Effects of Background Sounds on the User's Psychological Indices in Virtual Environment

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Abstract. The COVID-19 pandemic has changed the work style, with an increasing number of companies introducing homeworking. However, there are concerns about decreasing communication between workers and their supervisors, which increases stress and fatigue in workers. Efforts are being made to incorporate virtual reality technology into homeworking, enabling work to be conducted in virtual offices while encouraging communication. Studies on the effects of working in virtual environments have reported reduced stress in workers exposed to natural landscapes. However, studies on the effects of natural sounds in virtual environments on workers' stress levels are limited. In this study, twelve students were exposed to two types of background sound: forest sound and office sound in a virtual office. The effects of these two sounds were investigated using psychological indices. The results revealed that the forest sound reduced work stress even in virtual environments. Applying the knowledge of the results, it is assumed that background forest sounds in silent office environments helps the office workers calm stress.

Keywords: Virtual environment, Stress, Sound, Working environment

1   Introduction

The COVID-19 pandemic has changed the workstyle of employees, with an increasing number of companies introducing working from home. However, Killgore et al. state that employees forced to work from home due to telework experience increased stress owing to reduced interaction with colleagues and supervisors [1]. According to Selye, stress is a nonspecific response of the body to any demand [2] and includes fatigue caused by work or tension over upcoming tasks. With recent developments in virtual reality (VR) technology, some companies rely on VR techniques to increase employee communication.

Many studies have been conducted on the effects of virtual work environments on people. Jie et al. investigated the effects of four virtual environments on participants: office without houseplants and windows, office with houseplants, office with a plain-like landscape outside the windows, and office with houseplants and a plain-like landscape outside the windows. The office with houseplants and windows facilitated recov-ery from stress and anxiety compared to other virtual environments [3]. William et al.

stated that designing offices and other places with nature-inspired designs can reduce stress, improve cognitive function and creativity, enhance personal well-being, and promote healing [4]. For example, in the non-visual connection with nature design patterns, such as listening to nature-inspired sounds, can reduce the release of stress hormones [4]. Moreover, natural sounds promoted stress recovery compared to artificial noises, such as the sound of cars driving. Alvarsson et al. investigated stress recovery before and after a computational task in which participants were presented with four types of sounds: sounds reminiscent of a park, such as the sound of a fountain or birds singing, noises of cars and other vehicles recorded near a busy road, noises of cars and other vehicles recorded at a low volume, and sounds recorded in a quiet backyard. Stress recovery before and after performing calculation tasks was investigated using physiological indices. The park sounds were found to promote stress recovery more than the other three noise types [5].

In recent years, many studies have investigated the effects of forests on workers in virtual environments. For instance, Beverly et al. investigated the effects of forests on short-term subjective stress using VR environments depicting a lush, green nature with sounds of birds chirping and leaves rustling in the wind preserve to promote relaxation and peace. A three-minute VR simulation of a nature scene effectively reduced subjective stress in participants [6]. Though most studies used a forest environment for the background sound and landscape, the effect of the forest sound alone in the virtual environment remains unclear.

This study clarifies the effect of forest sound on stress using forest sound as the background sound and landscape as a general office view.

2   Method

2.1   Participants

Participants were twelve healthy male student volunteers of 21 to 24 years (mean = 22.3, SD = 1.0). They were asked to answer KG's daily life questionnaire before the experiment [7]. There was one Type A personality, four Type B personalities and seven were the other. The two menstrual cycles of follicular and luteal phases of menstruation may affect the results. Therefore, in this study, participants were male controls to remove the effects of gender differences [8].

This study was reviewed and approved by the Research Ethics Committee of the Chitose Institute of Science and Technology (Reception No. 2022-5). The participants' informed consent was obtained before the experiment.

2.2   Background sound and experimental environment

The experiment was conducted using three different background sounds: a forest sound from the wind and tweeting birds (forest condition: FC), office ambient sound from a keyboard typing and footsteps (office condition: OC), and reduced ambient sound from using earplugs (control). Forest and office sounds were recorded using the SONY

PCM-D10. The virtual environment created to imitate an office was used in the experiment (Fig. 1).

