Psychological and Physiological Effects of Japanese Cedar Indoors after Calculation Task Performance

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Abstract

In Japan, forest resources have not been used effectively, and much lumber from thinning has been left unused for a long time. These days, forest improvement has been reconsidered such that more wood will be used in public buildings and living spaces in Japan. Moreover, the arousing and/or sedative effects of wood extract fragrances have attracted increasing attention. We investigated the psychological and physiological effects of cedar's appearance and emissions in an indoor environment. Three test rooms varied in cedar cues: Room 1 contained cedar paneling, which provided both visual and odor cues; Room 2 had air circulating from the adjoining Room 1 (i.e., odor cues only); and the detached Control Room had no cedar-related cues. Twelve subjects (six males and six females) moved to the test room after they performed simple calculations for 15 minutes in an anteroom and stayed there for 10 minutes. Odor intensity in Room 1 was rated significantly higher than that of either Room 2 or the Control Room. Cedrol and β -eudesmol were specifically detected in Rooms 1 and 2 through an indoor air quality analysis. The subjects reported a faster rate of fatigue perception reduction in Room 1 via a visual analog scale (VAS). No between-subjects differences were detected in terms of physiological responses. The results indicate that an interior room that contains Japanese cedar facilitates psychological rehabilitation and supports well-being.

Keywords: Indoor air quality, Japanese cedar, Fatigue perception, Psychological response, Physiological response

Introduction

In Japan, forest resources have not been used effectively, and much of the lumber produced from forest thinning is left unused for long periods of time (Matsumura et al. 2013). Recently, the Ministry of Agriculture, Forestry, and Fisheries and the Ministry of the Environment recommended that this lumber be used in public buildings (Kato 2004; Kawaguchi et al. 2003). This is possibly representative of the recent attention paid to the humidity adjustment performance of wood. *Shoso-in* (the *Azekura-zukuri* style of architecture) in Nara, Japan, has protected items from the elements for many years. In addition, Chinese-style chests, which are wooden boxes used to store valuables, are effective due to the wood's excellent moisture absorption and distribution capacities (Haishi and

Norimoto 1997). Some studies have reported that cedar and cypress have cold-reduction abilities. Primary school occupants reported feeling less cold after interior work was completed with solid Japanese cedar and cypress (Fukushima 2002). Cedar has lower thermal conductivity than concrete (Ohara and Furusawa 1967), which may account for the increased perceptions of warmth. Furthermore, the atmospheres in schools using cedar appear to be calmer than those in the schools using reinforced concrete (Hattori et al. 1995). Therefore, a calm atmosphere is one possible feature of a wooden building.

There has also been much research into the arousal and/or sedative effects of fragrances from extracts of specific wood ingredients (Gohara and Iwashita 2001; Kim et al. 2000). Fragrance mixtures found in several

wood extracts, such as limonene and α -pinene, were shown to have inhibitory effects on the sympathetic nervous system, which can decrease feelings of fatigue (Hanawa et al. 2008). In a study investigating the effects of cedrol on sleep using polysomnography (Yamamoto et al. 2003), cedrol inhibited sympathetic nervous system activity excitement, perhaps enhancing the participants' abilities to fall asleep. In addition, the inhalation of air containing Volatile Organic Compounds (VOCs) emitted from Japanese cedar interior walls suppressed the increase in salivary α -amylase activity (sAA) and chromogranin A secretion (Matsubara and Kawai 2014). Although research investigating the effects of fragrant wood panels or structural elements in rooms has increased (Kimura et al. 2011b), the psychological and physiological effects have not been thoroughly documented.

In this study, we prepared three test rooms to investigate the effects of Japanese cedar (including the extracts used in fragrance studies) on fatigue recovery and stress (Gohara and Iwashita 2001) since cedar is one of the woods associated with an atmosphere of calmness in wooden houses (Hattori et al. 1995). This study investigated the psychological and physiological reactions to Japanese cedar's presence and emissions following a calculation task in an indoor environment. Cedar, whose fragrance is sweet and slightly acidic, is coniferous and is one of the most common trees found in Japanese forests (Okana et al. 2005). Because it is used to make pillars, structural plywood, structural glued laminated timber, flooring, and furniture, it is very familiar throughout Japanese architecture.

