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Investigation variance in human psychological responses to wooden indoor environments

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A R T I C L E I N F O

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A B S T R A C T

Indoor environment is of tremendous importance in people's daily life since it is where almost two-thirds of their lifetime is spent. Current studies are mainly focused on steel concrete structured buildings, whereas very few are concerned with wooden ones. How wooden buildings benefit human beings is still not clear. The purpose of this study was to investigate the different psychological responses to both wooden and non-wooden indoor environments assessed by systematic and quantitative tests. Twenty participants' psychological responses were evaluated in a sixty-minute survey including the *Profile of Mood States* (POMS), the fatigue symptom checklist, and a subjective evaluation. The results demonstrated that more positive emotions were generated in wooden environments than in non-wooden environments during the entire experimental process. Additionally, fatigue evaluation values of wooden environments were dramatically lower than those of non-wooden environments after continuous working, which implied that the participants in wooden environments suffered from less fatigue. Compared to non-wooden rooms, wooden ones were considered as more comfortable environments, whose occupants enjoyed a more delightful sense of color, odor, and light.

1. Introduction

Modern lifestyle determines that people spend the majority of their time indoors. A large number of studies have demonstrated that indoor environment influences the health and well-being of occupants [1–7]. This makes it a high priority for building designers to create a healthy and comfortable indoor environment. A considerable number of studies have been conducted on non-wooden indoor environments concerning indoor environment quality (IEQ) [8–12], as well as its effects on workers' performance [13–15], physiological [16–21] and psychological responses [22–27]. Studies on wooden indoor environments on the other hand, are still scarce.

It is well acknowledged that a natural environment is beneficial to health and helpful for stress release due to its restorative quality [28,29]. Wood, as a sustainable building material manufactured by nature, with low embodied energy, developed a good reputation in terms of impact on the environment [30,31], also has some positive effects on human being [32–34]. The study by L Tyrväinen [35] investigated seventy-seven participants who visited three typical types of urban natural environments: a built-up city center, an urban park, and urban woodland. Results showed that extensively managed urban woodland and large parks have almost the same positive influence on the human psychological state. Indeed, using wood for interior design in indoor environments has been shown to have a positive impact on occupants, especially in relation to indicators of human stress [36,37]. However, previous studies were mainly focused on the research of outdoor wooden environments or wood productions' visual stimulation indoors [38–41]. AQ Nyrud and T Bringslimark [42] proposed that psychological responses toward interior wood production use have generally followed three different outcomes: (1) perception of wood, including visual perception; (2) attitudes and preferences toward wooden products; and (3) psycho-physiological responses toward wood. They also found that there seemed to be similarities in preferences for wood, and that people preferred wood because it is natural. Satoshi Sakuragawa [43] examined the effects of contact with wood on the living human body using subjective evaluation and found that contact with wood produced natural sensations. Moreover, he did another comparative study on the effect of visual stimulation of

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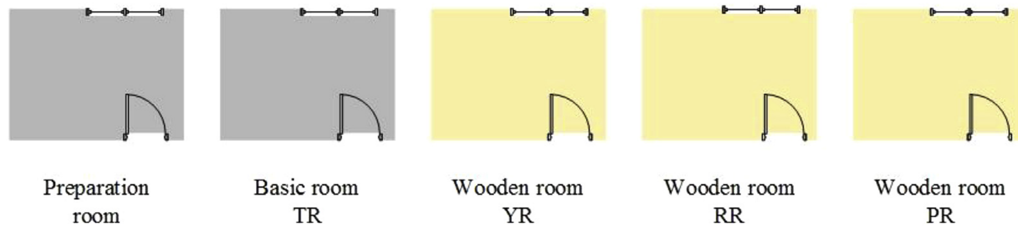

Fig. 1. Layout of five rooms.

wood on the body using full-sized hinoki wall panels and a white steel wall panel. The results indicated that visual stimulation from the white steel wall panel gave an unhealthy impression and a sense of depression. Results also showed that visual stimulation from wood panel and white steel wall panels had different psychological effects [44]. Similar results were reported in studies by Masuda M [45], where he investigated the correlation between an image of wood and its color by using sixteen groups of specimens. He concluded that red and yellow colors have a stronger reflection of Infrared (IR), which leads to a warmer feeling when people view wood productions.

In summary, studies examining psychological responses to wooden indoor environment can still be enhanced. The main purpose of the present paper is to compare the psychological responses during exposure in wooden and non-wooden indoor environments. Additionally, this study also aims to give a comprehensive and systematic investigation of psychological responses including emotion, fatigue, and subjective feeling in these two style environments.

2. Methodologies

2.1. Experimental conditions

This experiment was carried out in December of 2015, Suzhou, China. During the experiment period, outdoor maximum temperature was 10 °C, minimum temperature was 1 °C, the outdoor humidity range was from 40% to 70% and daily average solar radiation intensity was around 300–400 (W/m^2). In order to simulate the office environment, five rooms with identical size ($L \times W \times H = 3.8$ m $\times$ 3.2 m $\times$ 2.8 m) were established, one preparation room, one basic room and three wooden rooms. The layout of these five rooms were located in an open ground and there is no shelter from other buildings or plants around them (Fig. 1). The envelop of the preparation and basic rooms were all steel concrete structure, the interior walls have been painted white. In contrast, the envelop of the other three wooden rooms was wooden frame and interior wood walls were completely exposed (Fig. 2). All rooms used the same system of central air conditioning to control indoor temperature, the same insulation and impermeable materials were used inside the wall. The details of experimental rooms can be seen in Table 1. There was no decoration except a working table, a chair, and a laptop used for working tests (Fig. 3). Windows were opened for thorough ventilation during each experiment interval, minimizing the adverse influence on the next participant.

2.2. Participants

Referring to the psychological parameter study, the software G*Power analysis was applied to determine the required range for the number of participants [46,47], the minimum number of subjects were required 11 persons to ensure a balanced design. Finally, 20 persons were recruited to participated in this experiment, including 10 males and ten females. They were all healthy adults around twenty-six years old and their BMI lay in the normal range ($18.5 \leq$ BMI ≤ 24.5) [48], excluding cardiovascular disease, skin disease, blindness, rhinitis, and women in the menstrual period (Table 2). Furthermore, sufficient information about the procedure was given to the participants in order to eliminate the negative impact that resulted from unfamiliarity with the experiment. All participants completed the full test successfully.