Fig. 1. Experimental environment.

2.3   Procedure

The experiment was conducted with one participant at a time. The experimental procedures are shown in Fig. 2. The participants were explained about the experiment at the beginning. The participants were then asked to practice the test for 5 min to gain test proficiency, put on the head mount display (HMD), and practice the test again. After the test, the participants sat quietly for 5 min during the resting period (REST1). Next, they were asked to perform the trail making test. They were instructed to perform the test as accurately and quickly as possible and again sat quietly for 5 min after the task (REST2).

Subjective fatigue was assessed using subjective fatigue feelings (SFF) before REST1 and after REST2, psychological stress was assessed using the brief job stress questionnaire (BJSQ), and subjective mental workload was assessed using the National Aeronautics Space Administration-task load index (NASA-TLX). Then, after a few minutes break, the conditions were changed from FC to OC or OC to FC and the procedure was repeated.
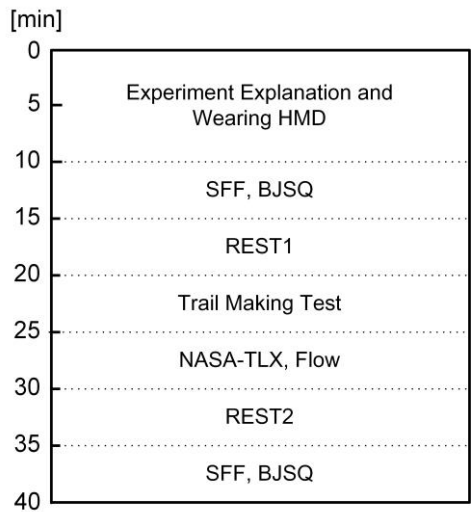
Fig. 2. Experimental procedure.

2.4   Subjective Assessments

SFF is a method of surveying respondents' current state of fatigue. Participants were asked to rate the questions on a 5-point scale, with 5 questions in each group: drowsiness, instability, feeling of uneasiness, local pain or dullness, and eyestrains (Table 1) [9].

Table 1. SFF questionnaires.

Group	Questions
Drowsiness	I feel giving a yawn.
	I feel drowsy.
	I feel lack of a desire to do something.
	I feel tired in the whole body.
	I feel a desire to lie down.
Instability	I feel nervous.
	I feel restless.
	I feel anxiety.
	I feel depressed.
	I feel difficulty in thinking.
Feeling of uneasiness	I feel heavy in the head.
	I feel ill.
	I feel headache.
	I feel the brain hot or muddled.
	I feel dizziness.
Local pain or dullness	I feel stiff in the neck and shoulders.
	I feel a pain in the hands or fingers.

	I feel dullness in the arms.
	I feel a lower back pain.
	I feel tired in the legs.
Eyestrains	I feel dry eyes.
	I feel a pain in the eyes.
	I feel eyes blurred.
	I feel eyestrain.
	I feel eyes blinking.

BJSQ is an index that measures respondents' psychological and physical stress reactions. In this study, only 18 items related to psychological stress reactions were used. Participants were asked to rate these 18 items on a 4-point scale. The items were categorized into 5 subscales: liveliness, irritability, fatigue, anxiety, and depression. We assigned 24 points for depression because it included 6 items and 12 points for the other groups with 3 items each (Table 2) [10].

Table 2. BJSQ questionnaires.

Sub scale	Questions
Liveliness	I have been very active.
	I have been full of energy.
	I have been lively.
Irritability	I have felt angry.
	I have been inwardly annoyed or aggravated.
	I have felt irritable.
Fatigue	I have felt extremely tired.
	I have felt exhausted.
	I have felt weary or listless.
Anxiety	I have felt tense.
	I have felt worried or insecure.
	I have felt restless.
Depression	I have been depressed.
	I have thought that doing anything was a hassle.
	I have been unable to concentrate.
	I have felt gloomy.
	I have been unable to handle work.
	I have felt sad.

