

The Restorative Effects of Virtual Reality Forests on Elderly Individuals During the COVID-19 Lockdown

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ABSTRACT

This study focuses on the restorative effects of immersive virtual reality (VR) forest experiences on elderly people during the COVID-19 lockdown. A field experiment with 63 elderly participants was conducted in an elderly care institution in China. The results showed that a five-minute VR forest experience with three minutes of subsequent reliving can bring immediate psychological improvements (i.e., increased positive affect, decreased negative affect, and enhanced stress recovery) to elderly individuals. The negative affect decrease and stress recovery enhancement were more obvious among introverted individuals. Furthermore, participating in three VR forest experiences over three consecutive days can bring continuous psychological improvements. Moreover, short VR forest experiences were unable to significantly decrease the blood pressure of participants. The effects of three VR experiences over three days on blood pressure improvement were also nonsignificant. Additionally, VR forest experiences can increase elderly participants' intentions to undertake real forest therapy.

KEYWORDS

Elderly, Negative Affect, Positive Affect, Restorative Outcomes, Virtual Reality Forest

INTRODUCTION

The outbreak of the COVID-19 pandemic has brought particularly serious challenges to the health of elderly people, as the elderly are more likely to be infected by the virus (Zhou et al. 2020), and the mortality rate of COVID-19 among elderly patients is significantly higher than that of other age groups (Yanez et al. 2020). Unfortunately, scientists are inclined to believe that COVID-19 could become a long-standing disease that coexists with humans (Telenti et al. 2021). In the new normal of COVID-19, finding ways to help the elderly population overcome infection anxieties and lockdown has become an important issue for elderly individuals, care institutions, and society as a whole.

Extensive evidence has shown that forest therapy — a combination of activities (e.g., walking, guided activities) performed in real forest environments — can play an active role in improving people's mental and physical wellbeing (e.g., Kim et al. 2015; Lee et al. 2011; Lyu et al. 2019; Rosa et al. 2021; Song et al. 2017; Yu and Hsieh 2020). However, the infection anxieties and lockdown measures due

to COVID-19, along with other barriers (e.g., low income), prevent most elderly individuals from improving or returning to their pre-COVID-19 states through engagement in real forest therapy.

Some recent evidence suggests that VR forest environment experiences could be an effective alternative to real forest therapy for improving people's health (e.g., Li et al. 2020; Mattila et al. 2020; Yu et al. 2018). VR forests are forest environments simulated via recent VR technology and devices (e.g., head-mounted displays with headphones) that can provide users with pleasant, vivid, and immersive forest experiences (Gammack and Hodgkinson 2003; Mattila et al. 2020; Yu et al. 2018). It has been demonstrated that VR forest experiences can enhance stress recovery (Annerstedt et al. 2013; Li et al. 2020), increase the level of vigor and positive affect, and decrease negative emotions, systolic blood pressure and heart rate (Mattila et al. 2020; Yu et al. 2018).

Although some positive effects have been documented, research focused on the restorative effects of VR forest experiences is scarce given "the short history of the latest immersive VR technology" (Yu et al. 2018, p. 107). In particular, prior studies have neglected (a) to test whether the restorative effects of VR forest experiences are still significant among elderly individuals; (b) to discern the immediate and sustained effects of VR forest experiences on individuals' restoration (Mattila et al. 2020); (c) to explore when the restorative effects of VR forest experiences are more obvious (Reese and Menzel 2021); and (d) to examine whether VR forest experiences can increase individuals' intentions to undertake real forest therapy.

To fill these research gaps, in this study, a field experiment was conducted over 3 consecutive days to investigate the immediate and sustained restorative effects of VR forest experiences on elderly individuals. Specifically, this study aims to test (a) whether a short VR forest experience can bring immediate psychological (e.g., emotional improvements and stress recovery) and physiological (e.g., blood pressure) restoration to elderly individuals; (b) whether three VR forest experiences over 3 days can result in sustained psychological and physiological improvements for elderly individuals; (c) whether those restorative effects are based on individuals' introverted versus extraverted personalities; and (d) whether VR forest experiences can elevate elderly individuals' intentions to undertake real forest therapy.

By examining the above effects, this study contributes to four aspects of the related literature. First, this work provides new evidence regarding the immediate and sustained psychological restorative effects of VR forest experiences on elderly people. Second, the findings challenged those of previous studies (e.g., Yu et al. 2018; Song et al. 2017) by revealing that VR forest experiences cannot bring immediately and sustained improvements in elderly individuals' blood pressure. Third, this study uncovers a boundary condition (i.e., individuals' introverted versus extraverted personalities) of VR forest experiences' psychological restorative effects. Finally, this study demonstrated that VR experiences can increase elderly people's intentions to undertake real forest therapy.

The remainder of the paper is organized as follows. The next section describes the theoretical background and hypotheses. The third section provides the details of an experiment performed over 3 consecutive days to test our hypotheses. The final section provides a discussion, implications, limitations, and directions for future research.

THEORETICAL BACKGROUND AND HYPOTHESES

Restorative Effects of Real Forest Therapy

Attention restoration theory (Kaplan and Kaplan 1989) and stress recovery theory (Ulrich et al. 1991) are two theories that have been widely used by previous studies to illustrate the restorative effects of real forest therapy. Based on the cognitive perspective, attention restoration theory argues that natural environments can provide people with positive psychological and physical health benefits. Our modern urban lifestyles impose increasing demands on people's cognitive resources (Kaplan and Berman 2010), likely leading to attention fatigue — a set of symptoms (e.g., feeling exhausted,

irritable) resulting from overload (Kaplan 1995; Kaplan and Kaplan 1989). Attention restoration theory claims that spending time in and having interactions with natural environments can enable the sufferer to recover from attention fatigue. Being in a natural environment can allow sufferers (a) to “be away” from daily stresses, (b) experience “softly fascinating” natural stimuli (e.g., trees, clouds, mountain paths), (c) experience expansive natural spaces (“extent”), and (c) be involved in activities that are “compatible” with their intrinsic motivations (Kaplan 1995). These factors jointly induce involuntary or indirect attention and restore the sufferer’s “voluntary” or “directed” attention capacities (Kaplan 1995; Ohly et al. 2016).

Based on the affective perspective, the stress reduction theory posits that living in a building-dominant urban environment can increase residents’ stress; thus, urban residents need to visit and experience natural environments periodically (Ulrich et al. 1991). Through visiting and experiencing natural settings, urban residents can recover from the stress that results from living in urban areas. Immersion in nonthreatening natural environments can induce more positive emotional states among urban residents and decrease their physiological arousal levels (Ulrich et al. 1991).

Drawing on these two theories, previous studies have documented substantial restorative effects from exposure to real forest/natural environments. The psychological aspects include an increase in positive emotions (e.g., Yu and Hsieh 2020), a decrease in negative emotions (e.g., Lee et al. 2011), reduced stress (Jung et al. 2015), and alleviated depression (e.g., Rosa et al. 2021). Physiologically, forest therapy has been reported to decrease systolic and diastolic blood pressure (e.g., Lyu et al. 2019), reduce heart rate (e.g., Song et al. 2017), and enhance the immune system (Kim et al. 2015; Lyu et al. 2019).