2.3. Experimental arrangement and procedure

The experiment was performed in December 2015. Within-subjective design and completely balanced experimental design were applied for this experiment. Twenty participants were

Fig. 2. The pattern of the interior wood wall.

Table 1
Information of five experimental rooms.

Rooms	Code	Room envelop	Interior wall	Physical indoor environment
Preparation room		Non-wooden (steel concrete)	100% painted white	T: 22–24 °C
Basic room	TR			RH: 30%–40%
Comparison rooms	YR	Wooden	100% dark brown wood	500lx
	RR		50% light brown wood 50% painted white	
	PR		100% light brown wood	

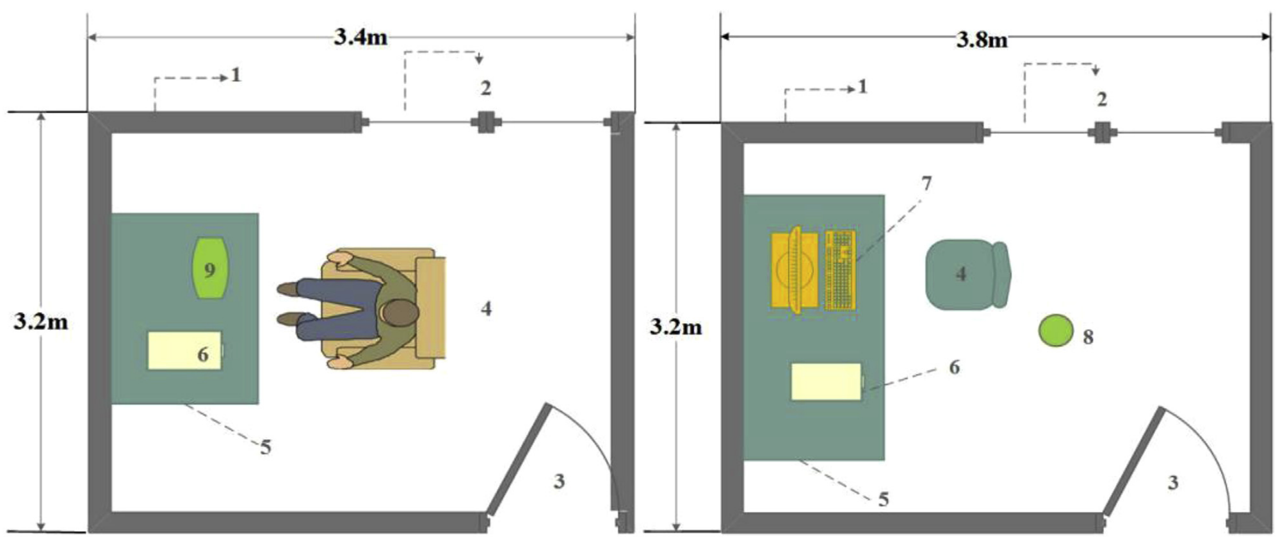

Fig. 3. Experimental set-up in room: (1) maintenance wall (2) shutters (3) entrance door (4) working chair (5) working desk (6) questionnaires (7) personal computer (8) thermal environment monitoring point (9) eye-patch.

divided into four groups (Table 3). Each group included five people with randomly selected gender. In order to avoid the order effect, the Latin method was adopted to arrange the group sequence.

Each experiment lasted seventy minutes (Fig. 4). Firstly, every participant completed emotion and fatigue questionnaires in the preparation room in order to provide the initial values. Secondly, the experimenter led the participant, who was required to put on the eye-patch, into the experimental rooms. All the participants were required to take two minutes of rest for stability before taking off the eye-patch. Finally, the participants started to feel the surrounding environment and filled out a series of experimental forms.

During the experiment, POMS and fatigue were investigated at the 10th (Time 1) and 55th (Time 2) minute while subjective evaluation was carried out at the 5th (Time 3) and 52nd (Time 4) minute, either of which was before or after the two working task phases (15th–30th minute, 35th–50th minute).

2.4. Measurements

The measurements of psychological investigation in this study included emotion, fatigue, thermal sensation (TSV), thermal comfort (TC), color sensation & comfort, odor sensation & comfort, and lighting sensation & comfort. Specific methods were introduced as follows:

2.4.1. POMS

Personal emotional state self-rating POMS questionnaire was used for subjective emotional survey [49], which included sixty-five options describing subjective feelings. They can be summarized into six categories: five negative categories named "Tension," "Depression," "Anger," "Fatigue," "Confusion," and a positive category named "Vigor." In this experiment, subjects were required to score each option from 0 (not at all) to 5 (very much) according to their feelings. TMD (Total mood disturbance), which is defined as the total POMS score and the TMD was calculated according to the following equation. It shows a greater negative emotion with a higher TMD value.

$$\begin{aligned} TMD = {} & \text{The total score of negative emotion } (T + D + A + F + C) \\ & - \text{The score of positive emotion } (V) \end{aligned} \tag{1}$$

Table 2
Anthropometric data of the participants (Mean ± SD).

Gender	No.	Age (Years)	Height (cm)	Weight (Kg)	BMI (Kg/cm^2)
Male	10	26 ± 2	173.2 ± 4.2	66.6 ± 5.3	22.3 ± 1.8
Female	10	25 ± 3	162.8 ± 3.9	55.2 ± 5.9	20.8 ± 2.0
All	20	26 ± 3	168.0 ± 6.6	60.9 ± 8.0	21.5 ± 2.0

Table 3
Room order of each group.