NASA-TLX is a subjective evaluation of mental workload, wherein six items, mental demand (MD), physical demand (PD), temporal demand (TD), own performance (OP), effort (EF), and frustration level (FR), are evaluated on a visual analog scale of 0 to 100 points, with low-high or good-bad as the extremes. Raw TLX, which represents the mean of the six items, was calculated [11].

Table 3. NASA-TLX questionnaires.

Item	Scale	Description

Mental Demand	Low / High	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical Demand	Low / High	How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal Demand	Low / High	How much time pressure did you feel due to the rate or pace at which the tasks occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	Poor / Good	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort	Low / High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration	Low / High	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

2.5 Trail making test

In this study, participants were asked to perform a trail making test as a task. The task was displayed on a monitor installed in a virtual environment (Fig. 3). We randomly placed 30 three-digit numbers on the display and asked the participants to click on them using a mouse in order of decreasing number. The numbers were repositioned each time the participant clicked on them or each time the blue bar at the bottom of the screen disappeared. The performance was evaluated based on the number of times the participant clicked the correct number in a 5-min period.
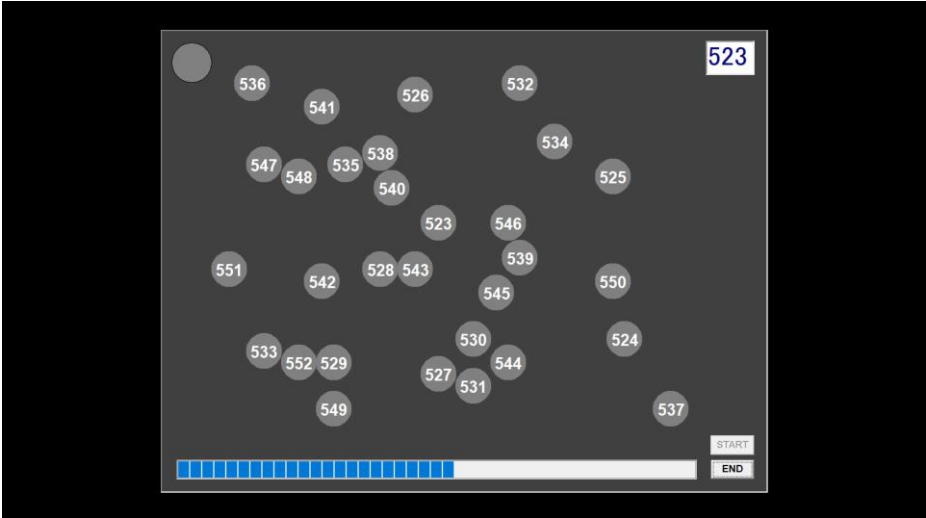
Fig. 3. Trail making test.

2.6   Statistical Analysis

SFF, BJSQ, NASA-TLX, and trail making test scores in the three environments (FC, OC, and Control) were compared using one-way ANOVA. The significance level was set to $\leq 5\%$.

3   Results

3.1   Task performance

The trail making test scores are shown in Fig. 4. There was no significant difference in the number of responses for different background sounds.
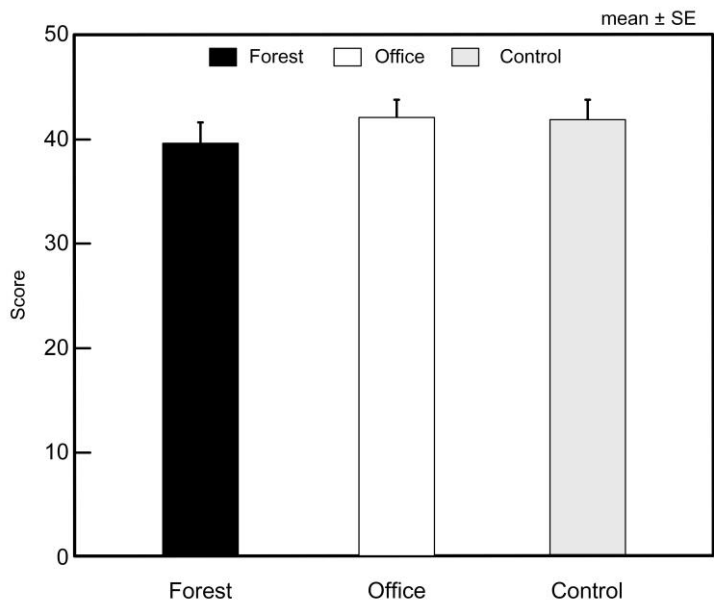
Fig. 4. Scores of trail making test (n = 12).

