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ORIGINAL PAPER

Durations of virtual exposure to built and natural landscapes impact self-reported stress recovery: evidence from three countries

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Abstract
Exposure to natural landscapes can benefit human health. However, several knowledge gaps remain regarding the impacts of duration and cultural differences on the health benefits of nature. If these gaps are filled, designers and planners can better design landscapes for stress recovery. This study examined the effects of durations of virtual exposure to the built and natural environments across three countries using an experimental design. Two-hundred and seventy people from USA, Taiwan, and Thailand were induced with an acute stressor and then randomly assigned to watch 360° videos of urban or natural landscapes for 1, 5, or 15 min. Self-reported stress recovery data were collected before and after the exposure. The results suggested that gender and duration of exposure to virtual natural landscapes impacted stress recovery. Female participants recovered from stress more when exposed to the virtual natural landscapes than urban landscapes. Among those participants who were exposed to virtual natural landscapes, 5 min of exposure resulted in greater stress recovery than shorter or longer durations of exposure. Perceived familiarity did not influence the extent of stress recovery. These findings support previous research on how nature exposure is related to stress recovery and varies by dosage, leading to better understanding toward landscape design. Future studies should explore other measures of stress, different landscape designs, participants' immersion, and levels of control in simulated nature scenes.

Keywords Virtual reality · Stress reduction theory · Environmental psychology · Nature contact

Introduction

Empirical evidence has revealed positive relationships between exposure to various forms of nature and human health. (Bratman et al. 2019; Hartig et al. 2014; Vos et al. 2022; Yang et al. 2021). One underlying mechanism of nature's health benefits is stress recovery (Bratman et al. 2019; Hartig et al. 2014). Stress is good for human's evolutionary survival, but prolonged stress without recovery can lead to chronic stress (Dickerson and Kemeny 2004; Juster et al. 2010). Chronic stress is a critical risk factor for cardiovascular disease, cancer, obesity, and infections (Russell and Lightman 2019). Fortunately, stress reduction theory (SRT) suggests that access to nature in living environments helps people recover from acute stress (Ulrich et al. 1991). Scientific evidence supports this theory. In one study, exposure to outdoor activities with moderate levels of nature led to a significant drop in cortisol levels, a biomarker of physiological stress (Hunter et al. 2019). Another study found that residents living in communities with more public and private green spaces reported lower levels of perceived stress (Ward Thompson et al. 2016). There is, moreover, evidence that spending time in, or living near, nature for an extended period of time is associated with reduced morbidity risks related to chronic stress, such as cardiovascular diseases

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(Seo et al. 2019), anxiety (De Vries et al. 2016), and depression (Bezold et al. 2018; Gascon et al. 2018).

Because of the growing body of evidence indicating that humans need consistent contact with nature, designers, planners, and decision makers agreed that human environments with natural elements may improve people's health and well-being, including stress reduction (Lindland et al. 2015). However, the evidence still leaves gaps of knowledge that limit the design translations (Sullivan et al. 2014). For example, researchers and designers do not know how much nature is needed to provide sufficient stress reduction for daily life. This gap, in particular, is incredibly wide, ranging from the time humans need to spend with nature (duration), the amount of nature the designers need to provide (intensity), and how often humans need to experience nature (frequency) (Jiang et al. 2014a; Shanahan et al. 2016a). We also do not know the extent to which the people the landscapes are designed for may differ in stress recovery due to their demographics, such as gender, cultures, and personal experiences (Lyons 1983; Richards et al. 2020; Rigolon et al. 2021; Sillman et al. 2022). Furthermore, current situations—such as air pollution, global climate changes, and pandemic—may prevent people from accessing physical nature or create more health risks (Browning et al. 2020b; Pinho et al. 2021; Suppakittpaisarn et al. 2020b). Fortunately, virtual reality presents an opportunity for those who are limited from the contact of nature, but with some questions about its effects relative to actual nature exposure (Browning et al. 2020a; Frost et al. 2022; Yin et al. 2022).

