 = 0.167$). Another simple effects analysis was conducted, showing a significant decrease in the post-test relative to the pretest in the working memory training group (F (1,58) = 5.061, p = 0.028, η^2 = 0.080). The water VR intervention group had significantly lower post-test results relative to the pretest (F (1,58) = 6.720, p = 0.012, η^2 = 0.104). These results are depicted in Figure 12.

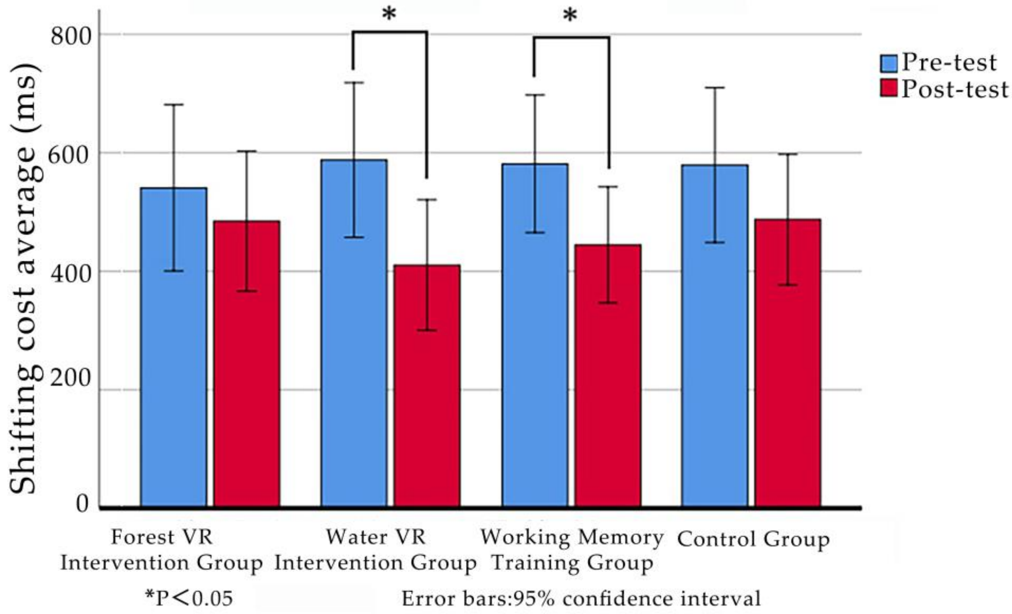

Figure 12. Pre- and post-measurement means for different groups of shifting cost.

The point-in-time and group main effects of the Stroop conflict effect and conflict accuracy were not significant, and the point-in-time × group interaction was not significant.

The main effects of the Stroop baseline accuracy group differed significantly (F (1,58) = 2.932, p = 0.041, η^2 = 0.132). The time point × group interaction was significant (F (3,58) = 3.062, p = 0.035, η^2 = 0.137). Another simple effects analysis was performed, and the water VR intervention group significantly improved in the post-test relative to the pretest (F (1,58) = 5.758, p = 0.020, η^2 = 090). This case is depicted in Figure 13.

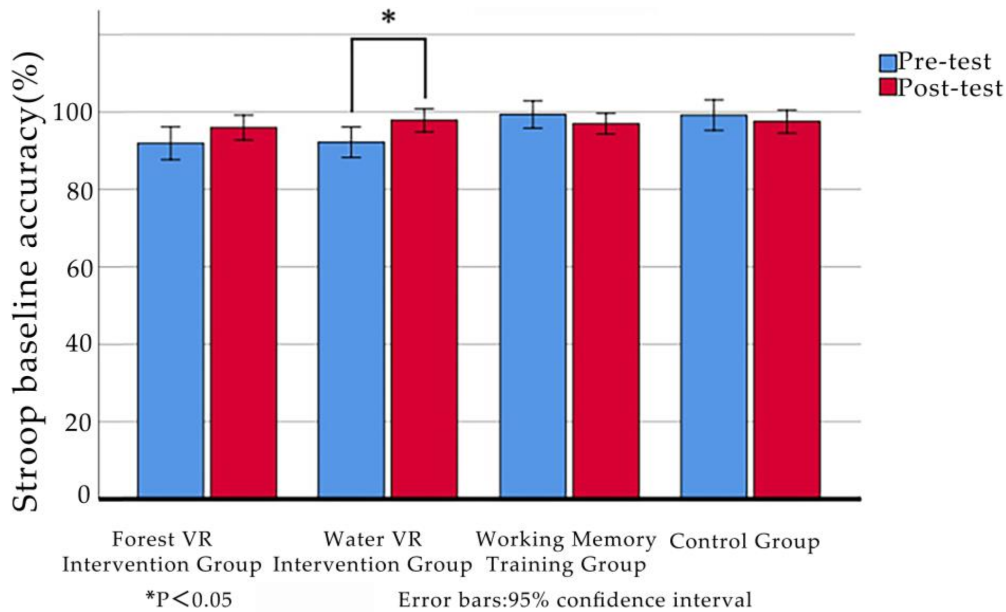

Figure 13. Pre- and post-test means of Stroop baseline accuracy for different groups.

