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Effects of Natural Environmental Stimulation Duration on Psychophysiological Recovery Benefits

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Abstract. **The rapid pace of modern life, as well as chronic work and academic overloading, contribute to our society's progressively increasing stress levels. Chronic stress can affect both physical and mental well-being. Numerous studies have confirmed that viewing a nature-based video presentation can reduce stress and result in attention recovery. However, the discourse has been primarily focused upon stimulation applied over a single duration, rather than over various durations. Therefore, the present study explored the effect of various viewing durations with regard to forest-related videos on stress reduction and attention recovery. Before the videos' presentation, the participants' stress and distraction levels were increased through stimulation. Data on stress, attention, and relaxation were collected through the implementation of the State–Trait Anxiety Inventory and an electroencephalogram instrument. Equal numbers from the 90 participants (i.e., 30) were assigned to watch a short, medium-length, or long video (5, 10, and 20 minutes in duration, respectively). The viewing of 20-minute forest-related videos significantly promoted stress reduction and physiological relaxation. The present findings advance the understanding of the relationship between viewing nature scenes duration and psychophysiological states; thus, they serve as a reference for future research on the natural-dose concept, as well as the development of relevant activities and courses.**

Under rapid urbanization, individuals in modern society are exposed to various stimuli and stressors and, thus, suffer from fatigue. Several studies have indicated that the negative physical and mental impacts of chronic stress extend to work efficiency and the ability to cope with the stresses of daily life (Brewer and McMahan, 2003; Kamaldeep et al., 2016). Rambo (1984) identified anxiety as an emotion triggered in reaction to stress. Spielberger (1966) asserted that the state anxiety response is a behavior generated after an individual consciously evaluates the situational stress they perceive. State anxiety is characterized by distress, which may take the form of apprehension or worry. Anxiety and stress exert negative impacts on mental health and, in the long term, this can easily lead to the development of specific chronic diseases (Schachter and Singer, 1962). Physical disease can be prevented and physical health can be promoted through the relief of anxiety or depression, and the generation of positive emotions; for example, through contact with nature or engagement in leisure activities (Farrow and Washburn, 2019; Godbey, 2003; Jason, 2011; Kaplan, 2001; Kim et al., 2019; Lee and Son, 2018; Roe and Aspinall, 2011; Weng and Chiang, 2014; Wijndaele et al., 2007).

Existing studies have found people prefer to carry out their lives in a natural environment as it can alleviate stress or restore attention fatigue (Hartig et al., 1991, 2003; Hartig and Staats, 2006; Ulrich and Addoms, 1981; Ulrich and Parsons, 1992). Several empirical studies have reported that participants who viewed natural landscapes after being subjected to stress stimulation exhibited negative and positive emotions to lesser and greater extents, respectively, compared with their counterparts presented with urban street scenes (Herzog et al., 2003; Honeyman, 1992; Ulrich et al., 1991). Coming into contact with natural environments, especially forests, can promote mental health, bring a sense of comfort, and soothe one's mind (Ikei et al., 2014; Kotera et al., 2020).

The bulk of studies on attention restoration are based on attention restoration theory (ART) (Kaplan and Kaplan, 1989) and the stress reduction theory (SRT) (Ulrich, 1984; Ulrich et al., 1991). ART, which focuses on the cognitive level, argues that a direct attention restoration can be achieved by participating in activities in the natural environment (Kaplan, 1995; Kaplan and Berman, 2010). Kaplan and Kaplan (1989) noted that direct attention requires mental focus. When something deserving of notice is unattractive, one must pay more attention to prevent distraction. Furthermore, maintaining direct attention for a prolonged or excessive period of time leads to attention fatigue. For people whose attentional capacity is exhausted, being in a fascinating natural environment brings a deep sense of calm and comfort; thus, direct attention can be maintained or restored. Herzog et al. (1997) observed that ordinary natural settings achieved more satisfactory attentional recovery effects than everyday urban or sports/entertainment settings. Multiple studies have demonstrated that recovery from stress and attention fatigue is facilitated by exposure to a natural environment (Cimprich, 1993; Hartig et al., 2003; Hartig et al., 1991; Staats et al., 2003; Taylor et al., 2002; Tennessen and Cimprich, 1995; Ulrich, 1984; Wells, 2000). According to the ART, the natural environment features elements that trigger fascination, particularly *soft fascination*. For example, nonthreatening natural environments (forests, parks, and waterfalls) are considered soft and alluring because they draw the attention effortlessly while providing pleasant emotional experiences (Kaplan, 1995; Kaplan and Kaplan, 1989). The natural environment is not only conducive to attention restoration but also to factors such as cognitive performance, working memory, attentional control, visual attention, vigilance, and cognitive flexibility (Stevenson et al., 2018). Through a critical review and meta-analysis of 31 papers, a study reported that exposure to natural environments had significantly positive effects, thus supporting the ART (Ohly et al., 2016).