To landscape designers, planners, and researchers' credits, these gaps are getting smaller. Several studies explored different durations of nature exposure and found varying durations of time that nature may provide stress recovery benefits, ranging from 5 min (Barton and Pretty 2010), 15 min (Jiang et al. 2014a), 30 min (Hunter et al. 2019), to 120 min (White et al. 2019), making the results inconclusive. The demographics, such as genders, ethnicities, and backgrounds, were explored to found that the benefits of nature among these people might be in the same directions, but with varying degrees, yet cases and comparisons may need for design recommendations (Browning et al. 2022; Ho et al. 2005; Kaplan and Talbot 1988; Rigolon et al. 2021; Sillman et al. 2022; Tinsley et al. 2002; Wells et al. 2019). Notably, the cultural background differences and natural benefits were explored highly between Eastern and Western Cultures. Western cultures were represented by participants from Europe, USA, and Canada in several studies (El-Baghdadi and Desha 2017; Le Lay et al. 2013). Chinese, Korean, and Japanese cultures were mentioned often to represent participants from Eastern Cultures (Ho et al. 2005; Lim et al. 2015; Petrova et al. 2015; Ueda 2014). However, sub-cultural groups, such as Southeast Asia, such as Thailand, Malaysia, and Singapore, has not been represented sufficiently in these studies, even though evidence existed that there might be differences between these subcultures (Brown and Hausner 2017; El-Baghdadi and Desha 2017). Finally, a growing body of literature is providing more evidence of virtual nature and health benefits, but the field needs more evidence (Browning et al. 2020a; Browning et al, 2020b). Researchers need to explore these questions further to better design and plan the physical and virtual landscapes for stress recovery as a part of human well-being.

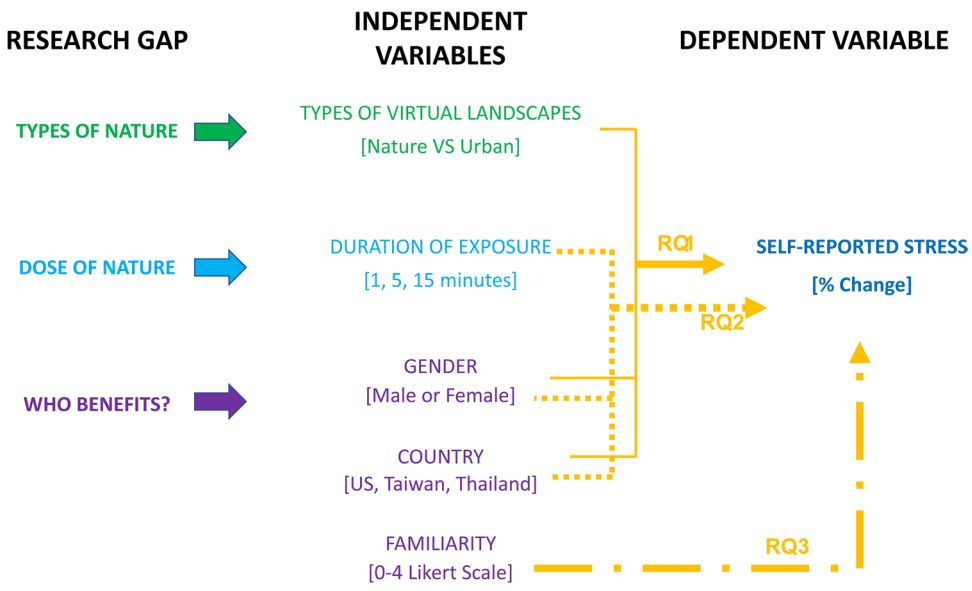

Fig. 1 Graphical summary of research questions

In this study, we examine questions regarding the duration of exposure to virtual nature on recovery from acute stress among females and males and participants from three countries. The following research questions guided this line of inquiry (Fig. 1):

RQ1: To what extent do urban and natural virtual landscapes impact self-reported stress recovery across demographics?

RQ2: To what extent does duration of virtual natural landscapes impact stress recovery across different demographics?

RQ3: To what extent does familiarity with nature scenes impact stress recovery?

Materials and methods

Locations

We used three locations for the study: Champaign, IL; Taipei, Taiwan; and Chiang Mai, Thailand. These locations have distinct cultures due to the different combinations of their overall topography (plain, island, and valley), climates, and cultural backgrounds (Bond 2002; Hofstede 1984; Wu 2006). Despite the differences, we selected the sites that shared similar modern urban characteristics.

Virtual landscapes

At each of the three research countries, researchers identified four landscapes: two urban landscapes, such as parking lots and busy streets that contained little vegetation, and two natural landscapes, such as parks and green spaces. Researchers set up a 360° camera to record high-quality video footage at approximately 120 cm above the ground between 9:00 AM and 3:00 PM on a sunny day. These virtual settings have been adjusted from prior studies on virtual nature, preference, and stress recovery (Jiang et al. 2014a; Jiang et al. 2015; Jiang et al. 2014b). Each video was recorded for approximately 180 s. The camera used was the Insta360 EVO with a resolution of 3008*1504 and recording speed of 100 fps. These resolutions balanced image quality and easy data transfer among the research team across the world.