Group 1	YR	TR	RR	PR
Group 2	TR	PR	YR	RR
Group 3	PR	RR	TR	YR
Group 4	RR	YR	PR	TR

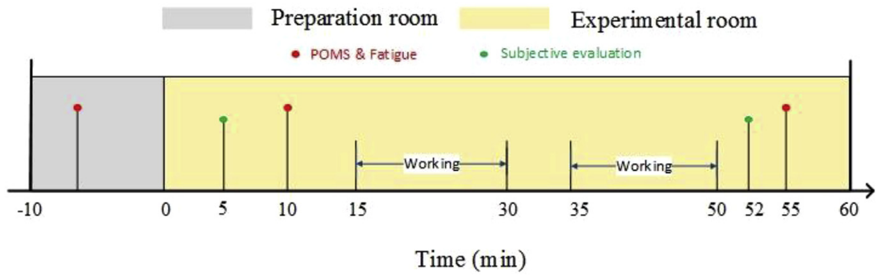

Fig. 4. Experimental procedure.

2.4.2. Fatigue ratings

Fatigue investigation was assessed using the Japanese subjective fatigue symptoms (2002 version) [50], which contains twenty-five symptoms. They are subdivided into five categories, the corresponding details of which are listed in Table 4. Participants answered each option on a 5-point scale varying from +1 (none) to +5 (extremely severe). The total score, which is proportional to the degree of fatigue, is the sum of all twenty-five options.

2.4.3. Subjective evaluation

Participants gave their subjective sense of warmth, color, odor, and lighting on continuous voting scales during the experiment. Meanwhile, the comfort level of the above four aspects was also evaluated in order to explore the differences in subjective feelings toward wooden and non-wooden environments, and the influence on comfort. A detailed description of the scale is shown in Fig. 5.

2.5. Statistical analysis

In this paper, the experimental data were analyzed using statistical software SPSS. All data were subject to normal distribution, and the paired samples *t*-test (*t*-test paired). When P value was less than 0.05, the results were considered to be significant.

3. Results and discussion

3.1. Results of POMS

The results of TMD score of the participants in four rooms are shown in Fig. 6, which indicate that there are significant differences between them, although all the participants had similar conditions during the initial values. The greater the value, indicating the greater proportion of negative emotions in the chart. The TMD score value in TR was higher than that in the three wooden rooms. More details were below:

After entering the rooms, the TMD scores in wooden rooms (YR, RR, and PR) were significantly lower than those of TR. These lower TMD scores indicated lower negative emotion generation, which demonstrated the better performance of wooden rooms. The same results appeared when participants completed two tasks after fifty minutes.

The recovery function effect was revealed from TMD variation. After entering the experimental rooms, two questionnaires were completed by participants at Time 1 and Time 2. By comparing the two surveys, it implied that negative emotions accumulated with the completion of a task in TR and that the TMD values (from −0.75 to 0.8) have an upward trend. However, an opposite trend was observed for YR (from −3.85 to −4.25). The declined TMD scores indicated a proportional decreased negative emotion. Therefore, it can be concluded that the negative emotion accumulation in wooden environment is less than that in non-wooden environment. Furthermore, YR shows the capability of after-work emotional recovery implied by the enlarged proportion of positive emotion.

Table 5 represents the *p* value of the TMD score under different conditions calculated by a paired *t*-test. Significant differences at both Time 1 ($p < 0.05$) and Time 2 were discovered between TR and the other three wooden environment rooms.

In order to explore the specific impact factors that dominate individual emotions in two environments, further analyses were conducted. Among the six options, three showed obvious differences through statistical analysis (Fig. 7). Participants were required to score each option from 0 (not at all) to 5 (very much) according to their feelings. In the negative items (depression and tension), the wooden rooms (YR, RR, PR) scored less than TR in Time 1. Moreover, almost no one showed a sense of depression in YR or PR, while participants in TR were more likely to feel tense and depressed. Additionally, the only positive item (vigor) scored less in TR than in the other three wooden rooms. PR showed the highest level of vigor and YR had an equivalent score to PR.

Fig. 8 illustrates that the significant differences for depression among the four rooms disappeared after finishing two tasks while those of vigor and tension remained. The bar chart reflects that the tension scores were higher for TR than for the other three wooden rooms, on average two times higher. In addition, the ratio of positive emotion (vigor) in wooden rooms was higher than that of TR.

A comparison of two time results in tension implied that TR had an upward trend (from 2.1 to 2.45) while YR (from 0.7 to 0.55) and

Table 4
The items of Japanese subjective fatigue symptoms (2002 version) [50].

Divided into five items					
	A. Drowsiness	B. Insecurity	C. Discomfort	D. Soreness	E. Fuzziness
1	Sleepy	Nervous	Feel headache	Arms ache	Hard to open eyes
2	Lie down and rest	Depressed	Feel heavy head	Waist aches	Feel eye fatigue
3	Yawn	Restless	Bad mood	Fingers ache	Feel eye pain
4	Lack of motivation	Quick temper	Mind wandering	Legs ache	Feel dry eyes
5	Feel weakness	Confusion	Feel dizzy	Shoulders ache	Blurred vision

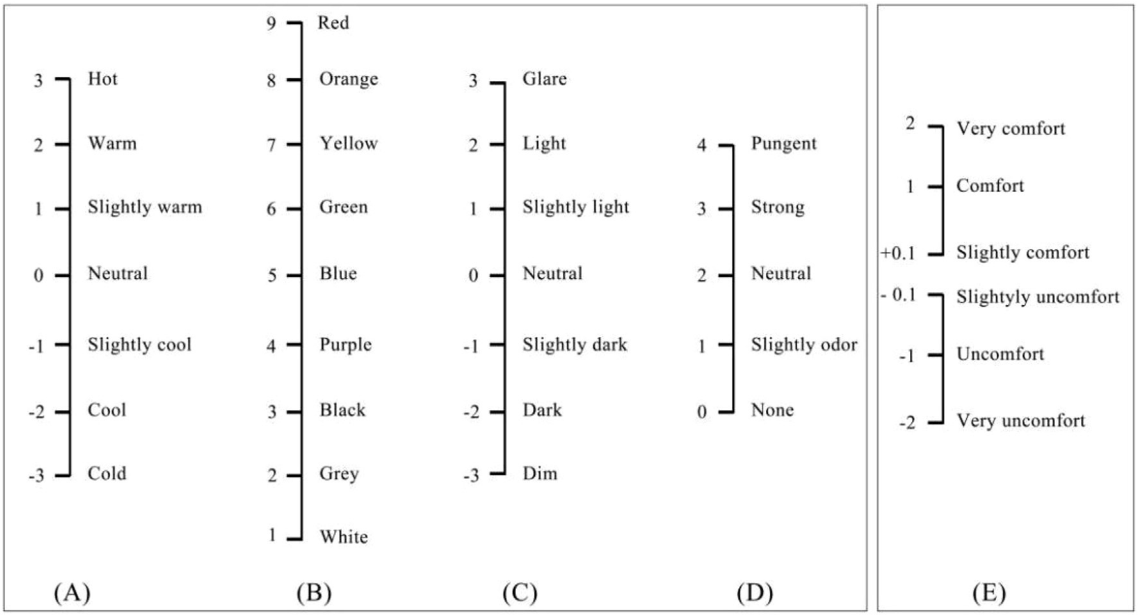

Fig. 5. Scales of multiple subjective responses:*A. thermal sensation B. color sensation C. lighting sensation D. odor sensation. E. comfort in thermal, color, lighting and odor.