SRT explains emotional and physiological responses to natural spaces that facilitate stress reduction (Ulrich et al., 1991). When people are in contact with nature, their attention is redirected to the landscape such that their negative emotions are replaced by positive ones; thus, the balance of their physiological system is regained (Hartig and Staats, 2006; Hansmann et al., 2007). As these emotions become positive, stress-induced impairments in cognitive operations and performance may also be mitigated (Parsons et al., 1998). SRT highlights the benefits of positive emotions, as well as the reduction and enhancement of negative and positive emotions, respectively (Ulrich, 1979; Ulrich and Addoms, 1981; Ulrich et al., 1991). Honeyman (1992) compared the effects of varying amounts of vegetation in countryside and urban scenes on the degree of perceived stress: participants were exposed to scenes of rural villages, cities with vegetation, and cities without vegetation, with the results determining that urban greening significantly reduced stress. In a similar vein, other studies have indicated that viewing natural environments can reduce stress, promote more positive emotions, trigger positive physiological functions, benefit cognitive functioning, and facilitate recovery from discomfort or illness

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(Berto, 2005; Knopf, 1987; Leather et al., 1998; Ulrich et al., 1991). In summary, the literature confirms the positive effects of a natural environment on both physical and mental health (Berto, 2014; Chun et al., 2017; Herzog et al., 2003).

Viewing nature scenes can generate positive benefits, in particular, mysterious natural settings. A study indicated that as presentation durations were extended, images depicting scenes perceived as high in mystery achieved greater improvements in recognition performance than images depicting scenes perceived as low in mystery (Szolosi et al., 2014). Therefore, presentation duration affects not only the psychophysiological benefits obtained therefrom but also memory recognition performance. Furthermore, in-depth research on the presentation duration of nature scenes remains lacking. Specifically, the presentation duration required to maximize the associated psychophysiological benefits remains unclear. To fill this gap in the literature, this study explored the impacts of the presentation duration of nature scenes on the psychophysiological benefits derived.

Relationship between natural environmental stimulation of varying durations and stress reduction

Stress refers to the physiological response that threatens the autonomic nervous and endocrine systems. The body tends to choose either an active response or passive avoidance. When the stress endured exceeds a tolerable level, homeostasis is disrupted (Taylor, 2006). Anxiety, which can be classified as trait and state anxiety, is a complex process contained within stress; if a stressful situation is perceived as a threat or danger, a temporary state of anxiety will be induced (Spielberger et al., 1972). Trait anxiety—a chronic emotional state—refers to stable anxiety tendency. By contrast, state anxiety is a transitory emotional state characterized by apprehension, perturbation, worry, and unease. State anxiety is induced when an individual believes or perceives an external stressor as dangerous or threatening (Spielberger, 1966). Therefore, the restoration of psychophysiological functions after a period of rest or stimulation by natural environments following the development of such pressure is termed *stress reduction*.

Ulrich (1979) demonstrated that students who viewed slides of nature-based scenes for 18 min after class experienced reductions in stress, sadness, and anger/aggression and increases in positive perceptions; the response of the students who viewed slides or urban scenes was the opposite. In a later study by Ulrich and Simons (1986), the participants watched a stress-inducing video before viewing slides of various scenes, and the psychophysiological effects were then determined. Blood pressure levels, muscle tone, and the electrodermal activity of participants who viewed slides of water-based nature videos were lower; only 4–6 min elapsed before fear and anxiety decreased, and positive emotions were provoked. In a study by Ulrich et al. (1991), 120 participants viewed a 10-min, black-and-white, stress-inducing video in which negligence or disregard for safety procedures caused several wood factory employees to sustain serious injuries. Subsequently, the participants viewed six natural and urban scenes with color and sound for 10 min. Physiological and verbal assessments revealed the participants recovered from stress faster when exposed to the natural environments. Kotera et al. (2020) performed a meta-analysis of 20 studies on the mental health impacts of shinrin-yoku (i.e., forest bathing) practices (e.g., breathing exercises, walking, and yoga). The interventions were effective in mitigating depression, anxiety, stress, and anger—especially anxiety—in both clinical and nonclinical samples. The authors concluded that negative mental health symptoms could be reduced through shinrin-yoku of durations ranging from 15 min to 9 d.