In total, 12 videos were selected for the experiment. Four videos were from parking lots, containing concretes, cars, street light fixtures, constructed ramps. All parking lots had trees in the distance, but not enough to be noticeable. Two videos were recorded from the busy urban streets, with streets, architectures, passing vehicles, and limited vegetation. For natural side, all were from urban parks which mainly contain green lawns, open spaces, and mature trees. Two from six videos included large bodies of water. In a video, cars could be seen passing in a distant street, but not intrusive to the experiences. All videos were recorded with sounds.

Next, we created six composite videos of the urban and nature categories. The researchers located at each country picked four places from their city: two urban and two natural places. The movements across the scenes such as cars, birds, and swaying grasses were recorded. Both urban and nature categories had 1-, 5-, and 15 min versions. Each original scene was shown for 10 s in the 1-min videos, 50 s for the 5 min videos, and 150 s for the 15 min videos. Using this approach, each participant saw landscapes from all three countries (Fig. 2). The videos were edited to transition smoothly with 3 sec cross-fade between the scenes to reduce the possibility of distortion effect that might disrupt the restorative process (Anderson et al. 2016; Deering 1992).

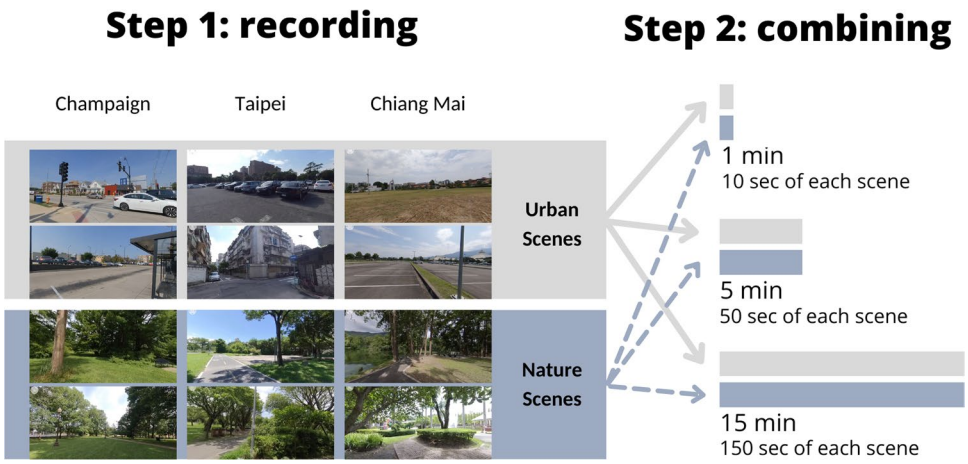

Fig. 2 Scenes collected from 12 sites across 3 research sites (Champaign, USA; Taipei, Taiwan; and Chiang Mai, Thailand) and made into 6 conditions for the experiment

Participants

Adults between ages 18 and 40 years who were living in one of the three countries for at least 5 years were eligible to participate. Individuals with a prior history of heart, metabolic, or brain conditions such as hypertension, hyperthyroidism, or ADHD were excluded. Participants were asked not to consume any alcohol, medicine that affects brain functions (such as cold medicine), caffeine, or tobacco products within 24 h of the experiment. Participants were also asked not to perform moderate to vigorous activity within 20 min of the experiment. We validated the inclusion and exclusion criteria using a health check form.

Procedure

Once a participant arrived at one of the research sites, they were informed about the study design, signed the consent form, and completed the health check form. Next, they were asked to watch a 2 min 360° video on an Oculus Quest VR head mounted display (HMD), with a resolution of 1440*1600 per-eye. The researchers observed the participants' behavior and asked if they felt dizzy or disoriented to ensure they would not experience motion sickness while viewing the virtual environment treatment.

Participants were then asked to complete a landscape familiarity questionnaire and report their baseline stress level using a Visual Analog Scale (VAS). The 12-item familiarity questionnaire contained images from the landscapes that would later be shown in the 360° videos. For each image, participants were asked, "How familiar is this landscape?" Responses ranged from 0 (not at all) to 4 (very much). Similar scales about landscape perceptions and preference had been used before in previous work (Suppakittpaisarn et al. 2020a). Using the VAS, participants were asked 'How stressed are you at the moment?' and asked to mark a spot on a 10 cm line from 0 (not at all) to 10 (very much) (T1).