Restorative Effects of VR Forest Experiences

Recently, a new stream of research (e.g., Li et al. 2020; Mattila et al. 2020; Yu et al. 2018) has focused on the restorative effects of VR forest experiences. For example, Mattila et al. (2020) indicated that participants (67% were younger than 35 years old) reported increased subjective vitality, positive affect, and restorative outcomes, as well as decreased negative affect after being subjected to an immersive VR forest environment for 5 minutes. Yu et al. (2018) found that compared to a ten-minute stay in a VR urban environment, the same time spent in a VR forest caused significant psychological (i.e., increased levels of vigor and decreased levels of negative emotions) and physiological improvements (i.e., decreased systolic blood pressure and heart rate) for participants (30 individuals aged between 20 and 35 years). Moreover, Li et al. (2020) showed that a 5-minute exposure to a natural light of medium brightness in a VR forest reduced the stress levels of university student participants ($M_{\text{age}} = 19.79$, $SD = 1.90$) relative to an overly bright or overly dark VR condition.

These studies argue that the latest immersive VR system with head-mounted displays (launched after 2016) and headphones provides a first-person perspective and offers pleasant, vivid, and real experiences, thereby allowing users to be fully immersed in a simulated forest (Mattila et al. 2020; Yu et al. 2018). VR forests based on three-dimensional VR technology can also bring a high sense of presence — a subjective feeling of being in the forest setting (Mattila et al. 2020). The level of immersion and sense of presence are key factors determining the restorative benefits of VR forests (Mattila et al. 2020; Rajoo et al. 2020; Yu et al. 2018).

However, there were also some suspicions regarding the restorative effects of an exposure to a VR forest setting lasting only a few minutes. For example, Rajoo et al. (2020) explicitly indicated that short exposures (i.e., treatments in real or VR forest settings lasting a few minutes) are “an oddity” because most practical forest therapy programs last for hours, and some are conducted for days or even weeks.

Additionally, there have also been some debates on whether the activities employed in real/VR forest therapy or the forest itself bring restorative effects (Rajoo et al. 2020) because light exercises (e.g., walking, stretching exercises) and relaxing programs (e.g., indoor handcraft making) can also offer significant health improvements to participants (Dolling et al. 2017; Kang et al. 2015).

Hypothesis Development

Drawing on the attention restoration and stress recovery theory and existing findings on the restorative effects of exposure to forests, we propose that experiences in VR forests can also lead to positive restorative outcomes for elderly individuals. Psychologically, infection anxieties and long-term lockdown due to COVID-19 have imposed great mental stress on elderly people. In this regard, previous studies have argued that exposure to a VR forest environment can immediately provide users with softly fascinating, expansive, and compatible natural experiences (Mattila et al. 2020), thereby decreasing their arousal levels (Ulrich et al. 1991), restoring their “voluntary” or “directed” attention capacities (Kaplan 1995), and immediately inducing positive changes in emotional states (i.e., increased positive affect and decreased negative affect, Ulrich et al. 1991). Accordingly, taking a break for a few minutes in a VR forest can likely result in increased positive affect and decreased negative affect for elderly individuals. Moreover, since the central component of stress recovery is positive changes in emotional states (Ulrich et al. 1991), a short break of a few minutes in a VR forest can also likely bring immediate stress recovery for elderly individuals. Thus, we hypothesize the following:

H1: Taking a break of a few minutes in a VR forest significantly increases the positive affect (H1a) of elderly individuals, decreases their negative affect (H1b), and enhances their stress recovery (H1c).

Given that previous studies (e.g., Mattila et al. 2020; Yu et al. 2018) have neglected to explore the sustained effects of VR forest experiences, this study also sheds light on this issue. Based on H1 and the notion that the length of stay in and frequency of visiting one’s favorite places are positively related to restorative experiences (Korpela et al. 2008), we further propose that regular experiences in a VR forest over a relatively long time (e.g., 3 consecutive days) can have sustained psychological restorative effects for elderly individuals. Stated formally, we propose the following:

H2: Taking three short breaks in a VR forest over 3 consecutive days (once a day) results in continuous psychological improvements, i.e., increased positive affect (H2a), decreased negative affect (H2b), and enhanced stress recovery (H2c), for elderly individuals.

Physiologically, this study focuses on the possible restorative effects of VR forests on elderly individuals’ blood pressure. Because hypertension is the most common comorbidity with COVID-19 among elderly patients (Zhou et al. 2020), investigating the impacts of forest therapy on cardiovascular health is a central issue in the field of forest therapy (Rajoo et al. 2020). Concerning the restorative effects of VR forests on blood pressure, Yu et al. (2018) indicated that a ten-minute stay in a VR forest can lower a subject’s systolic blood pressure (SBP). Similarly, Song et al. (2017) showed that a ten-minute viewing of forest landscapes can reduce participants’ SBP and diastolic blood pressure (DBP). However, more studies (e.g., Lyu et al. 2019; Ohe et al. 2017; Rajoo et al. 2020; Yu and Hsieh 2020) tend to support the finding that relatively long-term exposure (e.g., a few days or weeks) in real or VR forests is needed to achieve significant cardiovascular restoration for participants. Moreover, the subjects of Yu et al. (2018) were young people, and the participants of Song et al. (2017) were middle-aged people. The restorative effects of VR forests on hypertension among elderly participants (aged over 65 years) are questionable.

In fact, cardiovascular diseases, such as hypertension, in elderly individuals are caused by chronic psychological stresses (e.g., daily stresses, work overload, and financial difficulties; Rosengren et al. 2004) and other long-term risk factors, such as an unhealthy lifestyle (e.g., smoking, alcohol use, Lantz et al. 1998) and personality traits (e.g., aggressive Type A personality, Bass and Akhras 1987). Specifically, cardiovascular diseases, such as hypertension, develop through chronic sympathetic nervous system stimulation of the cardiovascular system due to stress and other risk

factors (Schneiderman et al. 2005). Combining the above arguments, we propose that a break of a few minutes in a VR forest likely will not result in immediate blood pressure improvement for elderly individuals. Stated formally, we propose the following:

H3: Taking a break of a few minutes in a VR forest does not significantly decrease the blood pressure of elderly individuals.

According to the exposure time requirement for forest therapy (Lyu et al. 2019; Ohe et al. 2017; Rajoo et al. 2020), a relatively long exposure to VR forests may be needed to achieve a significant blood pressure improvement for elderly participants. However, long-term immersion in a VR forest may cause problems, such as users feeling slightly dizzy (Yu et al. 2018). We therefore propose that multiple short breaks over several consecutive days (e.g., 3 days) in a VR forest will likely achieve the same restorative effects as long-term exposure in real forest therapy. The underlying theoretical bases are attention restoration theory (Kaplan and Kaplan 1989) and stress recovery theory (Ulrich et al. 1991). The two theories demonstrated that periodic interactions with natural environments can help individuals to recover from attention fatigue and psychological stress and, thus, improve their physical health, such as blood pressure reduction (Lyu et al. 2019). Stated formally, we propose the following:

H4: Taking three short breaks in a VR forest over 3 consecutive days (once a day) significantly decreases the blood pressure levels of elderly individuals.