3.2   Subjective Assessments

SFF Scores.
The SFF scores are shown in Fig. 5. The instability score of the SFF in FC significantly reduced after the task compared with that before ($p < 0.05$). In contrast, the uneasiness score in OC is significantly elevated after the task compared with that before ($p < 0.01$). In the Control group, the drowsiness and uneasiness scores are significantly elevated after the task than before ($p < 0.001, 0.05$).
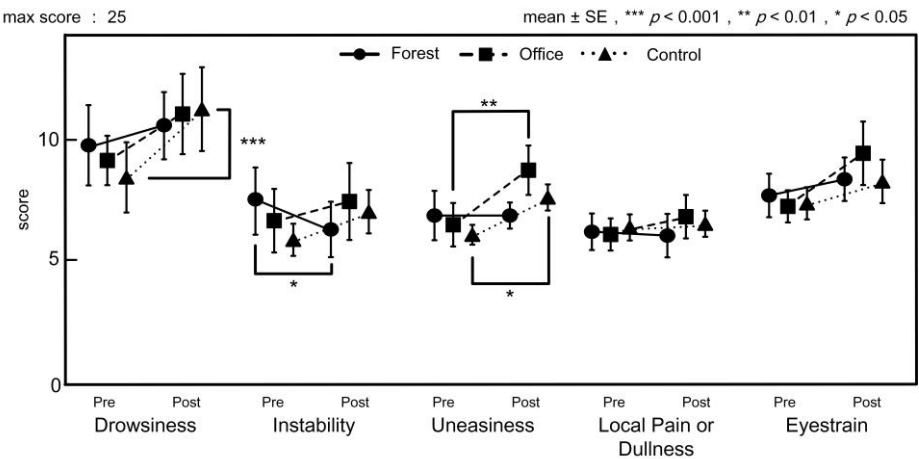
BJSQ Scores.

The BJSQ scores are shown in Fig. 6. Liveliness score in OC is significantly lower after the task than that before ($p < 0.05$). In contrast, fatigue score is significantly elevated after the task ($p < 0.05$).
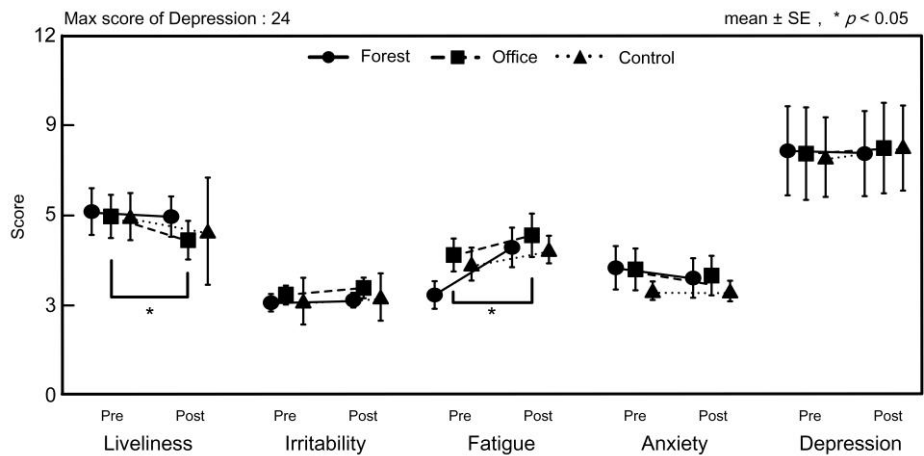

Fig. 6. Scores of BJSQ (n = 12).

NASA-TLX Scores.