4. Discussion

4.1. Indicators of Adherence, Preferences, and Future Willingness

The results of the chi-square test on adherence, preferences, and willingness of the participants in the experiment showed no significant differences between the groups. That is, the participants did not differ in terms of specific adherence characteristics, preferences, or willingness to participate in the working memory training, the forest VR intervention, the water VR intervention, or the control group. It is essential that the null hypothesis for Hypothesis 1 (H1) be accepted, as there was no difference.

It was found that the participants who participated in their group tended to choose other types of training regarding their willingness to participate in the future. The reason for this result may be due to curiosity, but it may also be due to the fact that a single training session is too long, which makes a young person bored, and over time, they may find it difficult to persevere. Through informal post-experimental interviews with the participants, it was found that improvements to the nature of the VR videos, such as shorter viewing times, increased interactivity, and the inclusion of bird calls and water sounds may have an impact on the participants' adherence, preferences, and willingness to participate. This may mean that more research is worthwhile for VR nature video content in future studies.

4.2. Emotions

On the psychological side, there were no significant changes in the values of the dimensions of the BPOMS scale and the Total Mood Disturbance (TMD) values, except for the anger (A) dimension of the BPOMS scale, which was significantly higher in the control group. For Hypothesis 2 (H2), it is necessary to accept the null hypothesis that there is no difference in the regulation of emotions among watching a forest VR video, watching a water VR video, and performing working memory training.

Regarding anger value A, the result might imply that the A value would be elevated without an intervention. The forest VR intervention, water VR intervention, and working memory training all contribute to the smooth maintenance of anger values if a home training intervention is performed. This indirectly suggests that the three home training methods all contribute to sustained emotional stability.

Part of the reason for this effect may be that VR distracts people from everyday stresses and gives them a mental break, thus stabilizing their moods [18]. The results of this study are also indirectly corroborated in existing studies, such as those stating that the experience of viewing simulated natural beauty increases positive emotions and thus contributes to a more stable emotional state [5,51]. The findings of this study are consistent with those of previous studies, including the result that working memory training could reduce susceptibility to repetitive negative thinking (RNT) episodes [25] and may also facilitate emotional regulation [26].

The mean value exhibited an upward trend of the anger (A) dimension in all groups, but it did not reach the level of significant difference. The reason for this result may be that the BPOMS scale is more responsive to emotions in a timely manner and perhaps somewhat insensitive to the emotional outcomes that result from long-term home training. Meanwhile, the experimental results showed no significant differences in all indicators except for the anger (A) dimension value. This corroborates with the results of a previously conducted 5-day forest video home intervention in which there was no difference between STAI-Y1 and STAI-Y2 [41]. In addition, the pretesting period at the beginning of the experiment was the mid-teaching phase for most of the participants, where participants were less academically stressed. The post-testing period at the end of the experiment was a time when these participants were facing many academic problems, such as final papers and exams, and they were generally stressed, which may have been one of the factors affecting their moods.

4.3. Cognitive

The results of both the running memory accuracy and the 2-back average accuracy showed that the post-test results of the working memory training group were significantly higher relative to the pretest. The forest VR intervention group also achieved significantly higher levels of 2-back average accuracy, suggesting that daily working memory training has a significant positive effect on the updating component of the brain's central executive function. It is worth mentioning that the improvement in the post-testing scores of the working memory training group on the home training task (dual dimensional n-back task) was well justified in terms of the 2-back mean accuracy; the forest VR intervention group also achieved a similar significant improvement as the working memory training group, which is also very rare. This may imply that the forest VR intervention has a positive facilitative effect on updating function similar to that of working memory training.

In terms of the results of the cost of shifting, both the working memory training group and the water VR intervention group had significantly lower post-test results relative to the pretests, indicating that the training of both groups significantly improved the shifting function of the brain's central executive system.

In terms of the results of the digital Stroop task, the baseline accuracy post-test scores of Stroop were significantly higher in the water VR intervention group, which, interpreted in terms of the automated generation mechanism of the Stroop effect, may imply faster automatic processing for participants in the water VR intervention group. However, the lack of significant changes in the digital Stroop conflict effect and conflict accuracy may mean that all training did not promote the brain's ability to inhibit processing.