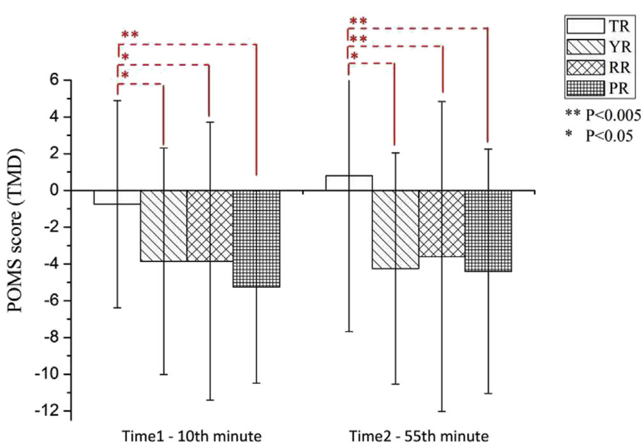

Fig. 6. Changes in TMD score for participants during the experiment.

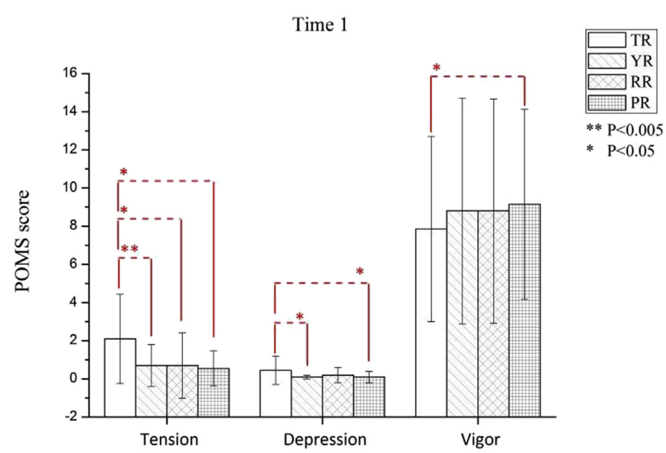

Fig. 7. The score of sub-item differences for participants at Time 1.

Table 5
P value of TMD score during the experiment in different rooms.

Times		TR - YR	TR - RR	TR - PR
Time 1	*P*	0.036*	0.024*	0.000**
Time 2		0.016*	0.001**	0.002**

RR (from 0.7 to 0.45) declined. With the passage of time, the wooden environment showed a tendency to alleviate or reduce the tension. Overall, non-wooden environment tended to produce the sense of tension and depression, resulting in a lower positive emotion. Wooden environments, on the other hand, were capable of regulating emotion, reducing the tension, and relieving negative emotions.

In addition, the POMS survey proved to be an efficient method for this kind of research since strong sensitivities resulting from environmental changes were observed. Differences in TMD score and the three sub-items of tension, depression, and vigor were particularly obvious. Table 6 represents the *p* value of sub-items under different conditions.

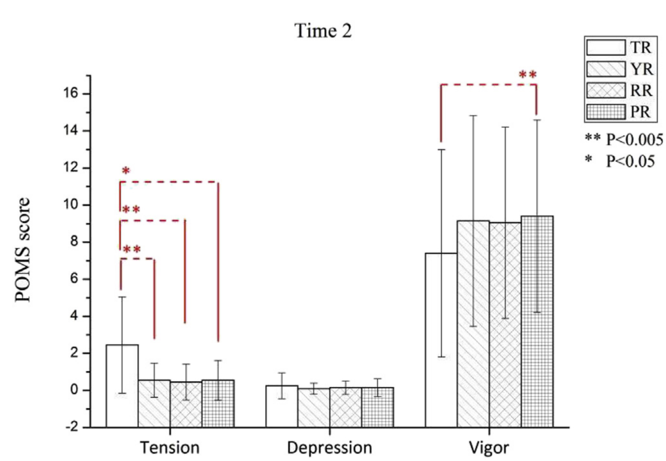

Fig. 8. The score of sub-item differences for participants at Time 2.

Table 6
P value of sub-items' score during the experiment in different rooms.

Times	Items		TR - YR	TR - RR	TR - PR
Time 1	Tension	*P*	0.003**	0.046*	0.009*
	Depression		0.016*	0.135	0.031*
	Vigor		0.304	0.234	0.044*
Time 2	Tension		0.002**	0.002**	0.008*
	Depression		0.379	0.577	0.606
	Vigor		0.081	0.051	0.003**

3.2. Results of fatigue

The results of fatigue symptom evaluation in different rooms were statistically analyzed, and are shown in Fig. 9. The comprehensive score is proportional to the degree of fatigue, which include twenty-five options. Participants answered each option on a 5-point scale varying from +1 (none) to +5 (extremely severe). The higher the fatigue value represents the stronger sense of fatigue. Specific analysis is as follows:

During the adaptation phase (Time 1), the mean value for the twenty participants in the wooden and non-wooden environments did not show a significant difference. TR was slightly higher than YR, RR, and PR. At Time 2, however, pronounced differences between the wooden and non-wooden environments appeared regardless of the simultaneously increased mean values in the four rooms. Table 7 shows the *p* value for fatigue score under different conditions.