Method

Subjects

Twelve healthy university undergraduate and graduate students (six males and six females) participated in this study. Table 1 shows the subjects' characteristics. We included individuals without symptoms of sick house syndrome, who had no history of becoming ill due to the smell of building materials, who were not currently being treated for allergies or asthma, and who were non-smokers.

All subjects were instructed to abstain from alcoholic beverages and garlic or other spicy foods. They were also told not to use perfume or any scented hair products for the day before and the day of the

experiment. Each subject participated in all three conditions on the day of the experiment.

They received information about the experiment before agreeing to take part. This study was approved by the Ethics Committee of Kinki University Faculty of Medicine (23-050) and was performed according to the guidelines of the Declaration of Helsinki (1975). All subjects provided written informed consent during the completion of an introductory questionnaire and received a monetary stipend in return for their participation. The study data was conducted from November to December 2011.

Test rooms

We used an anteroom and three test rooms in this study. The test rooms were located across a corridor from the anteroom, where the subjects performed calculations before visiting the test rooms. The test rooms were partitioned to create four rooms ($5075 \times 3630 \times 2555$ mm), and three of the four spaces were used. Figure 1 shows the physical layout. In Room 1, one wall was covered with Japanese cedar, which was visible to the subjects. In Room 2, which was connected to Room 1, the subjects were exposed to the olfactory emissions from the cedar but were not able to see it. In Room 3, there was no circulation of air available from the previous two rooms, nor were the subjects able to see the cedar.

To maximize odor cues, slits were cut into dried (45°C) cedar panels ($2520 \text{ mm} \times 2880 \text{ mm}$, see Fig. 2) collected from 70-year-old trees from the Kumamoto prefecture before the panels were installed in Room 1.

The following conditions were maintained throughout the experiment for all test rooms and the anteroom: operative temperature: 23°C ; relative humidity: 40-50%; outdoor air supply rate: 10 L/s per person, corresponding to an air change rate of 1.1 h^{-1} ; sound level: $<40 \text{ dB (A)}$; and desk surface illumination: 750 lx in the anteroom and 500 lx in the test rooms. The air conditioning was adjusted by a ceiling-embedded air-conditioner, heat exchangers, and a floor humidifier.

Measurements

Environmental measurements.

Temperature and humidity were measured continuously at the central point of the anteroom and adjacent

Table 1. Subjects' characteristics

Characteristic (mean $\pm$ SD)	All ($N = 12$)	Male ($n = 6$)	Female ($n = 6$)
Age ^a	20–35/23.3 $\pm$ 4.0 years	20–35/23.3 $\pm$ 5.3 years	21–27/23.2 $\pm$ 2.0 years
Height	162.0 $\pm$ 7.5 cm	165.6 $\pm$ 3.2 cm	158.4 $\pm$ 8.8 cm
Weight	55.1 $\pm$ 8.7 kg	60.8 $\pm$ 5.0 kg	49.4 $\pm$ 7.8 kg

^aIncludes range of ages

Fig. 1. Plan of experiment rooms.

Fig. 2. Slits in the cedar panel.

to the test room subjects' positions (height: 900 mm) using small temperature-humidity recording devices (TR-72Ui: T & D CORPORATION, Nagano, Japan). Sound level and desk surface illumination were confirmed before and after the experiment by a sound level instrument (SL-1320: CUSTOM Corporation, Tokyo, Japan) and an illuminometer (LX-1000: CUSTOM Corporation, Tokyo, Japan).