Liszio et al. (2018) placed participants under stress before exposing them to a natural virtual environment, presented using virtual reality (VR) technology or a computer desktop screen. After stress was induced through a Trier Social Stress Test, a total of 62 participants were randomly assigned to one of two relaxation conditions (i.e., VR environment or desktop screen), and systematic changes in physiological and psychological indicators were examined. The VR group experienced significantly less stress and higher positive effects, indicating that VR can relieve emotional strain under acute stress. Thus, such technology can be used to design feasible solutions for individuals for whom conventional nature therapy is not an option.

Jiang et al. (2014) established a dose–response curve reflecting stress reduction through exposure to the natural environment. Psychosocial stress was first induced through the Trier Social Stress Test, before 160 participants watched a 6-min three-dimensional video randomly selected from a selection of 10. The density of trees in the video ranged from 1.7% to 62%. Individual responses and stress recovery were evaluated through the measurement of various physiological indicators. The dose–response curve of tree density indicated nonsignificant results for women, but for men, the dose–response curve was an inverted-U shape. Wang et al. (2016) conducted a stress recovery study in which 140 Chinese university students (aged 18–24 years) were randomly assigned to watch one of seven videos (six depicting an urban park, one presenting a city road) during the stress recovery stage, after undergoing a stress-inducing oral exam. After data on psychophysiological measures, including stress and attention, were collected, stress recovery was found to correlate to exposure to natural landscape elements, and outdoor park scenes without people exerted greater restorative benefits than scenes in which people were present. These results are consistent with the existing body of research (Chiang et al., 2017; Gidlow et al., 2016; Peschardt and Stigsdotter, 2013).

Chun et al. (2017) randomly divided patients who had suffered chronic strokes into a forest group (residing in a recreational forest site) and an urban group (residing in an urban hotel), with both groups required to perform identical activities for the same duration. The patients were evaluated using the Beck Depression Inventory, Hamilton Depression Rating Scale, and State–Trait Anxiety Inventory at pretest and posttest. The researchers concluded that forest therapy was effective in alleviating symptoms of depression and anxiety in chronic stroke patients, particularly those for whom standard drug therapy is ineffective. Whether for patients with specific diseases or the general population, direct or indirect contact with the natural environment has been found to strongly activate the parasympathetic nervous system, the benefits of which include physical and mental relaxation and stress reduction, as well as reduced cardiovascular risks, enhanced cognitive function, improved sleep quality, and the prevention of dementia and attention deficit hyperactivity disorder (Farrow and Washburn, 2019; Ikei et al., 2014; James et al., 2015; Kim et al., 2019; Kuo and Taylor, 2004; Lee and Son, 2018; Lee et al., 2014; Ochiai et al., 2015).

Relationship among varying durations of natural environmental stimulation, attention, and relaxation

Attention refers to selective concentration. Individuals consciously respond to various stimuli in a situation and select those to which they wish to respond; perception is a key component of this process (Kaplan and Berman, 2010). Pretty (2004) proposed three beneficial levels of nature engagement for humans: remotely viewing nature, being in the presence of nearby nature, and active participation in and involvement with nature. In essence, nature participation at any level can positively affect stress and attention (Mackay and Neill, 2010). In a study on the restoration of attentional capacity through exposure to restorative environments (Berto, 2005), participants were asked to choose photographs depicting either restorative or nonrestorative environments, or geometrical patterns; the viewing duration for each photograph was less than 15 s. Only participants who viewed the restorative scenes improved upon their score in the final sustained attention test. In a study by Parsons et al. (1998), participants watched a 10-min simulated driving video in either a natural environment or urban landscape; their physiological responses and ability to concentrate were assessed. When comparing scores for calculation processing, concentration levels, and attention spans, participants who viewed the natural landscape video outperformed those who viewed the urban landscape. Hartig et al. (2003) tested changes in blood pressure, mood, and attention of adults before and after a 20-min walk in either a natural or urban field setting. The participants assigned to the natural environment outperformed those assigned to the urban environment, and the urban group exhibited a downward trend in attention.