Further investigation of fatigue sub-items (Table 4), clear differences in A1-Sleepy, A3-Yawn, E5-Blurred vision, and E2-Feel eye fatigue between rooms were observed. Each items scale also varying from +1 (none) to +5 (extremely severe). These four sub-items' ranges were from 0 to 2 at Time1 and from 0 to 3 at Time2. Fig. 10 shows that on average participants in wooden environments scored lower in A3-Yawn, E5-Blurred vision and E2-Feel eye fatigue than those in TR. The significant difference between the rooms occurred for the symptom "Sleepy," where TR was significantly higher than YR ($p < 0.05$) and PR ($p < 0.005$).

Fig. 11 illustrates the changes of the four symptoms above, within the four rooms, after fifty minutes. Mean values in wooden rooms were still lower than those in non-wooden ones, especially for the symptoms A3-Yawn, E5-Blurred vision, and E2-Feel eye fatigue.

Table 8 displays the *p* values of four fatigue items under different conditions. The significant differences were discovered between

Table 7
P value of Fatigue score during the experiment in different rooms.

Times		TR – YR	TR - RR	TR - PR
Time 1	*P*	0.202	0.385	0.163
Time 2		0.001**	0.007*	0.006*

Note: *P < 0.05, **P < 0.005.

TR-YR ($p = 0.031$) and TR-PR ($p = 0.004$) at Time 1. At Time 2, the effect on A3-Yawn and E5-Blurred vision was significant among the four rooms ($p < 0.005$), while E2-Feel eye fatigue was also significantly different between TR-YR ($p = 0.038$) and TR-PR ($p = 0.038$).

It can be concluded that wooden environments tend to produce a lesser fatigue feeling than non-wooden environment, especially after working. Additionally, the fatigue self-assessment proved to be an efficient method for exploring the differences between rooms and has the sensitivity of the yawn, blurred vision, feel eye fatigue and sleepy symptoms.

3.3. Results of subjective evaluation

3.3.1. Thermal sensation and comfort

The results of thermal sensation and thermal comfort in different rooms were statistically analyzed through an experimental design as well as through the voting ratio. Participants answered thermal sensation on a 7-point scale varying from −3 (cold) to +3 (cold). Fig. 12 illustrated that all the participants' thermal sensation score were from 0 to 1, which means they were in a "neutral" state in four rooms. Moreover, the thermal sensation in three wooden rooms were slightly higher than non-wooden room during the experiment. Further analysis was below:

At Time 3, participants in wooden rooms scored higher in thermal sensation value, and the voting range was between 0.5 and 1, slightly higher than that of TR. Although these values decreased in all rooms at Time 4 due to the participants' self-adaption to the ambient environment, wooden rooms still contributed higher values than non-wooden room and a significant difference in TR-PR ($p < 0.05$) was observed.

The temperature was controlled for a certain range, although the decreased TSV in all rooms and the enlarged difference between TR-PR, thermal comfort voting changed little during the entire experiment. Fig. 13 presents the voting percentage of thermal comfort under four rooms during the experiment. The majority of participants, up to 95% under every condition, reported that they were comfort or very comfort with the environment. There were a

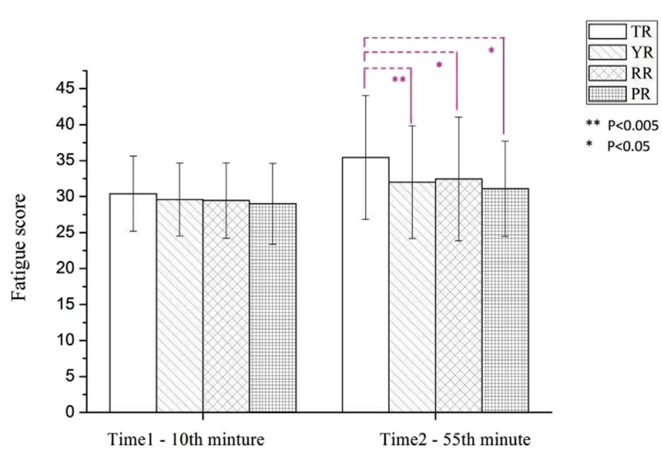

Fig. 9. The mean value of fatigue self-assessment score during the experiment in four rooms.

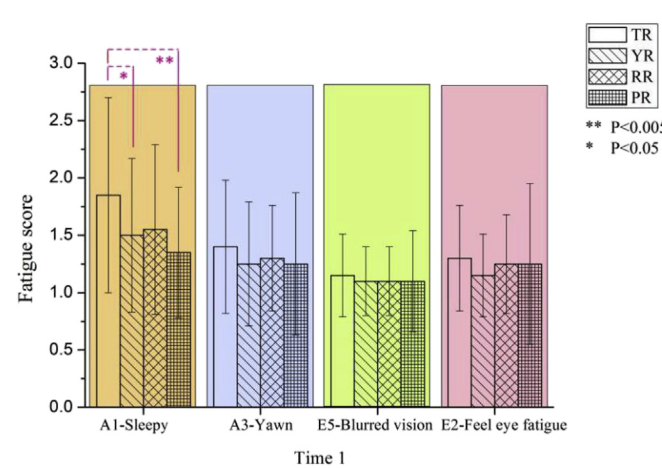

Fig. 10. The score of sub-items at Time 1 in four rooms.

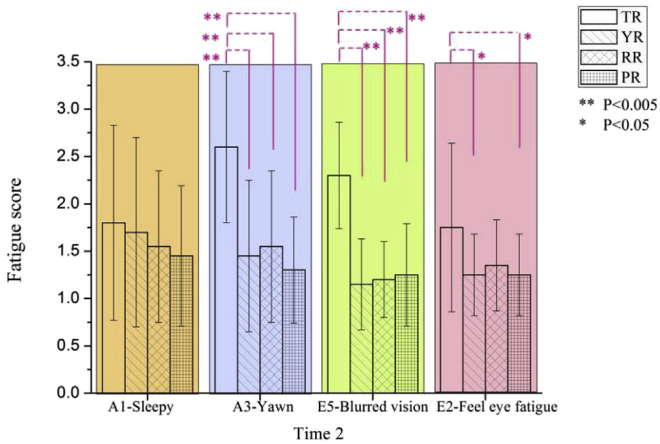

Fig. 11. The score of sub-items at Time 2 in four rooms.