Indoor and outdoor air quality were investigated at the experimental midpoint. Air was sampled from the middle of Rooms 1 and 2, the Control Room, and the outdoors. Formaldehyde and acetaldehyde were collected for 24 h using a passive DNPH sampling method and were measured with a High Performance Liquid Chromatography (HPLC) analyzer. VOCs were collected for 24 h using a passive VOC-SD sampling method and were measured by a Gas Chromatography/Mass Spectrometry (GC/MS) analyzer. Moreover, terpenoid was actively collected for 30 min (0.1 L/min) and was measured by a Gas Chromatography/Mass Spectrometry (GC/MS) analyzer.

Subjective measurements.

A visual analog scale (VAS), proposed by the Japanese Society of Fatigue Science (Hirayama 2009), was used to record fatigue perceptions (Fig. 3), which were defined as realizations of discomfort and decreases in activity, as well as lassitude or tiredness. Before the experiment, the experimenter explained the definition of fatigue perceptions used in this study questionnaire.

The subjects evaluated indoor odor intensity on a six-point scale, from 0 = *No odor* to 5 = *Very strong odor*. They evaluated feelings

Fig. 3. VAS used to assess fatigue perceptions.

of unpleasantness-pleasantness related to odor on a nine-point scale, from -4 = *Extremely unpleasant* to +4 = *Extremely pleasant*. The Architectural Institute of Japan has used these scales as a standardized measure of odor evaluation (Architectural Institute of Japan 2010). Furthermore, the subjects evaluated feelings of calmness-not calmness, familiarity-unfamiliarity, and air quality with VAS.

Physiological measurements.

Blood pressure, heart rate, and salivary alpha-amylase (sAA) exhibit circadian rhythms (Atkinson and Reilly 1996; Jenzano et al. 1987; Parkkila et al. 1995; Vandewalle et al. 2007); therefore, the subjects began the experiment at the same time on the same day of the week for each condition. Because mentality and secretion of saliva can change during the menstrual cycle (De Marchi 1976), the female subjects participated in this experiment as much as possible in the hypothermic phase.

Stress and emotional reactions are generally known to stimulate the sympathetic nervous system and act on heart rate and blood pressure. In this study, heart rate was recorded (RS800CX: Polar Japan, Tokyo, Japan). The high frequency (HF) component of the heart rate change sequential power spectrum was used as an index of the parasympathetic nervous system, and the low frequency (LF)/HF percentage was used as an index of sympathetic nervous system activity (Akselrod et al. 1981). We calculated both HF and LF in this study. Furthermore, sAA was measured by enzyme analysis equipment using a saliva amylase monitor (NIPRO, Osaka, Japan) (Takai et al. 2004; Yamaguchi et al. 2004).

Experimental procedure

The study protocol is shown in Figure 4. First, the physical condition of the subjects and the initial subjective and physiological measurements were assessed in the anteroom. Next, the subjects were asked to perform a calculation task, which consisted of adding digits one by one for two 15-minute sessions with a 5-minute rest period between them. After the task, the subjective and physiological measurements were assessed again in the anteroom. The subjects then moved to a test room opposite the anteroom and stayed seated there for 10 minutes. Subjective and physiological measurements were made at both the beginning and end of the test

Fig. 4. Study protocol.

room phase.

The presentation order for the experimental conditions (Room 1, Room 2, and the Control Room) was randomized by subject. Each subject participated in one experimental condition per day, once a week, for a total of three times. The subjects participated in an experimental session every week at the same time on the same day. The experiment was carried out with up to three people at a time, but the subjects who were in the same conditions did not participate at the same times.

Data analysis

The results of the subjective and physiological measurements taken before the experiment in the ante-room were examined using a one-way ANOVA. The results of the fatigue perception and physiological measurements after the task and at 0 and 10 minutes in the test rooms were examined by a two-way ANOVA after homoscedasticity was confirmed. If the interaction was confirmed to be significant, Tukey's HSD test was carried out. Differences in odor intensity with respect to pain-pleasure were examined by Bonferroni-adjusted matched-pair Wilcoxon tests. Differences in VAS scores with respect to room atmosphere were examined by a one-way ANOVA. All analyses were performed with SPSS Statistics 22 software (IBM Japan, Tokyo, Japan). The level of significance was set at $p < .10$.