Furthermore, we argue that the restorative effects of VR forests are more obvious among elderly people with introverted (vs. extraverted) personalities. Introversion and extraversion are two contrasting personality types. Individuals with introverted personalities are usually unsociable, reserved, and reticent and like to spend time in their inner worlds of ideas and images, while individuals with extraverted personalities are usually sociable, outgoing, and talkative and like to spend time in the outer world with people and things (Kim, 2019; John and Srivastava 1999). Individuals with introverted personalities (introverts) do not like social activities, while those with extraverted personalities (extraverts) tend to look for new experiences and social contacts that let them communicate with other people as much as possible (Digman 1990; Kim, 2019).

When confronting stressful events in daily life, social contacts and communications are beneficial for stress relief. Socializing helps release the hormone oxytocin, which is a stress reliever (Heinrichs et al. 2003). Accordingly, extraverts are more likely to release their stresses in daily life via social communications, while introverts are more likely to accumulate daily stresses. Thus, taking breaks in a VR forest will have more obvious psychological and physiological restorative effects for introverts than for extraverts. In combination with H1 and H4, we hypothesize the following:

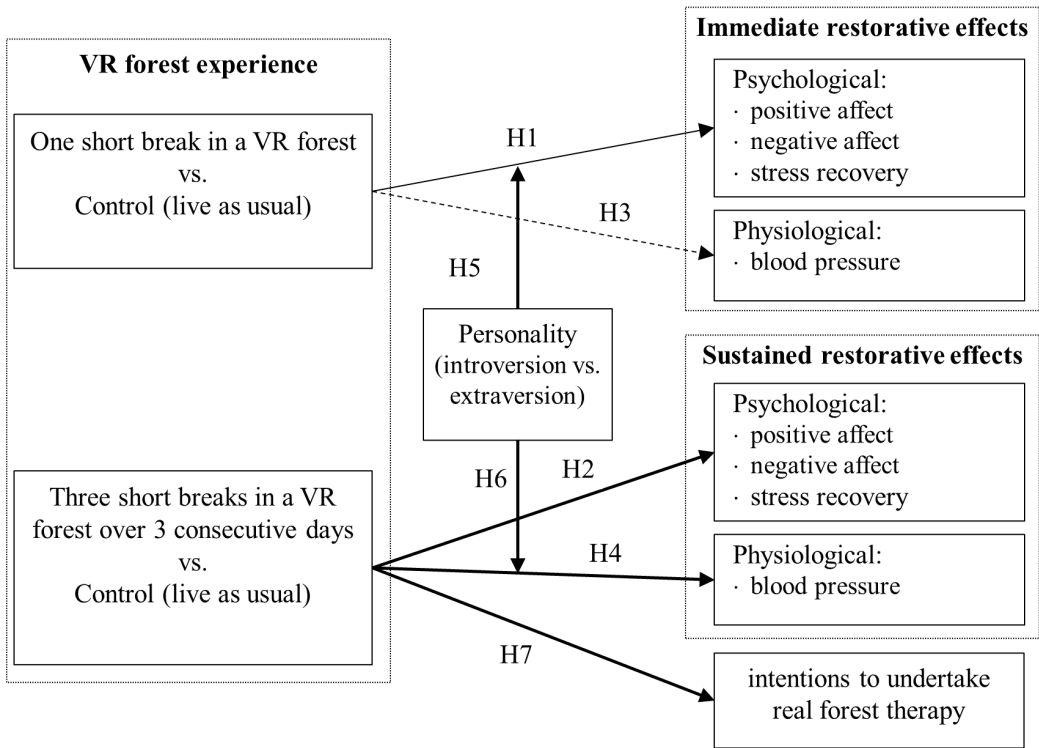
H5: Taking a break of a few minutes in a VR forest has more obvious psychological restorative effects, i.e., increased positive affect (H5a), decreased negative affect (H5b), and enhanced stress recovery (H5c), for introverted elderly individuals than for extraverted elderly individuals.

H6: Taking three short breaks in a VR forest over 3 consecutive days (once a day) results in a greater blood pressure reduction for introverted elderly individuals than for extraverted elderly individuals.

Finally, we argue that VR forest experiences may trigger users' intentions to undertake real forest therapy. Forest therapy involves a combination of recreational activities in forest environments with the aim of improving participants' health (Rosa et al. 2021). Exposure to a VR forest based on three-dimensional VR technology and head-mounted devices can provide the user with fascinating, comfortable, and peaceful natural experiences (Mattila et al. 2020). These pleasant experiences may enable users to reach the same goals as relaxing in a real forest (Ferguson 2008). However, a VR

forest is just a simulation of a real forest environment, and it cannot be completely replicate a real forest. For instance, the touch and smell in real forests cannot be simulated by current VR technology. Thus, the goal of relaxing in a real forest will make users evaluate real forest therapy more positively (Ferguson 2008) and further increase their intentions to engage in real forest therapy (Ferguson and Bargh 2004). Stated formally, we propose the following:

Figure 1. Conceptual framework.



Note:

- (a) The dotted arrow means the path is nonsignificant.
- (b) The paths indicated by thick lines were not examined by prior studies.

MATERIALS AND METHODS

Participants

Referring to the sample sizes of extant experimental studies with one between-subject factor published in top journals, such as the *Journal of Consumer Research* (e.g., Mead et al. 2011; Wang and Griskevicius 2014), we recruited 63 participants ($M_{age} = 81.98$ years, $SD = 7.15$, 21 males) from an elderly care institution named “Union Life” (a branch founded and operated by Union Life Insurance Co., Ltd.) in Shenyang, China. This field experiment was conducted at this institution. We collected response data from 63 participants in the experiment to test the hypotheses noted in the conceptual framework (Figure 1). None of the participants had hearing or speaking disorders or a history of severe cardiovascular disease. However, 38 of the 63 participants had hypertension (systolic, ≥ 140 mmHg or diastolic, ≥ 90 mmHg; cf. Song et al. 2017), and 25 were taking antihypertensive medication

during the period of this study. Hypertension is common in the elderly population. In this field study, participants with hypertension were still recruited and allowed to take antihypertensive drugs. We gave each valid participant a bottle of laundry detergent worth 15 yuan (US\$ 2.3) for participation. All participants consented to participating in the study.

Research Design

Referring to prior studies (e.g., Mattila et al. 2020; Yu et al. 2018), we employed both between-subject and pretest-posttest designs in the study. The experiment was conducted over 3 consecutive days (March 24–26, 2021). The participants were randomly assigned to one of the following two groups: (1) VR forest experience (VR) and (2) control.