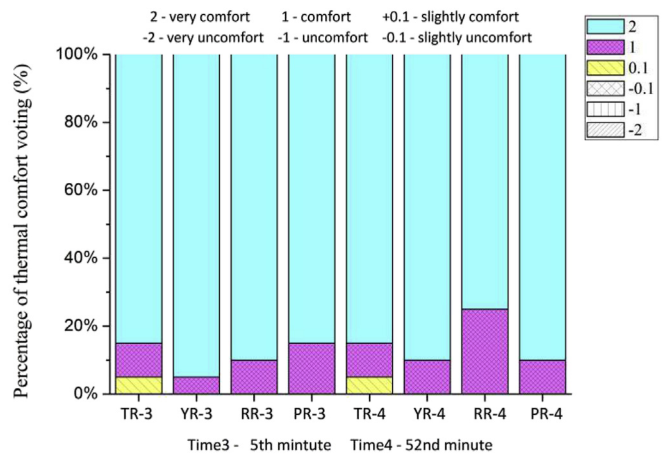

Fig. 13. The thermal comfort voting percentage in four rooms during the experiment.

Table 8
P value of Fatigue items during the experiment in different rooms.

Times	Items		TR - YR	TR - RR	TR - PR
Time 1	*A1-Sleepy*	*P*	0.031*	0.11	0.004**
	A3-Yawn		0.419	0.541	0.33
	E5-Blurred vision		0.666	0.577	0.577
	E2-Feel eye fatigue		0.186	0.748	0.804
Time 2	*A1-Sleepy*	*P*	0.629	0.135	0.069
	A3-Yawn		0.000**	0.000**	0.000**
	E5-Blurred vision		0.000**	0.000**	0.000**
	E2-Feel eye fatigue		0.038*	0.072	0.038*

Note: *P < 0.05, **P < 0.005.

certain number of participants selecting “slightly comfort” with the environment, although the ratio was small. In addition, the ratio of “slightly comfort” only appeared in non-wooden room (TR).

3.3.2. Color sensation and comfort

The influence of room interior colors on sense and comfort were also studied via similar methods above. Participants answered color sensation on a continuous voting scales from +1 (white) to +9 (red). The greater the value on behalf of color feel close to warm. Fig. 14 illustrates that the wooden rooms provided a higher degree of color sensation, among which YR and PR performed much better.

In terms of color perception, the warmer tends of color were indicated by higher values. PR and YR, which were 100% covered by different colored wood, showed almost identical average color sensation values (Table 9). In comparison, the color sensation of RR (50% light brown wood and 50% painted white) was less than half of that and only slightly higher than that of TR (100% painted white). This shows that wooden environments more easily generate a warm feeling of color.

In terms of color comfort (see Fig. 15), it presents the voting percentage of color comfort in all four rooms. Voting distribution revealed that a very small number of participants in TR felt uncomfortable, which did not occur in any of the wooden rooms. Correspondingly, the percentage of participants who chose +1 (comfort) or +2 (very comfortable) in wooden rooms was 100%, which was higher than TR. The difference in comfort level between wooden and non-wooden environments was not statistically significant.

This shows that wood rates of the interior wall were an important factor affecting the sense of color for participants, while the color of the interior wall was not significant.

3.3.3. Odor sensation and comfort

The effect of room interior odor on sensation and comfort was statistically analyzed through experimental design, as well as through the voting ratio. Participants answered odor sensation on a 5-point scale varying from 0 (none) to +4 (pungent). Fig. 16 showed that all the participants' odor sensation score were all below 1.5, which means the odor feeling was not particularly strong in four

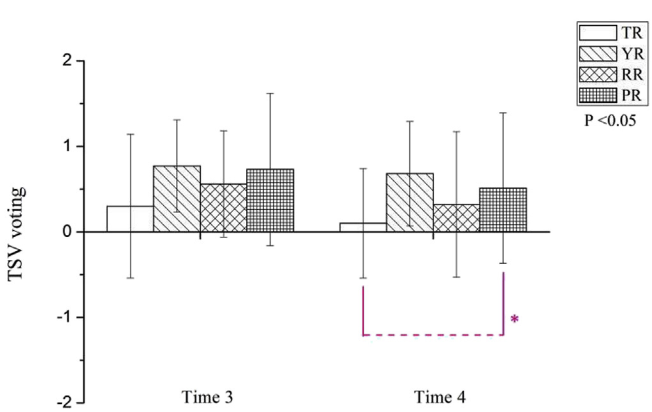

Fig. 12. The thermal sensation voting score of participants in four rooms.

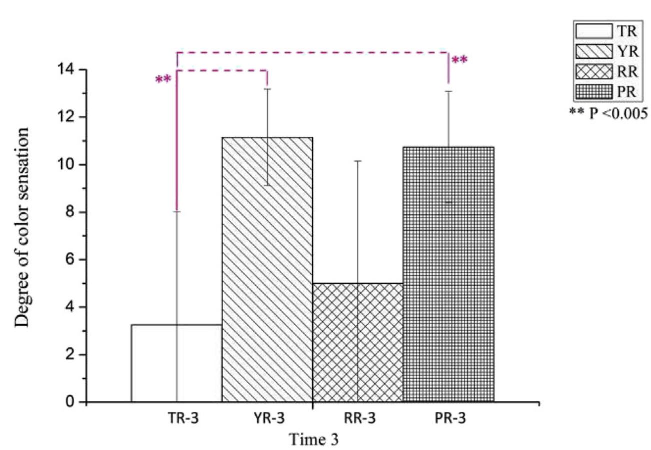

Fig. 14. The color sensation voting score of participants in four conditions at Time 3 (after entering the room).

Table 9
P value of color sensation when participants enter the rooms.

Times		TR - YR	TR - RR	TR - PR
Time 3	*P*	0.000*	0.279	0.000**

Note: *P < 0.05, **P < 0.005.