Existing studies have demonstrated that walking in nature facilitates attention restoration more so than walking in urban areas (Hartig et al., 1991, 2003; Martens et al., 2011). In a study on green exercise, Pretty et al. (2005) asked participants to run on an indoor treadmill while viewing pleasant rural, unpleasant rural, pleasant urban, and unpleasant urban landscapes; greater benefits to blood pressure, self-esteem, and mood were observed in the pleasant rural condition. In a later study, Pretty et al. (2007) noted that participants engaging in green exercise exhibited lower levels of anxiety. A study by Hartig et al. (1991) divided participants into two groups: one walked through a wilderness setting, while the second walked through a city; both participated in passive relaxation activities (listening to music and reading magazines) for 40 min. The researchers found that restorative effects were most substantial in the wilderness group. Hansmann et al. (2007) examined restoration and stress relief in Zurich residents before and after visits to green spaces (i.e., an urban forest and a city park). The overall reduction in stress and headaches following the visits were 87% and 52%, respectively, with the changes accounting for 40% of the possible mental balance improvement. Gidlow et al. (2016) randomly assigned participants to a self-paced, 30-min walk in one of three environments: residential (urban), natural (green), and natural with water (blue). Psychophysiological responses (e.g., emotion, cognitive function, and various physiological indicators) were measured at baseline (T1), at the end of the walk (T2), and 30 min after departure from the walking environment (T3). Indicator improvements were noted at T2 and T3 in all environments, and associations between walking in the natural (green and blue) environments and better restorative experiences, improved cognitive function, and reduced stress were observed—effects that persisted to T3. A meta-analysis study provided some evidence of the positive benefits of a walk or run in a natural environment in comparison with in a synthetic environment. With regard to the psychological indicators, the findings were more highly consistent among studies, whereas those on physiological indicators (e.g., blood pressure and cortisol concentrations) exhibit greater discrepancies (Bowler et al., 2010).

In the present study, the parameter of attention—we measured participants' brainwave through the electroencephalogram (EEG) instrument (MindBand, NeuroSky)—refers to the participants' attention level at that time. Relaxation (measured on MindBand) refers to the participants' relaxation level at the time, and reflects their mental rather than physical state. Relaxation levels cannot be enhanced over a short period of time, such as through an entire-body muscle relaxation routine. Nonetheless, for most people, physical relaxation facilitates mental relaxation under normal circumstances. An increase in the relaxation levels is clearly associated with a reduction in brain activity. Long-term observations have shown that closing the eyes reduces brain activity because it eliminates the need for the brain to process visual stimuli. Therefore, this simple action is typically effective in raising relaxation levels.

Research purpose and hypotheses

Multiple studies have confirmed that exposure to natural environments benefits human health (e.g., Farrow and Washburn, 2019; Herzog et al., 2002; Laumann et al., 2003; Li and Sullivan, 2016). However, the duration of exposure under which notable psychophysiological effects are produced remains unknown. Therefore, the present study sought to investigate the effect exposure duration has using the following psychophysiological indicators: stress, attention, and relaxation. Furthermore, state anxiety was used as a proxy for stress on the basis of the premise advanced by Spielberger (1966) that the transitory emotional state is caused by anxiety or tension-induced stress.

Relevant studies on the relationship between people and the natural environment primarily use photographs as stimuli in simulated situations, with the psychophysiological responses assessed following a set period of time. Therefore, determining exactly how long it takes for natural landscape exposure to yield restorative benefits is challenging. Moreover, whether the psychophysiological benefits in this situation increase over time has yet to be elucidated.

Thus, the present study explored the effect of varying durations of natural environmental (forest) stimulation on psychophysiological responses, namely stress, attention, and relaxation. The following hypotheses were proposed:

H1: Varying viewing durations lead to significant differences in the psychological response of the individual with regard to stress reduction.

H2: Varying viewing durations lead to significant differences in the physiological response (EEG brainwave) of the individual with regard to attention and relaxation.

H3: The pretest–posttest results of the psychophysiological measurements of the individual differ significantly by viewing duration.

Materials and Methods

Participants

Undergraduate and postgraduate students were recruited to participate in our study. Volunteers were recruited through announcements posted around campus. We employed a convenience sample of 90 participants. For all participants, questionnaire completion and physiological data collection (i.e., brainwaves) were conducted in the same indoor space. The participants were divided into three groups of 30 individuals that were randomly assigned to watch one of three nature videos of varying durations. A total of 90 valid participants of whom 47 (52.2%) indicated their gender as female and 43 (47.8%) indicated as male. Their age between 19 and 26 years (M = 22.1 years; SD = 1.14 years). All participants gave their informed consent for inclusion before they participated in the study.