Those assigned to the VR group ($N = 32$) were exposed to a VR forest environment once a day, and each time, they spent approximately 5 minutes in the environment (cf. Mattila et al. 2020). In the VR environment, Black Valley National Forest Park, Chongqing, China, which is famous for its primeval forest and vegetation, was presented (Figure 2). The participants experienced the environment via a head-mounted display (VR SHINECON AIO5, Figure 3). This device contained gyroscopes, nine axis sensors, headphones, and other auxiliary accessories and, thus, can offer realistic forest experiences to users. A soundscape consisting of a mix of ambient sounds, such as birds singing and

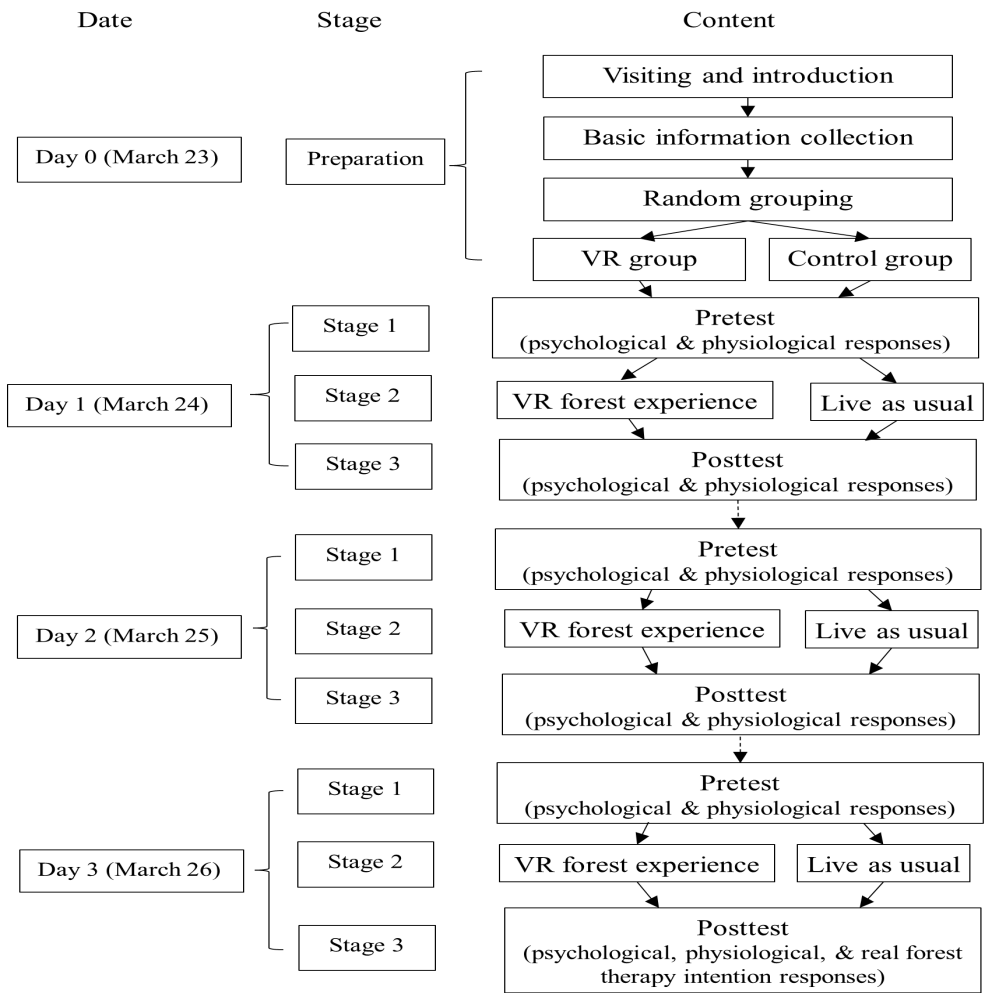
Figure 2. Screenshot of the VR forest.



Figure 3. The VR SHINECON display.



Figure 4. The study procedures.



running water, was also part of the experience (cf. Mattila et al. 2020). The participants could rotate freely in the VR forest setting and were informed of the right to drop out if any discomfort occurred. Those assigned to the control group ($N = 31$) continued their usual routines (e.g., engage in some recreational activities or rest).

The specific procedures of the study are depicted in Figure 4. On the preparation day (March 23), we completed the following work:

- (a) Each participant was visited in their living room and we briefly explained the purpose and procedures to them—they were ostensibly told that the purpose of the research was to investigate the health conditions of elderly individuals;
- (b) Some basic information, such as demographic variables, health conditions, and personality data was collected;
- (c) Each participant was assigned a number, and we randomly assigned them to either the VR or control group; and
- (d) The participants were reminded not to ingest alcohol, tobacco, coffee, or tea (cf. Annerstedt et al. 2013; Li et al. 2020).

On the first day (March 24), the experiment was divided into the following three stages:

- (1) Each participant was asked to complete the pretest tasks, i.e., psychological measurements, including a profile of affect states (PANAS), the restorative outcome scale (ROS), and physiological (blood pressure) measurements;

Figure 5. A participant is immersed in the VR forest.



Figure 6. A participant is reliving the VR experiences she just underwent.



- (2) The participants in the VR group were further told that we needed their help to evaluate the usability of a VR device, were exposed to a VR forest environment for 5 minutes (Figure 5) and were subsequently asked to relive the experiences for 3 minutes (Figure 6), while those assigned to the control group engaged in activities or rested as usual;
- (3) The same psychological and physiological measurements taken in Stage 1 were taken from everyone again.

The VR group participants experienced the VR forest in a large lounge area of the care institution, and four identical VR devices were available. They came to the lounge in groups of two to four and were seated at individually partitioned VR devices. In contrast, the control group participants performed activities or rested in other lounges or rooms of the institution. All the participants were tested individually with the help of the researchers. The study was conducted between 9:00-12:00 and 14:00-16:00 on each experimental day. Each participant took approximately 20 minutes to complete all the required tasks. The physical conditions (e.g., temperature, noise level) were the same for both groups.

The stages and contents on the second day (March 25) and the third day (March 26) were similar to those on the first day. The only difference on the second day was that the affect state measurement was not included in either the pretest or posttest for the purpose of saving the elderly people's time and energy. The only difference on the third day was that measurements regarding intentions to undertake real forest therapy were added to the posttest.

Measures

The participants' affect states were measured with the short version of the PANAS scale (Thompson, 2007). On a five-point scale (1 = *never*, 5 = *always*), everyone was asked to indicate their feelings

(“At this moment, to what extent do you feel:”) regarding five words describing positive affects (i.e., alert, inspired, determined, attentive, and active) and another five words describing negative affects (i.e., upset, hostile, ashamed, nervous, and afraid). The order of these ten words was randomized to avoid an order effect.

Stress recovery was measured with the six-item ROS scale adapted from Korpela et al. (2008) as follows: I feel restored and relaxed; I feel calm; I have enthusiasm and energy for my everyday routines; I feel focused and alert; I can forget everyday worries; and my thoughts are clear. SBP and DBP were measured with an arm-type electronic sphygmomanometer (YE630AR, YUYUE, China).