After these questionaries were completed, researchers prepared two stressors for the participants: the Trier Social Stress Test (TSST) and a 15 min proofreading test. The TSST was developed by the University of Trier and has been used to induce stress in numerous studies (Au-Birkett 2011; Kirschbaum et al. 1993). Participants were given 3 min to prepare for a 5 min speech and then asked to complete a 5 min subtraction test in front of two to three researchers who were trained to remain neutral and show no positive reinforcement. Then, participants were asked to complete a 15 min proofreading test to simulate stress-inducing academic and office work. For this test, the researchers provided a multipage document with strings of letters and asked participants to mark series of letters that matched the first four letters of each line. Following these stress tasks, stress levels were again measured with the VAS for the second time (T2). The TSST combined with a proofreading test has been demonstrated to induce stress in participants (Jiang et al. 2019; Li and Sullivan 2016).

Finally, participants were randomly assigned to watch one of the six 360° videos with varying landscape types and duration. Following the video, stress levels were collected with the VAS for a final time (T3). The study procedure is summarized in Fig. 3.

COVID-19 precaution

Because this experiment was held during the COVID-19 pandemic (December 2019–December 2020), precautions were taken. We waited during the first outbreak until each country's regulations permitted small group gatherings.

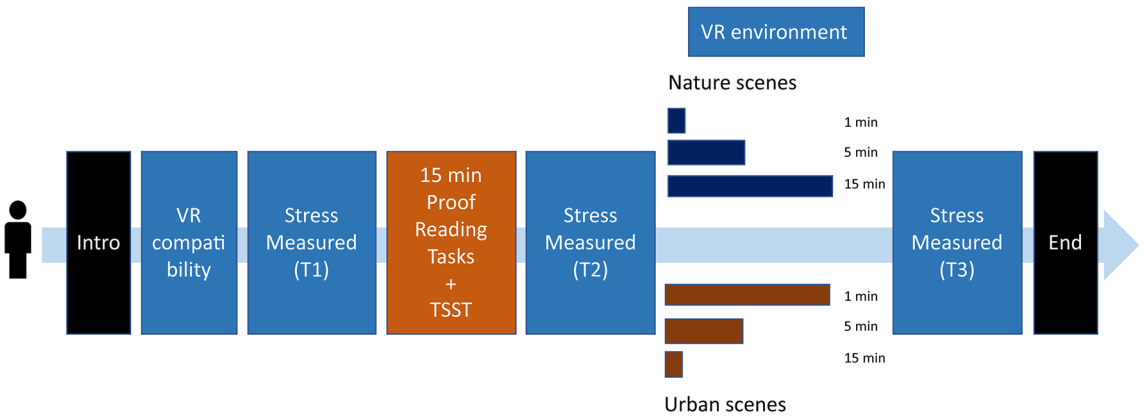

Fig. 3 Study design

After that, we practiced social distancing, ensured that participants and researchers wore face masks, and offered hand sanitizer for participants to use. The HMDs and keyboards were cleaned with antibacterial wipes after each participant. We also allowed participants to reschedule their appointments if they felt sick or felt uncomfortable participating in an in-person study, as recommended in previous guidelines for VR research (Browning et al. 2020b).

Statistical analyses

We tested the effect of the stressors by comparing scores before and after these tasks (T1–T2) using a paired *t* test. We then calculated the percentage of stress recovery attributable to VR exposure using the following formula:

$$\%\ \text{stress recovery} = \left(\frac{\left(\text{stress}_{T2} - \text{stress}_{T3}\right)}{\text{stress}_{T2}}\right) \times 100$$

We used the percentage stress recovery scores as a dependent variable and conducted three-way ANOVAs as followed.

Table 1 Results from three-way ANOVA testing impacts of virtual landscape types and demographic factors on stress recovery

Variable	*F*	df	*p*	Partial Eta^2
Landscape type	1.3	(1, 245)	0.3	0.01
Gender	1.6	(1, 245)	0.2	0.01
Country	4.5	(2, 244)	0.01	0.04
Landscape type x gender	5.4	(1, 245)	0.02	0.02
Landscape type x country	0.7	(2, 244)	0.5	0.01
Gender x country	0.8	(2, 244)	0.5	0.01
Virtual landscape type x gender x country	0.7	(2, 244)	0.5	0.01

1) Built vs Natural x Gender x Country to understand the relationships between virtual environments and demographics (RQ1).
2) Duration of Nature Scenes x Gender x Country to understand the relationships between the duration of virtual nature and demographics (RQ2).

In addition, we used linear regression to examine relationships between mean familiarity scores and stress recovery.