Stimuli

"Traveling around the National Forest Recreation Areas"—a video released by the Taiwan Forestry Bureau in 2007—was edited into three time lengths: 5, 10, and 20 min. To prevent the influence of different forest environments on participants, the three videos, featuring identical content, were played from the same starting point for the 10-min and 20-min videos, the 5-min video was looped twice and four times, respectively. Regarding the content, the videos showcase the botanical beauty and diversity of Taiwan's high-elevation coniferous forests, 1000-year-old trees in cloud forests, sacred trees, medium- and low-elevation primeval broad-leaved forests, and monsoon forests (Fig. 1). The videos contained the sounds of natural environments such as insects singing, birds chirping, and leaves rustling.

Assessment tools

State–Trait Anxiety Inventory. State anxiety, which refers to the varying degrees of anxiety responses produced immediately upon exposure to a situational stressor, and the perception that the stressor presents threat or danger (Spielberger et al., 1972), was assessed using a Chinese adaptation of the State–Trait Anxiety Inventory (Chung and Long., 1984). This self-reporting questionnaire comprises an equal number of items measuring state anxiety and trait anxiety. Since state anxiety is an immediate emotional response, the inventory only measured state anxiety as a stress measurement tool, with possible scores between 20 and 80 points, and higher scores indicating greater anxiety and

Fig. 1. Screenshots of the forest video.

stress. A reliability analysis for state anxiety was conducted. The Cronbach's α obtained was 0.84, indicating high internal consistency. The content validity of the scale has been reported to be favorable (Bados et al., 2010; Weng and Chiang, 2014).

Attention and relaxation. Data were recorded using MindBand EEG headsets (NeuroSky ThinkGear, San Jose, CA): noninvasive biofeedback instruments that measure responses through electrodes attached to the scalp. Recordings were made at 256 Hz from the forehead at the FP1 site. Raw EEG data were sent to a personal computer via Bluetooth technology, before being saved to disk. Studies investigating the validity of ThinkGear dry-sensor technology have indicated its superior validity and reliability as research-grade equipment (Bhatti et al., 2016; Johnstone et al., 2012; Rogers et al., 2016).

The EEG device is used to measure the four different brainwave frequency signals α, β, θ, and δ, through the eSense brain chip algorithms are used to calculate the context of the attention and meditation (relaxation) parameters (Neurosky Inc., 2009; Perhakaran et al., 2015). Previous studies have documented well that focused on obtaining attention and meditation (relaxation) states of mind from the characteristics of EEG (Jacobs and Friedman, 2004; Kaur and Singh, 2015; Liu et al., 2013). The attention value reflects the intensity of a participant's level of mental "focus" or "attention" during increased mental effort. Meditation (relaxation) is a measure of a person's mental levels, not physical levels, so simply relaxing all the muscles of the body may not immediately result in a heightened meditation level, while the meditation value point to participant's mental "calmness" or "relaxation." Each metric provides a relative measure of state from 1 to 100, these are not absolute values, where a value from 1 to 20 indicates "strongly lowered" levels of the state, and a value from 80 to 100 points heightened levels of that state (Maskeliunas et al., 2016).

Study procedure

Before being fitted with the equipment, participants were informed of the experimental procedure and, subsequently, completed the questionnaire. The questionnaire's first section was with concerned basic information, while the second comprised the attention-distraction test: Trail Making A Test (TMAT) (Charoenkitkarn et al., 2009). The TMAT caused the participants to experience physiological and physiological fatigue, such as brain and body fatigue (Gotts et al., 2015). Participants were presented with 49 sequential numbers, randomly scattered in a 7 × 7 grid, and were instructed to complete the connection, as well as identify repetitions and missing values. High levels of concentration while completing the task are expected to achieve attentional distraction following the test (Chiang et al., 2017). Next, participants' brainwaves were recorded as they completed the State–Trait Anxiety Inventory, and while

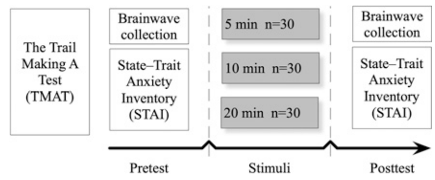

Fig. 2. Study procedure.

they viewed the video assigned to their condition. Lastly, as they completed the inventory again, the participants' brainwave data were collected concurrently (Fig. 2).