Results

Environmental measurements

Table 2 shows the results for the environmental measurements. The temperature and humidity (high = 900 mm) were kept at the same level for all the rooms. The sound level did not exceed 40 dB, which was the lower limit of sound level measurement range used. The mean illumination of the desk surface was 818 lx in the ante-room where the subjects performed the calculation tasks. There were no differences relating to the

positions of the subjects in the ante-room. The mean illumination was kept at the same level for all three test rooms (517-536 lx.)

Table 3 shows the results of the indoor air quality assessment. We examined it for Formaldehyde, Acetaldehyde, 35 kinds of VOCs, 13 kinds of terpenoid, and we show only one ingredient detected under each condition in Table 3. s-(s)-Limonene, terpinolene, Cedrol, and β -Eudesmol were detected as expected in Rooms 1 and 2, but very little was detected in the Control Room.

Subjective measurements

Table 4 shows the results of the ante-room pre-experiment subjective and physiological measurements. The mean fatigue perception VAS scores ranged from 37 to 47 before the experiment, and there were no significant differences between the rooms.

Figure 5 shows fatigue perception by VAS after the ante-room task and at 0 and 10 minutes in the test rooms. The VAS mean fatigue perception score was 67 after the task. It decreased to 43 in Room 1, 57 in Room 2, and 58 in the Control Room after 10 minutes. There were significant main effects of time ($F(2, 99) = 19.22$, $p < 0.001$) and room ($F(2, 99) = 4.22$, $p < 0.05$), and a marginally significant difference was found in the time $\times$ room interaction ($F(4, 99) = 2.11$, $p < 0.10$). Fatigue perception decreased to a marginally significant extent from post-task to 0 minutes in Room 1 and the Control Room ($p < 0.10$) and from post-task to 10 minutes in the Control Room ($p < 0.10$). It decreased significantly from post-task to 10 minutes in Rooms 1 and 2 ($p < 0.001$ and $p < 0.01$, respectively) and from 0 minutes to 10 minutes in Room 1 ($p < 0.01$). In addition, fatigue perception was rated significantly lower in Room 1 than in either Room 2 or the Control Room at 10 minutes ($p < 0.05$).

Fig. 6 shows a box plot of odor intensity and pain-pleasure in the test rooms. In Figure 6a, the median odor intensity at 0 minutes was "Easily noticeable odor" for 3 in Room 1, "Faint odor" for 2 in Room 2, and "Very faint odor" for 1 in the Control Room, and this measurement decreased over time for all rooms. It was significantly higher in Room 1 than in either Room 2 or the Control Room at 0 minutes as assessed by the Wilcoxon matched-pairs signed-rank test with Bonferroni correction ($p < 0.05$).

Table 2. Results of environmental measurements.

Variable mean $\pm$ SD	Anteroom	Test room		
		Room 1	Room 2	Control
Temperature ($^{\circ}\text{C}$)	22.4 $\pm$ 1.3	23.2 $\pm$ 1.2	23.4 $\pm$ 1.3	22.7 $\pm$ 1.5
Relative humidity (%)	48 $\pm$ 7	44 $\pm$ 6	44 $\pm$ 6	45 $\pm$ 6
Sound level (dB (A))	< 40	< 40	< 40	< 40
Illumination (lx)	818 $\pm$ 23	517 $\pm$ 9	535 $\pm$ 66	536 $\pm$ 9

Table 3. Results of indoor air quality.