Results

Overview

Two-hundred and seventy participants joined the study. Twenty-two participants did not complete the experiment. We removed three participants whose Z-score of the percentage stress recovery were higher than 2.0 and lower than − 2.0, thus considered outliers. Thus, a final sample of 245 participants was used in analyses. Among the 270 participants, 130 (53%) identified as female, 79 (32%) were recruited from Urbana-Champaign, 76 (31%) were from Taipei, and 90 (37%) were from Chiang Mai.

The Trier Social Stress Test and the 15 min Proofreading Test successfully induced acute stress among the participants. Stress levels were lower before these tasks (M= 0.23, SD = 0.2) than after (M = 0.26, SD = 0.2, t (244) = − 9.7, $p < 0.0001$).

Impact of landscape type, gender, and country on stress recovery (RQ1)

Table 1 shows the results of a three-way ANOVA that tested the impacts and interactions between landscape

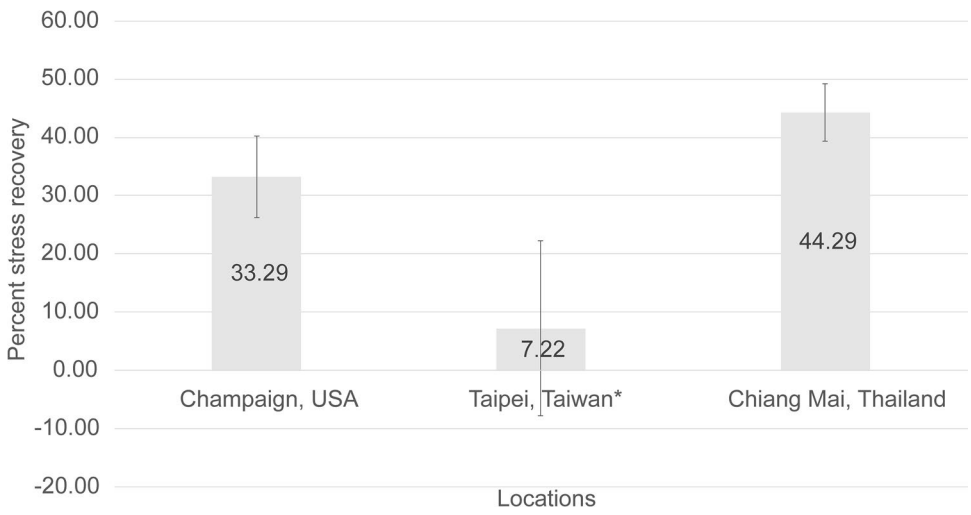

Fig. 4 Stress recovery by country

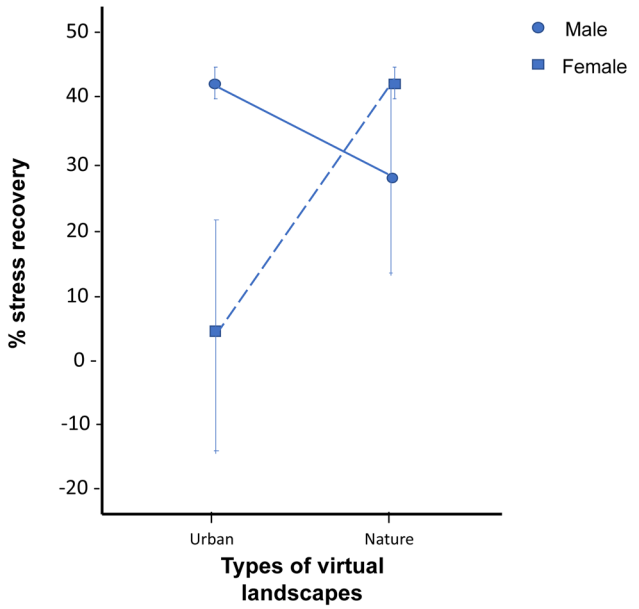

Fig. 5 Crossover interaction between landscape type and gender on stress recovery, with whiskers representing standard errors of means

Table 2 Results from three-way ANOVA testing impacts of exposure duration and demographic factors on stress recovery

Variable	*F*	df	*p*	Partial Eta^2
Duration of exposure (nature scenes)	3.2	(2, 117)	0.046	0.06
Gender	0.7	(1, 119)	0.4	0.01
Country	2	(2, 117)	0.1	0.04
Duration of nature x gender	1	(2, 117)	0.4	0.02
Duration of nature x country	1.1	(4, 115)	0.5	0.04
Gender x country	0.6	(2, 117)	0.4	0.01
Duration of nature x gender x country	0.3	(4, 115)	0.8	0.01

type, gender, and country on stress recovery. Participant's country had a significant and small-medium effect on stress recovery (Partial Eta^2 = 0.04). The interaction between gender and landscape type also had significant and small effect on stress recovery (Partial Eta^2 = 0.02). Tukey's HSD Post-hoc analysis found that participants from Taiwan reported less stress recovery overall than participants from other countries (Fig. 4). Women showed significantly greater recovery from exposure to natural landscapes (M = 0.4, SD =0.4) than built landscapes (M = 0.0, SD = 1.3); t (1,128) = − 2.2, p < 0.05. Men showed the opposite pattern, with lesser recovery from exposure to natural landscapes (M = 0.3, SD =0.9) than built landscapes (M =0.4, SD =0.4), but the comparison was not statistically significant (t (1,128) = − 2.2, p <0.05) (Fig. 5).