Statistical analysis

All analyses used IBM SPSS Statistics 22.0. A one-way analysis of variance (ANOVA) was performed to test for variations in the levels of stress reduction, attention, and relaxation according to the stimulation duration, as well as to validate H1 and H2. A dependent samples *t* test was conducted to test the pretest–posttest differences under H3. The effect sizes were further analyzed. Cohen (1988) stated that "there is a certain risk inherent in offering conventional operational definitions for those terms for use in power analysis in as diverse a field of inquiry as behavioral science" (p. 25). Cohen's *d* can be interpreted in terms of the nonoverlap percentage of the pretest scores with the posttest scores. The present effect sizes are based on unadjusted coefficients of correlation (i.e., in a within-group design). Therefore, the effect sizes were computed on the basis of the formula adapted for correlated designs developed by Dunlap et al. (1996) (p. 171, Eq. [3]): $d = tc(2\,[1-r]/n)1/2$. According to the benchmarks developed by Cohen, effect sizes can be classified as small (d = 0–0.2), medium (d = 0.3–0.5), and large (d = 0.6–0.8). In addition, analysis of covariance (ANCOVA) was used to compare the posttest results for stress, attention, and relaxation among the groups exposed to videos of 5-, 10-, or 20-min duration, with pretest results as covariates to avoid the influence of different baselines between the treatment conditions.

Results

Duration-dependent differences in psychophysiological responses

To determine the effect of watching videos of varying durations on the participants' stress, attention, and relaxation levels, the posttest scores were subjected to a one-way ANOVA. Viewing videos of varying length were found to significantly affected stress, $F(2, 87) = 3.065$, $P < 0.05$, as well as relaxation, $F(2, 87) = 6.542$, $P < 0.01$ (Fig. 3). However, attention was not significantly affected, $F(2, 87) = 0.578$, $P = 0.56$. Regarding the Scheffé post-hoc pairwise comparison results, a comparison of the 10- (M_{posttest} = 29.65) and 20-min (M_{posttest} = 34.43 for both) durations revealed that greater stress reduction effects were achieved in the 10-min condition. Watching the 20-min video (M_{posttest} = 64.56) had significantly better effects on relaxation compared with watching the 5- or

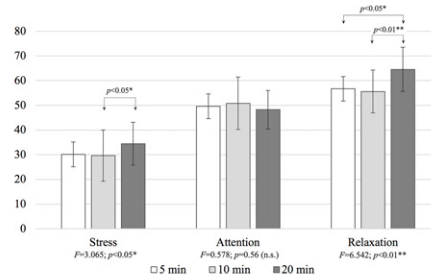

Fig. 3. Results from the analysis of variance of psychophysiological responses by stimulation duration.

10-min videos (M_{posttest} = 56.58 vs. 55.60). This finding indicates that viewing a longer-length nature video had excellent psychophysiological benefits, including relaxation.

Pretest–posttest differences in psychophysiological benefits under varying stimulation durations

The stress, attention, and relaxation data of the participants in the 5-min condition before and after the viewing were examined through a dependent samples *t* test. The pretest–posttest differences were significant for stress, $t(29) = -6.89$, $P < 0.001$, as were for relaxation, $t(29) = 2.19$, $P < 0.05$, but not for attention, $t(29) = 0.18$, $P > 0.05$ (Table 1). These results demonstrate that stress was reduced and relaxation was increased after the 5-min video was presented. Moreover, regarding effect sizes, the results on stress and relaxation under all three durations exhibited a satisfactory effect size (Table 1).

Data of the participants in the 10-min condition were also examined through a dependent samples *t* test. The pretest–posttest differences were significant for stress, $t(29) = -5.65$, $P < 0.001$, as were for relaxation, $t(29) = 2.78$, $P < 0.01$, but not for attention, $t(29) = 1.92$, $P > 0.05$ (Table 1). In other words, significant reductions in stress and increases in relaxation were observed, but no differences in attention were detected.

Similarly, performance of the dependent samples *t* test on the data from the 20-min condition revealed significant pretest–posttest differences for stress and relaxation, $t(29) = -3.90$ and 2.98, $P < 0.01$, respectively), but not for attention, $t(29) = 0.44$, $P > 0.05$ (Table 1). In short, stress decreased and relaxation increased following the video's presentation.