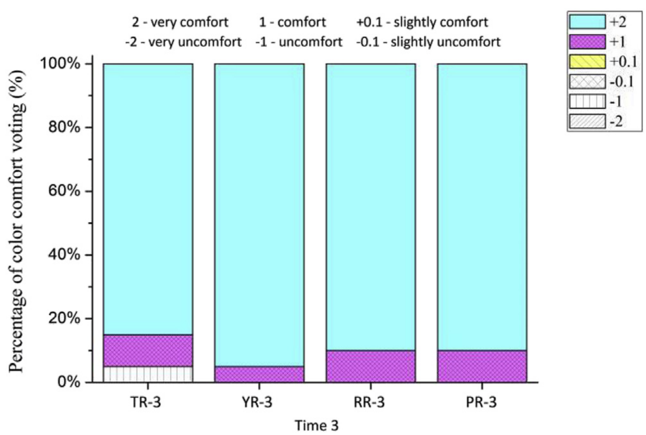

Fig. 15. The color comfort voting percentage in four conditions at Time 3 (after entering the room).

rooms. Besides, the odor sensation in three wooden rooms were slightly higher than non-wooden room especially at Time3. More analysis was below:

Two sequence surveys were conducted on odor sensation and comfort. At Time 1, strong odor sensation of wooden rooms was observed while that of TR remained modest. Significant differences appeared on TR-YR and TR-PR (Table 10). After fifty minutes, all odor sensation values decreased, among which TR still remained the lowest. In general, the odor sensation in wooden environments was more intense, but with the passage of time, the sensitivity of that decreased gradually.

Fig. 17 presents the voting percentage results of odor comfort in all rooms. It showed that 10% participant felt uncomfortable in TR at Time 1, while the amount in the other three wooden rooms was only half of that (5%). After 50 min of adaptation, the sense of comfort was improved in TR, YR, and RR, but the level of comfort in wooden rooms was still higher. While the difference in comfort

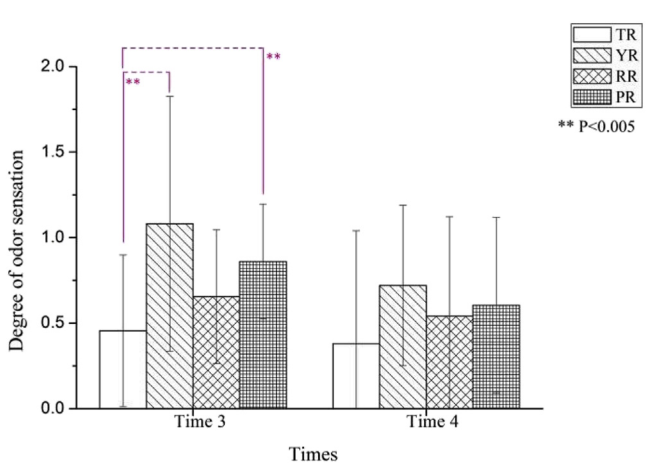

Fig. 16. The odor sensation voting score of participants in four rooms during the experiment.

Table 10
P value of odor sensation during the experiment process in four rooms.

Times		TR - YR	TR – RR	TR - PR
Time 3	*P*	0.004**	0.109	0.001**
Time 4		0.075	0.457	0.247

Note: *P < 0.05, **P < 0.005.

level for the different rooms was not statistically significant with regard to the adaptation to the environment, it did show an increase in the wooden environment and produced slightly more comfort than non-wooden environment.

3.3.4. *Lighting sensation and comfort*

The effects of interior lighting on sensation and comfort were statistically analyzed though experimental design. Fig. 18 illustrated that the voting range of lighting sensation was from the −0.5 to +0.5 in four rooms, it represented that all the participants' lighting sensation were around "neutral". However, the lighting sensation in the non-wooden room (TR) was below "0", all the wooden rooms' lighting sensation value were above "0". The participants felt more lighter in the wooden rooms than in the non-wooden room. Further analysis was below:

Significant differences between rooms in lighting sensation appeared despite the controlled illumination. At Time 1, the lighting sensational range of TR decreased from 0 to −0.5 while the other three wooden rooms oppositely varied from 0 to +0.5. Fifty minutes later, the situation was similar. Significant differences appeared between TR and the wooden rooms for both Time 1 and Time 2(Table 11). Wooden rooms supplied more bright feeling than non-wooden rooms.

When reviewing the comfort voting (Fig. 19), it showed that the subjects felt comfortable (>+0.1) in four rooms. However, the indication of feeling comfortable (+1) and very comfortable (+2) in wooden rooms was higher than that in TR. Overall, comfort levels in both wooden and non-wooden rooms were similar with wooden rooms performing slightly better.

4. Conclusions

In the field laboratory experiment, emotion, fatigue survey, and subjective evaluation were used to evaluate the effects of wooden and non-wooden environments on psychological responses. Conclusions can be obtained as follows:

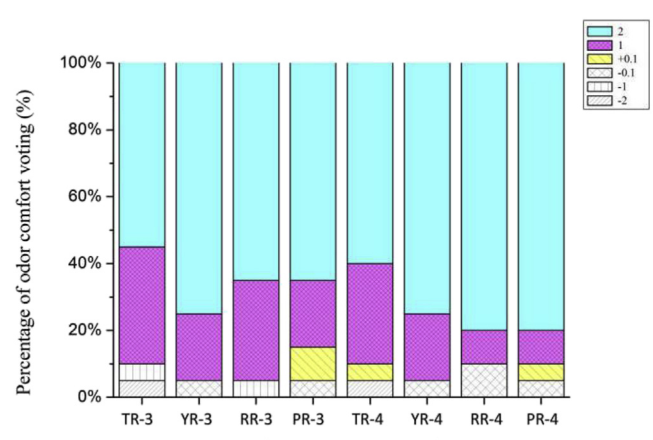

Fig. 17. The odor comfort voting percentage in four rooms during the experiment.

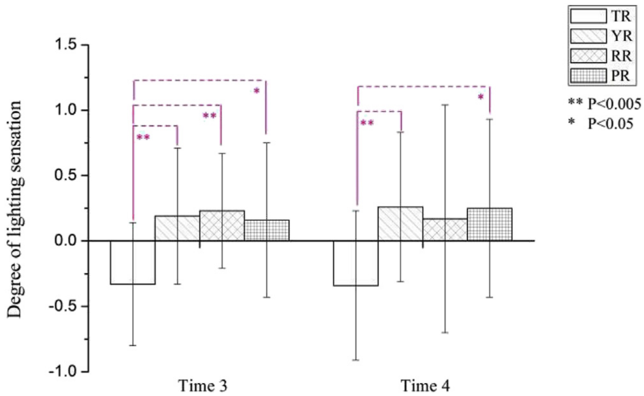

Fig. 18. The lighting sensation voting of participants in four rooms during the experiment.