Formaldehyde, Acetaldehyde

Sampling: Active method, 0.1 L/min $\times$ 24 h, Analysis: HPLC

($\mu\text{g}/\text{m}^3$)	Room 1, 2	Control Room	Outdoor
Formaldehyde	11.9	9.9	2.7
Acetaldehyde	13.1	14.2	5.4

VOCs

Sampling: Passive method, 24 h, Analysis: GC-MS / HPLC

($\mu\text{g}/\text{m}^3$)	Room 1, 2	Control Room	Outdoor
Aliphatic hydrocarbons	12.4	13.3	8.4
Aromatic hydrocarbons	17.6	18.3	17.4
Terpenes	4.5	4.4	4.4
Halogens	10.9	15.9	15.6
Esters	3.5	3.0	1.9
Aldehydes, Ketones	10.5	10.8	5.2

Terpenoid

Sampling: Active method, 0.1 L/min $\times$ 30 min, Analysis: GC-MS

($\mu\text{g}/\text{m}^3$)	Room 1, 2	Control Room	Outdoor
α -pinene	0.99	0.82	0.25
Camphene	0.08	0.07	0.01
3-Carene	0.01	ND	ND
s-(s)-Limonene	0.26	0.06	ND
Terpinolene	0.13	ND	ND
Camphor	0.51	0.49	0.22
1-Bornylalcohol	0.15	0.13	0.13
Cedrol	0.94	0.02	0.19
β -Eudesmol	0.69	ND	ND

Air was sampled in the middle of the experimental session.

Fig. 5. Fatigue perceptions by VAS.

Values shown are mean $\pm$ SEM of fatigue perceptions by VAS.Two-way ANOVA: Room: $p < 0.05$, Time: $p < 0.001$, Room $\times$ Time: $p < 0.1$ Simple main effects according to Tukey's HSD test: Room: * $p < 0.05$, Time: + $p < 0.1$, ++ $p < 0.01$, +++ $p < 0.001$

As shown in Figure 6b, the median pain-pleasure at 0 minutes for odor was "Pleasant" for +2 in Room 1 and "Neither" for 0 in both Room 2 and the Control Room. This measure decreased over time in Room 1 only. The differences between Rooms 1 and 2 and the Control Room were marginally significant, as measured by the Room 1-Room 2 Wilcoxon matched-pairs signed-rank test with Bonferroni correction ($p < 0.10$).

Figure 7 shows the results of the room atmosphere evaluation by the VAS. The "calm – not calm" value was higher in Room 1 (mean = 65) than in either Room 2 (mean = 63) or the Control Room (mean = 57). The "familiar – unfamiliar" value was higher in Room 1 (mean = 66) than in either Room 2 (mean = 60) or the Control Room (mean = 57). However, none of these differences was significant.

The mean heart rate was 75–79 bpm across all cases before the experiment (see Table 4). Autonomic nervous activity was analyzed by both the low frequency (LF: 0.04–0.15 Hz) and high frequency (HF: 0.15–0.4 Hz) components. The HF mean was 544–758 msec², and the LF/HF mean was 168–206% before the experiment for all cases. There were no significant differences in subjects' heart rates between rooms. Figure 8 shows the heart rate measurement results.

The mean heart rate across all test rooms was 74–78 bpm during the task, and it decreased to 71–75 bpm at 0–10 minutes. HF and LF/HF slightly increased after the task for all the rooms. However, none of these differences was significant.

The pre-task mean sAA across all test rooms was 48–58 KIU/L. There were no significant differences between rooms (see Table 4). Figure 9 shows the results of the sAA from after the task in the anteroom to after 10 minutes in the test rooms. The sAA mean across all test rooms was 47–61 KIU/L after the task. It decreased to 36 KIU/L in Room 1 and 48 KIU/L in the Control Room after 10 minutes in the test rooms. It was almost unchanged (66 KIU/L at 10 minutes) in Room 2. However, none of these differences was significant.

Discussion

Concerning indoor air quality assessment, s-(s)-Limonene, terpinolene, Cedrol, and β -Eudesmol were

Table 4. Results of subjective and physiological measurements taken before the experiment in the anteroom.