Effect of duration on stress, attention, and relaxation

To determine whether the effects of duration on stress, attention, and relaxation varied between pretest and posttests, pretest scores were set as the control variable and ANCOVA was conducted. The stress analysis results indicated that by excluding the covariate variable (i.e., pretest) and dependent variable (i.e., posttest), stimulation time exhibited pronounced effects on stress posttest scores. To further understand the effects of the varying simulation time on stress, the Bonferroni post-hoc analysis was performed, which revealed that the

Table 1. Pretest–posttest differences in psychophysiological effects under varying stimulation durations.

	Pretest		Posttest			
	M	SD	*M*	SD	*t*	*d*
5 min (n = 30)						
Stress	40.93	8.92	30.15	5.80	−6.89***	−0.91
Attention	49.24	10.38	49.61	10.68	0.18	0.04
Relaxation	52.33	5.53	56.68	8.67	2.19*	0.56
10 min (n = 30)						
Stress	41.50	10.18	29.65	5.93	−5.65***	−0.89
Attention	46.54	10.62	50.82	8.11	1.92	0.45
Relaxation	48.30	6.83	55.60	7.80	2.78**	0.78
20 min (n = 30)						
Stress	41.80	8.68	34.43	7.04	−3.90**	−0.93
Attention	47.41	8.63	48.20	6.62	0.44	0.10
Relaxation	51.64	4.24	64.56	8.99	2.98**	0.81

Lower stress scores represent a lower level of psychological stress.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

effect of the 10-min video (M = 29.65) on stress was lower than that of the 20-min video (M = 34.43). In other words, the 10-min video had a more favorable performance in terms of stress reduction than the 20-min video did (Table 2).

The attention analysis results indicated that when excluding the covariate variable (i.e., pretest) and dependent variable (i.e., posttest), stimulation time did not exhibit pronounced effects on attention posttest scores; significant differences were observed only between the pretest and posttest. The relaxation analysis results indicated that stimulation time exhibited pronounced effects on relaxation posttest scores. Significant differences were also observed between the pretest and posttest. Bonferroni post-hoc analyses revealed that the effects of the 20-min video (M = 64.56) on relaxation were greater than those of the 5-min video (M = 56.68) and 10-min video (M = 55.60). In other words, the 20-min video yielded greater relaxation effect than the 5- and 10-min video did (Table 2).

Conclusions and Recommendations

Numerous studies have noted that a natural environment can benefit human health. The presentation of nature scenes is found to exert positive mental effects, with studies using videos that run anywhere between 4 and 20 min (Berto, 2005, 2014; Herzog et al., 2003; Liszio et al., 2018; Ulrich and Simons, 1986; Wang et al., 2016). In the current study, varying stimulation durations were used to assess the effects of a natural environment on stress, attention, and relaxation. Viewing the nature videos—regardless of their duration—significantly reduced stress levels, and increased relaxation levels.

Regarding the pretest–posttest differences in stress, participants experienced substantial reductions in stress after watching the nature videos, regardless of duration. Taking at least 20 min out of your day to stroll or sit in a place that makes you feel in contact with nature will significantly lower your stress levels (Hunter et al., 2019). Because the rapid pace of modern life makes it difficult to engage in activities in nature, the present experiments were not conducted outdoors. Nevertheless, stress reduction can be achieved even through the brief viewing of nature-related videos. The present results are consistent with those of existing studies in that stress reduction was achieved through exposure to nature (Kim et al., 2019; Ulrich, 1979, 1986; Ulrich et al., 1991), regardless of the duration. Regarding the exposure duration, brief viewing (5–10 min) contributed to stress reduction, whereas the benefits of extended viewing (>20 min) were limited, likely because the sensory stimulation remained incomparable to real experiences in nature.

Regarding the pretest–posttest differences in attention, no significant effect was observed under any duration, and an overall declining trend was noted. This is likely because the attention–distraction test administered before the video presentation required complete concentration, thereby reducing the participants' attentional capacity following the test. However, this test was modified on the basis of relevant literature. In other words, the modified test may have insufficiently distracted the participants; their calmness and concentration during the video viewing may have caused a slight drop in attention. Another possible reason is the discrepancies between the measurement methods used in the present study and in numerous other studies. Previous studies used self-reported psychological assessments of attention, such as the Perceived Restorativeness Scale (PRS) (Hartig et al., 1997) and the Restorative Components Scale (RCS) (Laumann et al., 2001). By contrast, the present study obtained physiological brainwave data. According to Bowler et al. (2010), the consistency of the findings on psychological indicators among various studies is high, whereas those on physiological indicators are inconsistent. In short, findings on physiological indicators might be affected by factors such as study design, sample size, type of natural environment, type of exposure to and engagement with nature, and duration of exposure.