The NASA-TLX scores are shown in Fig. 7. Raw-TLX is significantly lower in the FC than in the Control ($p < 0.05$). The other subscales did not differ significantly between the three conditions.
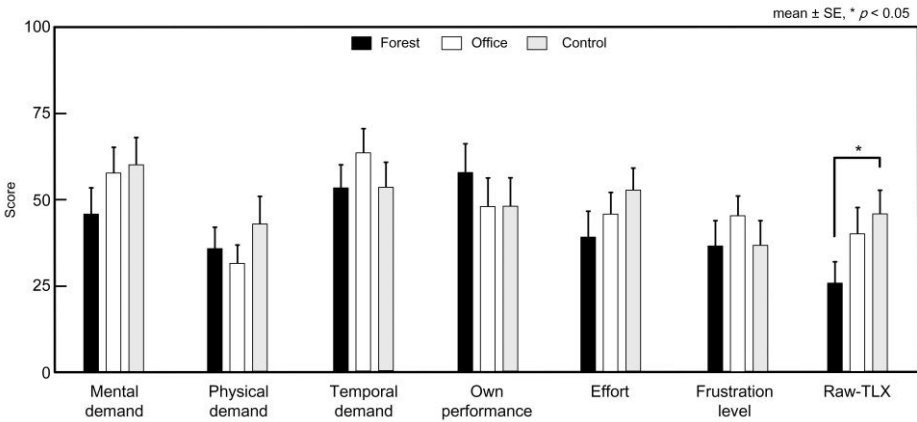
Fig. 7. Scores of NASA-TLX (n = 12).

4   Discussion

The SFF and BJSQ results showed that the sense of instability significantly decreased after the task in the FC. Moreover, uneasiness and fatigue increased significantly after the task in the OC, while liveliness decreased significantly. Participants stated after the experiment that 'the FC made me feel relaxed because I could hear birds singing,' 'the FC made me feel relaxed because I felt like I was in a forest,' and 'the OC made me feel tired because I could hear sounds of work being done around me in the office. These results suggest that FC reduces stress and fatigue after the task compared to OC. FC can satisfy the being away and extent properties of the attention restoration theory [12]. In the attention restoration theory, the suitability of an environment for recovery from mental fatigue is determined by four characteristics: being away, extent, fascination, and compatibility. Being away refers to the feeling of being away from everyday events, extent refers to the openness of the environment itself and the number of elements in the environment, fascination refers to the inclusion of things that generate involuntary attention, and compatibility refers to the appropriateness of the environment for the purposes and actions of the users. Kaplan et al. stated that nature contains many of these characteristics and can be expected to restore mental fatigue [12]. Participants stated that 'OC is similar to the sounds that I often hear when I perform my usual work' and 'OC feel like when I am in the laboratory.' It is highly likely that FC fulfilled the 'being away' characteristics because participants felt that OC was closer to their daily tasks and FC was further away from their daily tasks. In addition, participants stated that 'FC gave me a feeling of openness as if I was in a forest because I could hear birds singing,' satisfying the extent characteristics. In contrast, participants stated, 'OC feel like being in a laboratory' and 'were close to the sounds they were used to hearing,' which may have been contrary to the being away characteristic. All participants in this study were college students, and they often viewed OC as a laboratory-like

environment. Therefore, OC is likely influenced by the organization to which the participant belongs.

5   Conclusion

This study investigated the effects of background sounds on workers' stress by presenting participants with two background sounds: FC and OC. The subjective evaluation results suggested that stress after work was decreased with FC than with OC. In addition, many participants reported feeling more relaxed with FC than with OC. For this reason, it is likely to be effective to play forest sounds when working within a virtual environment.

In this study, the number of participants was small, which may have resulted in large individual differences. Hyunju et al. stated that the Type A and Type B groups experienced different psychological effects from forest-derived auditory stimulation [13]. Therefore, future studies should increase the number of participants while considering individual characteristics.

In this study, wind and tweeting birds were used as FC. However, other sounds can also suggest forest. For instance, Pheasant et al. [14] state that a tranquil environment, such as the sound of water, reduces stress. Therefore, combining various forest sounds is highly likely to further reduce stress.

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