Introverted/extraverted personalities were measured with a two-item 5-point scale (1 = *strongly disagree*, 5 = *strongly agree*) (John and Srivastava 1999) with the following items: (a) I see myself as someone who is uncommunicative; and (b) I see myself as someone who is outgoing, sociable. Each participant's score on the second item was reverse scored, and their scores on these two items were averaged to index their introversion or extraversion levels ($\alpha = .68$). A high score on the two items indicated an introverted personality, whereas a low score indicated an extraverted personality.

Finally, intention to undertake real forest therapy was measured by the following two questions: (a) If possible, would you like to take a real forest therapy tour with your friends? (1 = *definitely not*, 5 = *definitely will*) and (b) If possible, how many days would you prefer to spend on a real forest therapy tour? (1 = “ ≤ 2 days”, 2 = “3–5 days”, 3 = “6–8 days”, 4 = “9–11 days”, 5 = “ ≥ 12 days”).

Statistical Analysis

Following the statistical analysis methods that are widely used by prior studies for investigating the restorative effects of VR forests (e.g., Li et al. 2020; Mattila et al. 2020; Yu et al. 2018), two-way repeated-measures ANOVA was used to examine H1, H3, H5, and H6; one-way ANOVA was employed to test H7. Given that the testing of H2 and H4 involved comparing participants' responses at several time points (longitudinal data), linear mixed models (LMM) analyses were performed to test H2 and H4 (Goldstein 2011; Shek and Ma 2007; Zhang and Dong 2015). Compared to generalized linear models (GLMs), the usage of LMMs can better help us understand variations in human behavior over time (Shek and Ma 2007). Additionally, paired sample t-tests (cf. Yu et al. 2018) were used in the examination of H3, and a two-stage cluster analysis (cf. Lee and Ro, 2016) was also used in the examination of H5. All these tests and analyses were conducted using IBM SPSS 25 and following the tutorials of Shek and Ma (2007) and Zhang and Dong (2015).

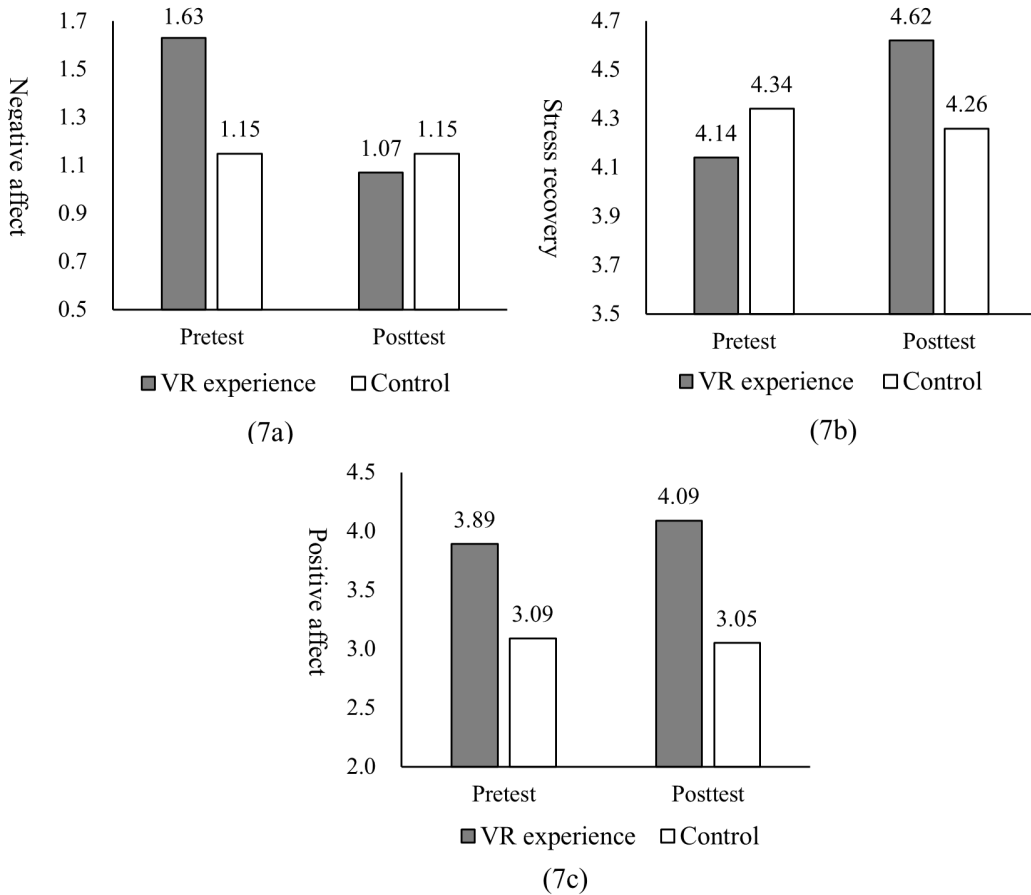
RESULTS

The results of Cronbach's alpha tests based on the pretest responses from Day 1 showed that the internal consistencies of PANAS positivity, PANAS negativity, and ROS were .753, .602, and .683, respectively. Given the limited sample size, these indices were acceptable (Hair et al. 2010). Thus, we averaged the participants' scores on items of these scales to generate their positive affect, negative affect, and stress recovery level.

H1 Testing

Both groups' psychological responses on Day 1 were used to test H1. A two-way repeated-measures ANOVA with time (pretest versus posttest) and treatment (VR experience versus control) was conducted (cf. Yu et al. 2018) separately on positive affect, negative affect, and stress recovery. As predicted (H1), the interactions on negative affect ($F(2, 60) = 20.42, p < .001, \eta^2 = 0.251$, Figure 7a) and stress recovery ($F(2, 60) = 33.44, p < .001, \eta^2 = 0.354$, Figure 7b) were significant, and the interaction on positive affect was marginally significant ($F(2, 60) = 3.54, p = .065, \eta^2 = 0.055$, Figure 7c). These results indicate that taking a break of a few minutes in a VR forest could significantly increase the positive affect of elderly individuals, decrease their negative affect, and enhance their stress recovery.

Figure 7. Means for participants' negative affect, stress recovery, and positive affect as a function of time (pretest versus posttest on Day 1) and treatment.