For relaxation, all video durations (i.e., 5, 10, and 20 min) increased relaxation scores (from pretests to posttests). The increases were most pronounced with a video duration of 20 min. This may be because the participants in the lengthier video condition were mentally refreshed as a consequence of the extended viewing duration and comfortable environment, which may have contributed to greater physiological relaxation. Our results are in respects similar to those in previous study examining the relaxing effects of forest bathing on humans (Tsunetsugu et al., 2010). According to the operational definition of relaxation in this study, relaxation can induce calmness, and the longer the duration, the greater the benefits.

Once the pretest scores were controlled, the effects of stimulation time on stress and relaxation varied considerably by video duration, where the 20-min forest video caused more stress but induced more relaxation than did the other videos. This may be because the 20-min video made the participants more irritated mentally, but more relaxed physically.

There are a number of limitations associated with this study. First, the current experimental group comprised only undergraduate and postgraduate students. Various studies have also used university students as the experimental group (Chiang et al., 2014; Hartig and Staats, 2006; Wang et al., 2016; Weng and Chiang, 2014), with significant results. Nonetheless, because of the relatively limited demographics, extrapolation of the present findings to other populations warrants caution. Second, although research confirms that responses to static color photos or dynamic videos generalize well to on-site response (Herzog and Kutzli, 2002; Stamps, 1990),

Table 2. Covariance analysis of the effect of duration on the participants' stress, attention, and relaxation during the pre- and posttests (dependent variable: posttests).

Source	Sum of squares	df	Mean square	F	Sig.	Partial η^2	Post-hoc
Stress							
Pretest	312.671	1	312.671	8.620	0.004	0.091	
Duration	233.125	2	116.563	3.213	0.015	0.070	10 < 20
Error	3119.529	86	36.274				
R^2 = 0.151 (Adj R^2 = 0.121)							
Attention							
Pretest	651.409	1	651.409	7.086	0.009	0.083	
Duration	142.010	2	71.005	0.772	0.465	0.018	
Error	7905.345	86	91.923				
R^2 = 0.088 (Adj R^2 = 0.056)							
Relaxation							
Pretest	315.726	1	315.726	5.455	0.022	0.060	
Duration	826.610	2	413.305	7.140	0.001	0.142	5 < 20, 10 < 20
Error	4977.851	86	57.882				
R^2 = 0.203 (Adj R^2 = 0.176)							

some researchers raise legitimate concerns about the generality of such results (Heft and Nasar, 2000; Scott and Canter, 1997). Thus, research would do well to test the results on-site or in response to dynamic displays. Finally, no control group (e.g., assigned to watch videos depicting urban or neutral scenes) was enrolled for comparison. Thus, only differences among viewing durations could be analyzed.

In future research, first, researchers are recommended to alter the stimulation durations and incorporate videos depicting other types of landscapes for cross-comparison purposes. In addition, researchers should observe the participants' behavior while they watch the videos and inquire upon their feelings afterward; this would form a basis for any auxiliary analysis of physiological indicators, as well as add other psychological measurement tools to explore the relationship between physiological and psychological health. Second, this study only measured the duration of a single stimulation, but contact with nature is not limited to one-time experiences. Thus, assessing the frequency and quality of nature stimulation in future studies is recommended for gaining deeper insights into the benefits of nature on human health.

In practical recommendations, considering the rapid pace of modern life, office workers and students can obtain psychological benefits through the brief viewing of nature scenes. Although the short durations of rest at work or school do not allow for breaks in nature, psychophysical relaxation can be achieved by viewing nature-related videos, and work efficiency can be improved substantially. In addition, the present findings can be used to develop a reference test with regard to the time dose to understand how varying durations of exposure to the natural environment affect physical and mental health. Moreover, the current findings can provide a clinical reference with respect to the dose-of-nature concept and can contribute toward the development of treatment that involves exposure to natural landscapes for both the general public and patients. In addition to facilitating scientific and practical applications of the natural-dose concept, these findings can also promote and encourage people to engage in outdoor activities, as well as create awareness of the importance of leisure, all with a view to relieving the stress of urban residents and improve mental health on a public scale.

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