Variable (mean $\pm$ SEM)		Room 1	Room 2	Control Room
Subjective measurements	Fatigue perceptions by VAS (mm)	37 $\pm$ 6	47 $\pm$ 4	43 $\pm$ 6
	(bpm)	78 $\pm$ 3	75 $\pm$ 3	79 $\pm$ 3
Physiological measurements	Heart HF (msec ²)	758 $\pm$ 145	544 $\pm$ 79	552 $\pm$ 126
	LF/HF (%)	206 $\pm$ 46	168 $\pm$ 40	172 $\pm$ 41
	sAA activity (KIU/L)	49 $\pm$ 10	58 $\pm$ 12	48 $\pm$ 9

Mean heart rate was calculated 10 minutes before the task and was analyzed by both low frequency (LF: 0.04–0.15 Hz) and high frequency (HF: 0.15–0.4 Hz) components.

Fig. 6. Box plot of odor intensity and pain-pleasure in the test rooms.

The values shown are the median, lower quartile, upper quartile, maximum, and minimum values for odor intensity and pain-pleasure. The measurements were made at 0 and 10 minutes in the test rooms. Wilcoxon signed rank test (Bonferroni correction): † $p < .10$, * $p < .05$.

Fig. 7. Evaluation of room atmosphere on the VAS.

Values shown are mean ± SEM of room atmosphere by VAS.

Fig. 8. Results of heart rate, and HF and LF/HF by R-R interval measurements.

Values shown are mean ± SEM.

Two-way ANOVA: Room: n.s., Time: n.s., Room × Time: n.s.

detected as expected in Rooms 1 and 2 (Table 3). These were not detected in either the Control Room or the outdoors, and it is thought that the presence of cedar was responsible. However, we analyzed 13 kinds of terpenoids in this study, and we did not analyze it regarding sesquiterpenes, except Cedrol and β -Eudesmol. We will include more sesquiterpenes as analysis objects in the future, in addition to arresting the characteristic of the radiation material from cedar innocence materials.

Stress and emotional reactions stimulate the sympathetic nervous system and act on the heart rate. Our results indicate that the subjects' heart rates gradually decreased after entering the test rooms, but there were

no significant differences over the 10 minutes spent in the test rooms (Fig. 8). The HF's in Rooms 1 and 2 were slightly higher than those of the Control Room. Calm feelings and parasympathetic nerve activity were expected to increase, but there were no significant differences in the HF's and LF/HF's. Individual variability was also evident.

Salivary stress markers are useful for evaluating stress conditions in a noninvasive and simplified manner (Kirschbaum and Hellhammer 1994). Saliva amylase is controlled by the sympathetic nervous-adrenal medullary system (Speirs et al. 1974). In addition, because saliva amylase is also affected directly by

neurological events, it was expected to be a good index with which to assess presence of mind (Yamaguchi 2007). Furthermore, saliva amylase activity was reportedly increased by unpleasant stimulation (Takai et al. 2004). The sAA in Room 1 was lower than that in either Room 2 or the Control Room after 10 minutes, but no significant differences were found during the time spent in the test rooms (Fig. 9).

The cedar panel was not found to influence either heart rate or sAA. The interior wood influenced physiological responses (Tsunetsugu et al. 2007), and there were differences in saliva amylase activity changes by use of *hiba* (*thujopsis dolabrata*) for the interior construction (Kimura et al. 2011b). Furthermore, the VOCs emitted by Japanese cedar reportedly assisted in physiological relaxation under stressful conditions, similar to the LF/HF ratio in electrocardiogram recordings and salivary amylase activity (Okano et al. 2005).

On the other hand, there was no physiological effect comparable to the psychological effect in response to cedar. In the study that examined the influence of cedar consumption on sight stimulation and, as a result, work efficiency, there was a difference for the evaluation result of comfort and the atmosphere, but there was no difference in work efficiency and sAA (Kimura et al. 2011a). In the study that examined cedar's effect on olfactory stimulation, a difference appeared for the result of the profile of mood states before and after admission to the room in which was installed cedar panel covered by a curtain. The smell of cedar did not lead to changes in blood pressure, sAA, or cortisol (Azuma et al. 2010). Further examinations of the influence of interior wood on physiological responses, including the relationship between physiological responses and quantity of stimulus or type of wood, are necessary.