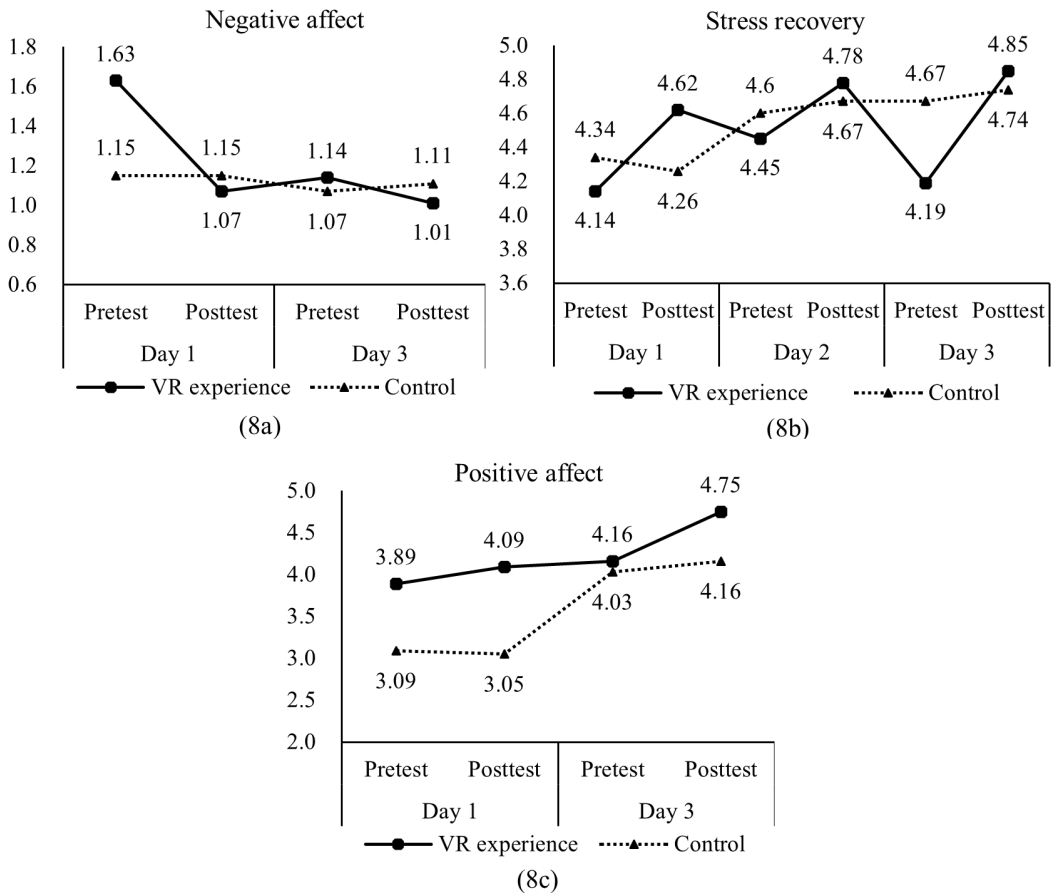


H2 Testing

Both groups' psychological responses over the 3 days were used to test H2. Three linear mixed effects analyses¹ showed that the interaction effects of time points and treatment on negative affect ($F(3, 187) = 14.40, p < .001$, Figure 8a), stress recovery ($F(5, 247) = 11.94, p < .001$, Figure 8b), and positive affect ($F(3, 169) = 10.09, p < .001$, Figure 8c) were significant.

Further mean comparison analyses showed that the VR group's posttest stress recovery levels over the 3 days ($M_{day1} = 4.62$ vs. $M_{day2} = 4.78$ vs. $M_{day3} = 4.85$; $F(2, 93) = 8.92, p < .001$) had significant differences, and their posttest negative affect ($M_{day1} = 1.07$ vs. $M_{day3} = 1.01$; $F(1, 62) = 4.59, p = .036$) and posttest positive affect ($M_{day1} = 4.09$ vs. $M_{day3} = 4.75$; $F(1, 62) = 41.73, p < .001$) differed significantly between Day 1 and Day 3. These results supported H2, which stated that three short breaks in a VR forest over 3 consecutive days can lead to continuous psychological improvements among elderly individuals.

Figure 8. Means for participants' negative affect, stress recovery, and positive affect as a function of time points (pretest versus posttest over 3 days) and treatment.



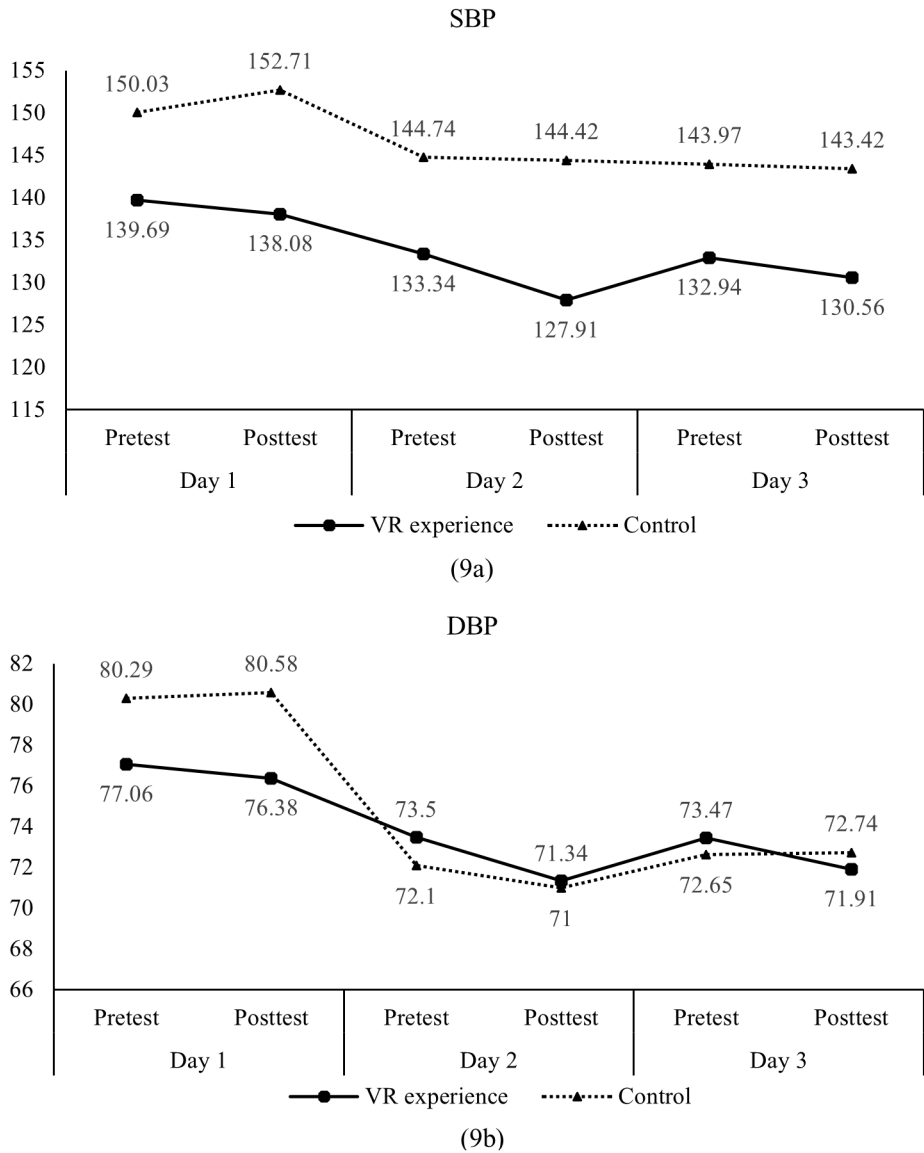
Note: To save the elderly participants' time and energy, negative affect and positive affect were not measured on Day 2.