The above findings further support the conclusion of existing studies that online mobile working memory training has a significant near transfer (working memory-related) effect, while the far transfer (emotion-related) effect does not form a consistent conclusion, and researchers have reservations about the effects of online training [52].

VR exposure to nature rejuvenates cognitive functions by providing a restful environment that restores attentional capacity [2]. This digital immersion into nature fosters focus and memory recall, mimicking the cognitive benefits of physically being in natural landscapes [53]. VR's ability to deliver high-fidelity nature experiences can offer similar cognitive benefits, leading to improvements in focus, memory retrieval, and creativity, as supported by research such as the work by Berman, Jonides, and Kaplan [6].

In settings such as hospitals, rehabilitation centers, long-term care facilities, prisons and detention centers, and quarantine zones, where individuals may lack access to genuine natural environments, regular exposure to nature-themed virtual reality (VR) videos or cognitive training may confer emotional and cognitive benefits to these individuals. It is similarly important to ensure that the emotional and cognitive benefits of virtual nature are accessible to the managers of the aforementioned organizations, who can then utilize them to their advantage.

4.4. Limitations and Future Directions

In this study, only 65.3% of the training sessions were actually completed more than seven times, which directly led to a sharp decrease in the number of valid participants for emotion and cognition. Also, lower completion rates can affect the accuracy of the data results and weaken the strength of the actual impact of home training on participants over the course of a month.

It should be noted that the scales and indicators employed in this study to reflect emotion may be subjected to certain limitations. The utilization of the Brief Psychiatric Rating Scale (BPOMS) may not have been optimal for a long-term intervention. The BPOMS scale measures short-term, transitional mood states. As there is no "gold standard" measure of emotional responding, experiential, physiological, and behavioral measures are all relevant to understanding emotion [3]. Other scales, such as the PANAS, could be used. At the same time, more physiological signals can be used as indicators, such as electroencephalograms (EEGs), electrodermal activity (EDA), electrocardiograms (ECGs), and electro-myography (EMG) [6].

In this study, the participants were only college students or graduate students. The ages, structures, and intelligence levels of the participants were too homogeneous and did not reflect the various groups of people. In particular, the participants did not reflect specific populations that might benefit from the intervention, such as those who were isolated during the epidemic, elderly people with limited mobility, hospitalized patients, prisoners, people with disabilities, and so forth. At the same time, the number of participants in each group was small. The results of this experiment can be considered as results of an exploratory study, and future studies need to include a richer population type and a larger number of participants for further validation.

5. Conclusions

There were no significant differences in the individuals' adherence, preference, or willingness or in the effects of training on emotion and cognition among different types of home training (watching forest VR videos, watching water VR videos, or working memory training) in the long term using mobile terminals. However, home training may be more conducive to the stabilization of anger. A forest VR intervention has a positive impact on the updating function of the central execution system. A water VR intervention has a positive effect on the shifting function of the central execution system and can increase the automatic processing speed. Working memory training has a significant beneficial effect on the updating and shifting functions of the brain's central executive system.

This study suggests that individuals may engage in VR nature videos or working memory training when seeking to maintain emotional stability in their daily lives. Similarly, individuals may choose to watch forest VR videos or perform working memory training when aiming to enhance the updating function of the central executive system. Additionally, subjects can choose to enhance their shifting function by watching a water virtual reality video or performing working memory training. In terms of temporal dosage, the findings indicate that a 20 min home training routine thrice weekly yields positive results.

Concurrently, while mobile-based home training may have some positive effects on emotion and cognition, further research is required to ascertain how to improve adherence and motivate individuals to actively engage in home training.

Author Contributions: Have made substantial contributions to the conception and design of the work, X.W., X.L., Y.S. and D.P.; the analysis and interpretation of data for the work, X.W.; Drafting the work and revising it critically for important intellectual content, X.W. and X.L.; Final approval of the version, X.W., Y.J., X.L., Y.S. and D.P.; Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved, X.W., Y.J., X.L., Y.S. and D.P.; The acquisition of data for the work, Y.J.; Drafting the work, Y.J. and D.P.; the interpretation of data for the work, X.L.; Revising it critically for important intellectual content, Y.S.; the analysis of data for the work, D.P. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The experimental materials are three-dimensional videos, and the amount of data is too large. So, the data were not uploaded to a public data platform. Researchers who need the data can contact the authors in order to obtain the relevant data.

Conflicts of Interest: The authors declare no conflicts of interest.

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