Impact on duration of exposure on stress recovery (RQ2)

Table 2 presents the results of three-way ANOVA that tested the impacts and interactions between exposure duration, gender, and country on stress recovery among participants who saw the nature scenes. Duration had significant and medium size effect on stress recovery (F (2, 117) = 3.4, p < 0.05). Tukey's HSD post-hoc analysis found a significant difference between 5 min of exposure (M = 0.56, SD = 0.3) than 1 min (M = 0.20, SD = 0.6) or 15 min (M = 0.28, SD = 0.9) of exposure (Fig. 6).

Closer examination three-way ANOVA suggested no other significant predictors or interactions between the independent variables with a medium effect size (Partial Eta^2 = 0.06). This suggested that among people who watch nature scenes in this experiment, the durations of the video were the only predictor of stress recovery (Table 2).

Fig. 6 Stress recovery by exposure of duration to virtual nature

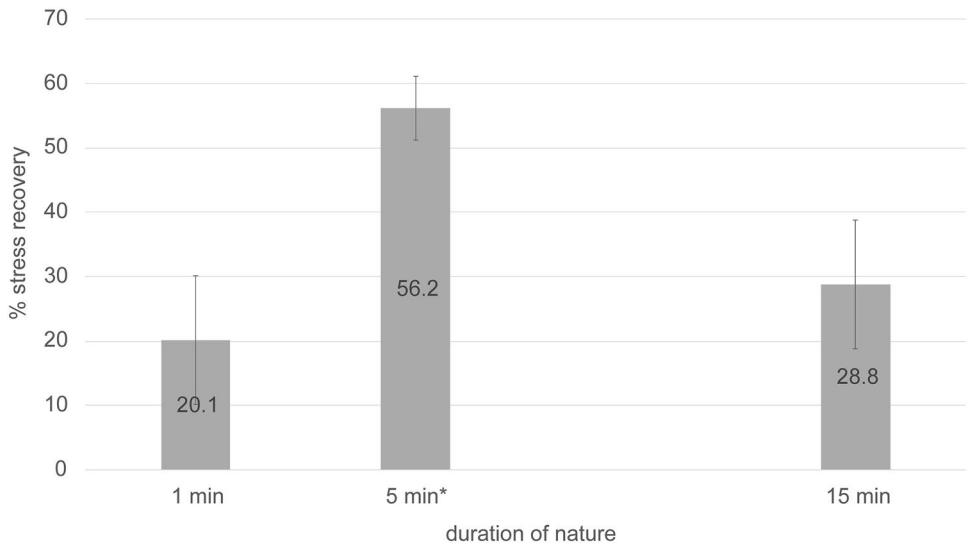

Table 3 Simple linear regression results between familiarity with nature scenes and self-reported stress recovery

	df	*F*	*p*	Adj-R^2	β	Confident interval	
						Lower	Upper
familiarity	(1, 118)	0.4	0.5	0.0	0.1	− 0.17	0.33

Impact of familiarity on stress recovery (RQ3)

Table 3 displayed the linear regression results between the familiarity of the scenes with self-reported stress recovery among participants who saw nature scenes. We found that familiarity and stress recovery did not correlate in this study. This finding suggested that perceived familiarity of nature scene has little influence on self-reported recovery from stress.

Discussion

Key results

In this experiment, we aimed to fill critical gaps in our knowledge about the extent to which duration of exposure to virtual nature impacts stress recovery by gender and culture. There are four main findings. First, for women (but not for men), watching virtual natural environments allowed greater stress recovery than watching urban scenes. Second, participants from different locations (e.g., Thailand, Taiwan, and the U.S.) reported different stress recovery results. Third, duration of exposure conferred different levels of stress recovery, with the greatest recovery produced by a 5 min duration. Finally, familiarity with nature scenes was not associated with stress recovery.