H3 Testing

To test H3, both groups' blood pressure responses on Day 1 were analyzed. Two two-way repeated-measures ANOVAs with time and treatment were conducted on the SBP and DBP values. The results show that the interactions on both SBP ($F(2, 60) = 1.36, p = .248$) and DBP ($F(2, 60) = 0.27, p = .607$) were nonsignificant.

Moreover, the VR group's pretest and posttest blood pressure responses on Day 1 were compared. The results indicated no significant differences between their pretest and posttest SBP levels ($M_{\text{pretest}} = 139.69$ vs. $M_{\text{posttest}} = 138.03; t(1, 31) = .648, p = .522$) or between their pretest and posttest DBP levels ($M_{\text{pretest}} = 77.06$ vs. $M_{\text{posttest}} = 76.38; t(1, 31) = .552, p = .585$). These results supported H3, which stated that taking a break of a few minutes in a VR forest does not significantly decrease elderly individuals' blood pressure.

Figure 9. Means for participants' SBP and DBP as a function of time points (pretest versus posttest over 3 days) and treatment.



H4 Testing

To test H4, we first analyzed the VR group's SBP and DBP responses over the 3 days. Two linear mixed effects analyses indicated that the effects of time points on SBP ($F(5, 155) = 5.55, p < .001$, see the solid line in Figure 9a) and DBP ($F(5, 155) = 4.47, p = .001$, see the solid line in Figure 9b) were significant.

Furthermore, the multiple comparisons analyses (with the Bonferroni method) indicated that the VR group's pretest SBP on Day 1 was not significantly different from their posttest SBP on Day 1 ($M_{\text{pretest_Day1}} = 139.69$ vs. $M_{\text{posttest_Day1}} = 138.08, p > .9$) or pretest SBP on Day 2 ($M_{\text{pretest_Day1}} = 139.69$ vs. $M_{\text{pretest_Day2}} = 133.34, p = .28$). Nevertheless, their pretest SBP on Day 1 was significantly different

from their posttest SBP on Day 2 ($M_{pretest_Day1} = 139.69$ vs. $M_{posttest_Day2} = 127.91$, $p < .001$) and posttest SBP on Day 3 ($M_{pretest_Day1} = 139.69$ vs. $M_{posttest_Day3} = 130.56$, $p = .012$).

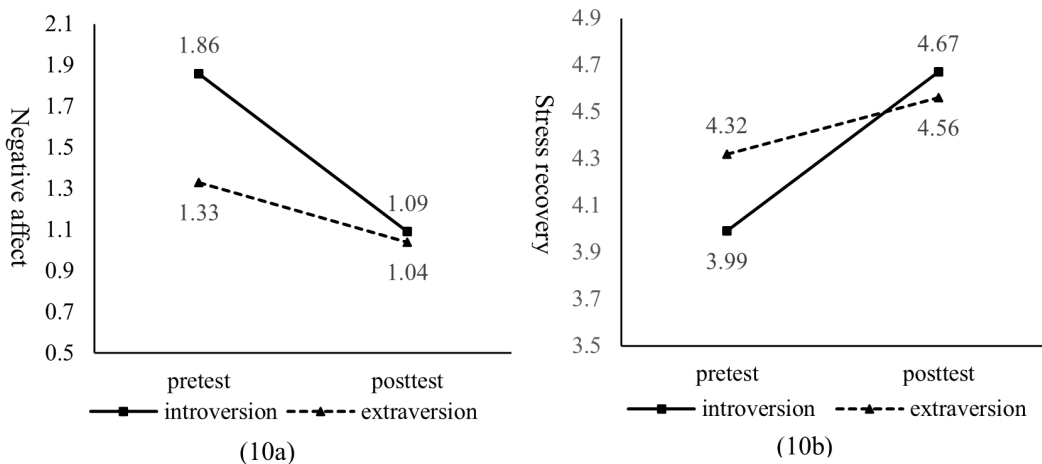
Moreover, the VR group's pretest DBP on Day 1 was also not significantly different from their posttest DBP on Day 1 ($M_{pretest_Day1} = 77.06$ vs. $M_{posttest_Day1} = 76.38$, $p > .9$) or pretest DBP on Day 2 ($M_{pretest_Day1} = 77.06$ vs. $M_{pretest_Day2} = 73.5$, $p = .35$) but was significantly different from their posttest DBP on Day 2 ($M_{pretest_Day1} = 77.06$ vs. $M_{posttest_Day2} = 71.34$, $p = .005$) and posttest DBP on Day 3 ($M_{pretest_Day1} = 77.06$ vs. $M_{posttest_Day3} = 71.91$, $p = .017$).

These results seemingly supported H4, which stated that taking three short breaks in a VR forest over 3 consecutive days significantly decreases elderly people's blood pressure. However, further linear mixed effects analyses indicated that the interactions of time points and treatment on both SBP ($F(5, 272) = 0.29$, $p > .9$, Figure 9a) and DBP ($F(5, 265) = 1.57$, $p = .17$, Figure 9b) were nonsignificant. These results indicated that when considering the joint influence of treatment and time, the effects of having three VR forest experiences over 3 days on elderly people's blood pressure were nonsignificant; thus, H4 was not supported.

H5 Testing

To test H5 and be consistent with the examination results of H1, the VR group's psychological responses on Day 1 were analyzed. We first further divided the VR group participants into two clusters according to their scores on the two personality measurement items. The results of the two-stage cluster analysis (cf. Lee and Ro, 2016) indicated that the 32 participants were classified into two clusters as follows: introverted individuals (18 respondents) and extraverted individuals (14 respondents). As expected, individuals in the introvert group had higher scores on the personality measures than those in the extravert group ($M_{introvert} = 3.11$ vs. $M_{extravert} = 1.18$, $p < .001$).

Figure 10. The effects of VR forest experiences on participants' negative affect and stress recovery based on personality traits (introversion versus extraversion).



Next, three two-way repeated ANOVAs with time and introversion versus extraversion personality were conducted on positive affect, negative affect, and stress recovery. The results showed that the interactions of time and personality on negative affect ($F(1, 30) = 4.56$, $p = .041$, $\eta^2 = .132$; Figure 10a) and stress recovery ($F(1, 30) = 7.14$, $p = .012$, $\eta^2 = 0.192$; Figure 10b) were significant, whereas the interaction with positive affect was nonsignificant ($F(1, 30) = .56$, $p = .46$).

These results supported H5b and H5c, which stated that taking a break of a few minutes in a VR forest results in more obvious psychological restorative effects, i.e., decreased negative affect and enhanced stress recovery, for introverted (vs. extraverted) elderly individuals. However, H5a was not supported. Specifically, a VR forest experience lasting a few minutes cannot result in a greater increase in positive affect for introverted (vs. extraverted) elderly individuals.