In the subjective measures analysis, fatigue perceptions were relieved more during the 10 minutes

spent in Room 1 than in either Room 2 or the Control Room (Fig. 5). The reason for this seems to be the influence of VOCs emitted from Japanese cedar in Room 1. Forest terpenes are known to relax the mind (Yatagai 2000). A mixed fragrance from several wood extracts, such as limonene and α -pinene, has been found to have sedative effects on the sympathetic nervous system (Hanawa et al. 2008), and cedrol has reportedly inhibited the excitement of sympathetic nervous system activity (Yamamoto et al. 2003). In this study, limonene and cedrol were detected characteristically in Room 1. The presence of these components in the indoor air is expected to improve recovery from fatigue perceptions. However, the psychological effect was large for Room 1, but it was not found in Room 2, which was next to Room 1 and received its circulated air.

In relation to this, the highest response to odor intensity was in Room 1, followed by Room 2, and then the Control Room. It was significantly higher in Room 1 than either Room 2 or the Control Room at 0 minutes (Fig. 6a), and it decreased over time because of olfactory adaptation. Furthermore, the median pleasant-unpleasant sensation for odor was higher in Room 1 than in either Room 2 or the Control Room just after entering (Fig. 6b). This was as expected due to the partition between Rooms 1 and 2, which influenced the sight, but not the odor, of the cedar panel. Air was exchanged between Rooms 1 and 2 by an air circulator, but there was still a difference in the odor intensity and pain-pleasure reported in Rooms 1 and 2. Distance differences between the panels were thought to influence the results.

In addition, some reports have suggested that sight information influences the evaluation of smell. The rate of correct odor evaluations was changed by displaying the fragrance and color combinations (Dematte et al. 2006). Thus, the visual identification of an adhesion solvent, although it does not emit odor, causes errors in odor reports (Engen 1972). Furthermore, subjects reportedly sense odor more strongly when the name of the sample smell has not been given than when it is given before sample smell introduction (Fujiwara et al. 2004). The subjects might have become sensitive to the odor in Room 1 because they were able to visually identify the cedar paneling.

The terpenoid, which has been shown to have sedative effects on the sympathetic nervous system, reportedly radiated from the cedar panel used in this experiment. Its influence on physiological responses was small in this study. Because the subjects reported a stronger cedar odor and were more comfortable in Room 1 than either Room 2 or the Control Room, cedar odor was believed to have greater psychological effects on Room 1's decreased fatigue perceptions. This is

Fig. 9. Salivary α -amylase activity.

Values shown are mean $\pm$ SEM of Salivary α -amylase activity (sAA). Two-way ANOVA: Room: n.s., Time: n.s., Room $\times$ Time: n.s.

supported by the report that VOCs emitted from Japanese cedar affected physiological relaxation (Matsubara and Kawai 2014) and that the smell of cedar affected psychological states (Azuma et al. 2010). In this study, because the differences between the reported room atmospheres were small (Fig. 7), we assumed that the fragrance's psychological effect was large, and it was thought that this study demonstrated synergy of sight and smell stimulation that led to the reduction of fatigue perceptions in this study.

However, most studies have not compared the effect size of comparisons of olfactory and visual stimulation, and we are not able to make any conclusive arguments concerning this issue as a result of this study alone. Therefore, future research is needed to assess this more thoroughly.

Conclusion

This study examined the influence of cedar paneling on psychological and physiological reactions following a calculation task. In Room 1, which had cedar paneling, perceived fatigue reduction was greater after 10 minutes than was perceived fatigue reduction in either Room 2, which shared circulated air with Room 1, or in the Control Room, which had neither the sight nor the odor of wood. In Room 1, the subjects reported a stronger odor, and Cedrol and β -eudesmol were detected in both Rooms 1 and 2. These results suggest cedar fragrance affects subjective fatigue perceptions. It is important to continue researching the physiological effects of interior wood, as well as the effects of only visual or olfactory stimulation.

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Declaration of competing interests

The authors declare that there are no conflicts of interest.

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