Contributions to theory

Our results support the stress reduction theory prediction that people are hardwired to thrive in natural environments that bring health benefits, such as stress recovery (Ulrich et al. 1991). We found that women reported lower stress levels after the nature intervention, compared to the urban intervention. While the nature intervention did not predict stress recovery for men, this finding is consistent with previous findings showing that men demonstrate stress recovery after viewing nature scenes when cortisol levels are used to measure stress but not when stress levels are self-reported (Jiang et al. 2014a; Jiang et al. 2014c). This gender difference may be attributable to women's heightened sensitivity to stressors (Day and Livingstone 2003) or restorative benefits of nature exposure than men (Sillman et al. 2022). Gender-specific outcomes suggest that researchers need diverse tools, both subjective and objective measurements, to measure health outcomes when exploring the relationships between nature and stress recovery.

Self-reported stress recovery was also different among participants from different geographic locations and cultures, agreeing with several studies that compared the relationships of nature and health across cultures, thus we confirm the robustness of the previous studies (Faggi et al. 2017; Ji et al. 2000; Kamičaitytė et al. 2020; Ordonez-Barona 2017; Yu 1995). In this study, Participants from Taiwan expressed the lowest levels of stress recovery. This may due to several factors, including cultural background, daily background stress levels, awareness, and resiliency toward stress. In a recent study toward US and Taiwan's cultural differences, Taiwan scored higher than the US in Confucian Dynamism (Wu 2006), which focused on persistence, perseverance, and sense of shame (Francesco 2015). This clue may support the possibility that the self-reported stress levels may appear relatively neutral, not as low nor as high, among participants from Taiwan. However, when we examined only the participants who only watched the natural virtual environments, the significant stress recovery difference between countries disappeared. These results together suggest that people from different geographies or cultures may express or perceive their own stress to different degrees but in similar directions, and that nature may provide universally positive results across different backgrounds.

Our results also provide novel contributions regarding the duration of exposure to nature and stress recovery. This study is one of the first to systematically compare the effects of different durations of nature exposure on stress recovery using an experimental design. Here, a 5 min dose of nature produced greater stress recovery than a 1 min or a 15 min dose, suggesting a bell-shaped pattern (Shanahan et al. 2016b). This bell-shaped pattern resonates with Bin Jiang and colleagues' study on simulated nature exposure and stress recovery, which used vegetation density as the independent variable (Jiang et al. 2014a). Taken together, these findings provide a clearer understanding of the dose of virtual nature—both density and duration—necessary to enhance stress recovery, and that the relationship might not be linear.

When comparing our results with the results of other studies regarding durations of nature, we notice some similarities and differences. A meta-analysis showed that shorter durations of nature exercise (5 min) provided the highest mental health benefits, with diminishing but positive

effects as the duration increased (Barton and Pretty 2010). In another study using salivary cortisol as the measure of stress recovery, however, the most efficient duration for stress recovery was 20–30 min (Hunter et al. 2019). This incongruency may stem from differences in experimental design, since our study used VR technology, while other studies used outdoor nature experiences. The virtual landscape scenes used in our study, while immersive, were non-interactive, which may induce boredom or frustration as the duration increases. Furthermore, a literature review found that some participants reported simulator sickness starting at 5 min when exposed to virtual environments, while other participants did not experience simulator sickness until 20–30 min, or not at all (Dużmańska et al. 2018). If the participants started to feel motion sickness between 5 and 15 min in virtual environment, the experience might hinder stress recovery. In this study, participants were pre-tested for only 2 min to exclude overt symptoms of simulator sickness. Thus, we did not know whether mild motion sickness occurred during the study. Future studies should find ways to reduce simulator sickness for longer exposures.

Finally, this study found no significant relationship between familiarity with the urban environment and self-reported stress recovery. This finding is incongruent with previous studies suggesting that the local characteristics and familiarity may affect participants' preference and mental well-being (Liu et al. 2020; Mangone et al. 2021; Mansor et al. 2017; Pilotti et al. 2019; Wang et al. 2019). The incongruence may come from the fact that the videos of all three cities were combined together into each virtual landscape type, thus the participants may feel familiar with a few scenes from each video, but not all of them.

Practical implications

The results of this study suggest that experiencing virtual natural landscapes can elicit positive mental effects, especially with relieving acute stress before it becomes chronic stress. They confirmed that people with can use virtual environments to gain some mental health benefits of nature. The nature scenes did not have to be familiar to provide mental health benefits. Still, we found these benefits only for women.