H6 Testing

According to the results of Figure 9a and 9b, the VR group's pretest blood pressure responses on Day 1 and posttest blood pressure responses on Day 2 were compared to test H6. Two-way repeated ANOVA with time and introverted versus extraverted personality were conducted on SBP and DBP, respectively. The results showed that the interactions on SBP ($F(1, 30) = 0.20, p = .66$) and DBP ($F(1, 30) = 0.87, p = .36$) were nonsignificant. Thus, H6 was not supported, which meant that taking three short breaks in a VR forest over 3 days did not result in a greater blood pressure reduction for introverted (vs. extraverted) elderly individuals.

H7 Testing

Finally, both groups' intentions to undertake real forest therapy, which were reported in the posttest of Day 3, were compared to test H7. As predicted (H7), one-way ANOVA showed that the VR group's intention to receive real forest therapy ($M_{\text{VR_group}} = 4.28$ vs. $M_{\text{control_group}} = 3.39$; $F(1, 61) = 5.49, p = .02$) and the preferred duration days for real forest therapy ($M_{\text{VR_group}} = 2.53$ vs. $M_{\text{control_group}} = 1.94$; $F(1, 61) = 3.97, p = .05$) were significantly higher than those of the control group, which meant that VR forest experiences significantly increased users' intentions to undertake real forest therapy.

DISCUSSION

Theoretical Contributions

This study contributed to the literature in the following ways. First, a short break in a VR forest with a subsequent few minutes of reliving the experience has immediate psychological restorative effects, i.e., decreased negative affect, increased positive affect, and enhanced stress recovery, for elderly individuals. These findings are consistent with those of previous studies (e.g., Mattila et al. 2020; Yu et al. 2018).

Going a step further, this study tested and revealed the sustained psychological restorative effects of VR experiences over 3 consecutive days. However, the findings suggested that although the participants reported significant psychological improvements in the posttest on Day 3 relative to the baseline (pretest on Day 1), the psychological restorative effects (especially the stress recovery) needed continuous reinforcement to be maintained. That is, without daily VR experience reinforcement, the psychological restorative effects vanish in a short time. These findings expand the existing knowledge regarding the sustained effects of VR forest experiences.

Second, the findings of this study did not support the immediate restorative effects of VR forest experiences on blood pressure; that is, the elderly participants did not show significantly lower SBP or DBP after participating in a VR forest experience lasting a few minutes. This is not consistent with the results of prior studies (Song et al. 2017; Yu et al. 2018), which supported the positive links between a VR forest experience lasting a few minutes and participants' immediate SBP and DBP decrease. However, these findings are consistent with the idea of Rajoo et al. (2020), who argued that a short forest experience may not result in positive physiological restorative outcomes.

Furthermore, concerning the sustained restorative effects of VR forest experiences on blood pressure, this study revealed that although the participants showed significantly lower SBP and DBP after two VR experiences over 2 days, the interaction effects of time points and treatment were nonsignificant. These results tend to support the proposition that the activities (e.g., conversations,

blood pressure measurement) employed in the experiment but not the VR forest experience itself resulted in the reduction of the elderly participants' blood pressure (Rajoo et al. 2020).

Overall, our findings suggested that neither taking one short break nor three short breaks over 3 days in a VR forest can significantly reduce elderly participants' blood pressure. These results are inconsistent with the empirical findings of Yu et al. (2018) and Song et al. (2017) but are consistent with the theoretical arguments of Rajoo et al. (2020).

Third, regarding the immediate psychological restorative effects, this study demonstrated that VR forest experiences have more obvious effects (i.e., decreased negative affect and enhanced stress recovery) on introverted (vs. extraverted) elderly individuals. To the best of our knowledge, no previous studies have reported this finding.

Finally, this work revealed that VR forest experiences were positively related to elderly people's intentions to receive and the preference duration in days for real forest therapy. These findings indicate that VR forest experiences can increase elderly people's intentions to undertake real forest therapy. No prior studies have reported this finding.

Practical Implications

According to the findings of the study, we offer the following practical recommendations for elderly individuals and care institutions. First, in the new normal of COVID-19, individuals or care institutions can introduce VR forest experience programs to address the psychological threats resulting from infection anxiety and lockdown. In fact, VR devices with the recently developed immersive technology are becoming popular in other areas (e.g., game and film industries), and their prices are not high (approximately 2,000 RMB in China). Second, since the psychological restorative effects of VR forests are particularly obvious among introverts, care institutions should identify those who have introverted personalities and pay special attention to applying VR forest experience programs among them. Third, the VR forest experience program may not be able to reduce hypertensive elderly individuals' blood pressure. Finally, after the COVID-19 pandemic, VR experiences could be a useful strategy for real forest bases to use to attract elderly people to undertake real forest therapy.

Limitations and Future Directions

First, we did not find significant restorative effects of VR forest experiences on elderly individuals' blood pressure based on the between-subject and pretest-posttest comparative results of the experiment. The most common antihypertensive medications can reduce short- and long-term blood pressure variability (Parati et al. 2018), which corresponds to the results of VR forest experiences in participants (10 in the VR group and 15 in the control group) who were taking antihypertensive medication. Future studies should deliberately control the issue of taking antihypertensive medication and then investigate the possible restorative effects of long-term (e.g., one week) VR forest experience programs on elderly individuals' blood pressure. Second, due to the nature of the field study, the participants in the control group of this study were not well controlled. Future studies should design rigorous lab experiments with elderly participants to further examine the restorative effects (especially the physiological effects) of VR forest experiences. Third, we discussed but did not empirically test the mediating role of individuals' immersion and sense of presence levels between VR forest experiences and restorative responses, which also deserves examination in future studies. Finally, more moderators between VR forest experience and psychological improvements should be investigated in future studies.

CONCLUSION

The outbreak of COVID-19 has imposed particular challenges to elderly people's health. Some recent studies argued that VR forest experiences may be an effective way to restore elderly individuals' health. However, little research has empirically examined the restorative effects of VR forest experiences among elderly individuals. This study shed light on the immediate and sustained restorative effects

of VR forest experiences on elderly participants. Our findings reveal that VR forest experiences can have immediate and sustained psychological restorative effects for elderly individuals during the COVID-19 lockdown. The immediate psychological restorative effects of VR forest experiences were more obvious among introverted (vs. extraverted) elderly individuals. Possible immediate and sustained restorative effects of VR experiences on blood pressure were not found in this study. Regarding elderly people's psychological restoration in the new normal of COVID-19, VR experience programs could be an effective alternative to real forest therapy, especially for introverted elderly people. VR experiences can also be used to encourage elderly people to undertake real forest therapy programs.

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ENDNOTE

- ¹ Note: “Participants ID” was set as the “subject variable” and “time points” was set as the “repeated variable”, the “Repeated Covariance type” was specified as AR(1) (i.e., First-Order Autoregressive), and a “fixed-effects model” was chosen in the analyses. The specific procedures and algorithms were described in Shek and Ma (2007); they were also shown on the official site (https://www.ibm.com/docs/en/SSLVMB_25.0.0/pdf/en/IBM_SPSS_Advanced_Statistics.pdf) of IBM SPSS 25.

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