While the experiment was conducted in a virtual environment and not a physical environment outdoors, our results reaffirm the need for designers and planners to engage in urban greening, especially in places with little to no urban nature. Environmental designers can and should make nature accessible to everyone. The mental health benefits of nature are especially crucial during a pandemic when many people feel isolated and disconnected from one another or are experiencing stressful situations due to the health and economic crises that follow. Any visual access to nature—through a window, through a TV screen, and through a walk in a park—is likely to enhance stress recovery.

The results suggest that 5 min of nature exposure is a more optimal dose than 1 or 15 min for stress recovery. This, together with a previous study on duration of nature exercise (Barton and Pretty 2010), suggests to employers, teachers, and health care providers that even a short break in nature can provide stress reduction benefits. Viewing a short nature video may be even more optimal than a longer break.

Finally, our results hint at differences in how genders and cultures interact with nature and reap stress recovery benefits. Designers and planners should base their decisions on the local population and target demographics, using participatory-based design, or human-centered design methods to increase the possibility that their work results in significant human health benefits.

Future research recommendations

Future research should expand upon this study in several ways. First, we found that women reported stress recovery benefits, while men did not. Researchers should explore diverse ways to measure stress, given the differences in stress response due to gender and culture. Coupling self-reported measures, such as Profile of Mood States (POMS) and Visual Analog Scale (VAS) on stress measurements, with psycho-physiological responses, such as heart rate variability (HRV) or cortisol levels, should be further explored. Richer explanations regarding the demographic differences may also be achieved using qualitative or mixed-method data.

Second, this study used non-interactive virtual landscapes, which does not fully simulate an experience in nature. Virtual landscapes may also influence participants' perception of control and boredom, especially for longer experiments. Furthermore, while we attempted to minimize the distorting effects from the transitions in each video and followed the protocols from previous studies, it is possible that the shifts between scenes brought participants out of their immersions, which may impact the results. Researchers should develop ways to use interactive virtual environments to explore the health benefits associated with nature and test for distorting effects in the future. In addition, participants were tested for simulator sickness during a 2 min VR experience prior to the experiment, but it might take longer periods of time for some participants to experience to symptoms (Koo and Kim 2019; Zhang and Wang 2020). In future research, other screening methods, such as in-depth interviews, may be helpful in the screening process.

Third, the virtual landscape scenes were filmed during summer and did not take seasonal variations into consideration. Seasonal changes may play a bigger role for people viewing landscapes outside their climate zone (those who

are unfamiliar with snow, for instance). Further studies should explore these possibilities.

Fourth, the study compared the differences between participants across genders and cultural backgrounds. However, there might exist other socio-demographics that predicted differences in nature-human relationships including age, education, employment status, and lived experience. Future studies must explore these factors to provide more precise evidence of nature-human relationships.

Fifth, this study may be influenced by the impact of the COVID-19 pandemic. This study was conducted at the beginning and middle of the global pandemic, which may increase the stress levels of participants and may impact how participants perceived the head-mounted device and interacted with our researchers (Stockwell et al. 2021). These factors may affect the outcomes of our experiment. While we mitigated the anxiety as much as possible, such as allowing more flexible experiment schedule, keeping our devices clean, and ensuring masks and hand-sanitation protocol (Browning et al. 2020b), we cannot eliminate the possibility that the effects of the pandemic might remain in our study. Further careful examination may reveal how the pandemic influenced the results of psychological and physiological experiments conducted during the pandemic.

Finally, nature scenes used were mostly of highly designed urban landscapes. While our experiment provided six groups of experience, the virtual landscape types were binary between nature or urban scenes. In addition, the internet provides an endless variety of natural virtual landscape scenes, including national parks, forests, blue spaces, caves, deserts, and polar areas (Li et al. 2022; Yin et al. 2022). Furthermore, design features of urban parks should be used and considered whether it might factor into stress recover. Future experiments should examine how a wider variety of types of nature, experienced through VR and other means, impact human health.

Conclusions

In this study, we tested the effects of virtual nature, duration of exposure, and familiarity with natural landscapes on self-reported stress recovery across three countries. We found that women, but not men, reported greater stress recovery when viewing nature scenes than urban scenes. The duration of exposure had a significant effect on stress recovery, with a 5-min exposure yielding the greatest rates of recovery. Unexpectedly, familiarity with the scenes was not associated with self-reported stress recovery despite videos representing unique biomes (southeast Asian and midwestern U.S.).

This study provides novel contributions by being one of the first studies that compared both durations of virtual natures and the demographics of participants toward stress recovery. It increases our understanding of the relationship between nature and human health, including questions on simulated nature, dose of nature, and how different demographics respond to nature. Future research should explore these relationships further, so that everyone can gain benefits from nature and designers and planners can, more confidently, bring nature to every doorstep.

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