Table 11
P value of lighting sensation during the experiment process in four rooms.

Times		TR - YR	TR - RR	TR - PR
Time 3	*P*	0.001**	0.000**	0.008**
Time 4		0.004**	0.057	0.006**

Note: *P < 0.05, **P < 0.005.

1) Participants had more positive emotions in wooden rooms, especially after working. Clear differences were shown for the sense of "tension," "depression," and "vigor" between wooden and non-wooden environments.
2) Working in a non-wooden environment was more likely to produce fatigue. The differences in fatigue in the two kinds of environments were clearly reflected through the symptoms of "sleep," "yawn," "see fuzzy," and "eye fatigue."
3) The survey method using emotion questionnaire and fatigue self-assessment showed that the wooden environment had the potential to restore the ability to regulate emotion and relieve stress.
4) The subjective feeling was different for the sense of color, warmth, lighting, and odor in wooden and non-wooden environments. Participants feel more warmth and brightness in wooden rooms and have sensitivity to odor, but it has little influence on the comfort degree.

Note: It is usually difficult to give concrete results about human behavior and feeling by conducting survey alone with a small sample. The simultaneous experiment concerning human physiological response to wooden indoor environment has also been performed. And their results have a good agreement with each other. Details about physiological response to wooden indoor environment can be found in its companion piece which has been submitted to another journal.

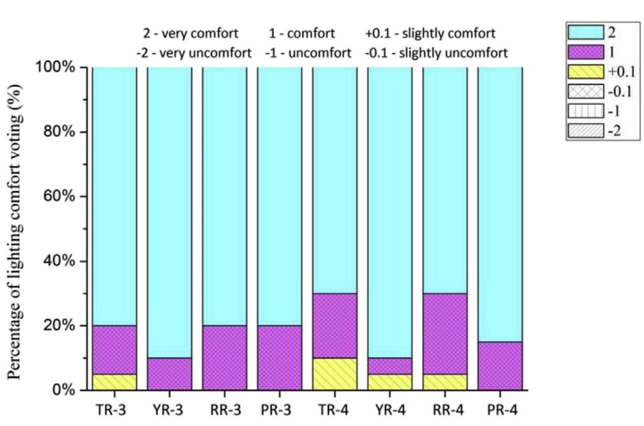

Fig. 19. The lighting comfort voting percentage in four rooms during the experiment.

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References

[1] USGBC, Green building and LEED Core Concepts, USGBC United States Green Building Council (USGBC), Washington, DC, 2010.
[2] S. Kaplan, The restorative benefits of nature: toward an integrative framework, J. Environ. Psychol. 15 (3) (1995) 169–182.
[3] R. Ulrich, Effects of interior design on wellness: theory and recent scientific research, J. Health Care Inter Des. 3 (1) (1991) 97–109.
[4] Y.A. Horr, M. Arif, M. Katafygiotou, et al., Impact of indoor environmental quality on occupant well-being and comfort: a review of the literature, Int. J. Sustain. Built Environ. 5 (1) (2016) 1–11.
[5] D. Clements-Croome, Intelligent Buildings: An Introduction, Routledge, 2013.
[6] M.J. Mendell, W.J. Fisk, K. Kreiss, H. Levin, D. Alexander, W.S. Cain, J.R. Girman, C.J. Hines, P.A. Jensen, D.K. Milton, L.P. Rexroat, K.M. Wallingford, Improving the health of workers in indoor environments: priority research needs for a national occupational research agenda, Am. Public Health 92 (2002) 1430e1440.
[7] Yuzhen Shang, Baizhan Li, A.N. Baldwin, Yong Ding, Wei Yu, Li Cheng, Investigation of indoor air quality in shopping malls during summer in Western China using subjective survey and field measurement, Build. Environ. 108 (2016) 1–11.
[8] M.C. Lee, K.W. Mui, L.T. Wong, W.Y. Chan, E.W.M. Lee, C.T. Cheung, Student learning performance and indoor environmental quality (IEQ) in air-conditioned university teaching rooms, Build. Environ. 49 (2012) 238–244.
[9] Jungsoo Kim, Richard de Dear, Christhina Cândido, Hui Zhang, Edward Arens, Gender differences in office occupant perception of indoor environmental quality (IEQ), Build. Environ. 70 (2013) 245–256.
[10] Jungsoo Kim, Richard de Dear, Impact of different building ventilation modes on occupant expectations of the main IEQ factors, Build. Environ. 57 (2012) 184–193.
[11] Zhe Wang, Haitian Zhao, Borong Lin, Yingxin Zhu, Qin Ouyang, Juan Yu, Investigation of indoor environment quality of Chinese large-hub airport terminal buildings through longitudinal field measurement and subjective survey, Build. Environ. 94 (2) (2015) 593–605.
[12] Jieun Han, Soon-bark Kwon, Chungyoon Chun, Indoor environment and passengers' comfort in subway stations in Seoul, Build. Environ. 104 (2016) 221–231.
[13] Yousef Al Horr, Mohammed Arif, Amit Kaushik, Ahmed Mazroei, Martha Katafygiotou, Esam Elsarrag, Occupant productivity and office indoor environment quality: a review of the literature, Build. Environ. 105 (2016) 369–389.
[14] M. Frontczak, S. Schiavon, J. Goins, et al., Quantitative relationships between occupant satisfaction and satisfaction aspects of indoor environmental quality and building design, Indoor Air 22 (2) (2012) 119–131.
[15] Sanae Chraibi, Tatiana Lashina, Paul Shrubsole, Myriam Aries, Evert van Loenen, Alexander Rosemann, Satisfying light conditions: a field study on perception of consensus light in Dutch open office environments, Build. Environ. 105 (2016) 116–127.
[16] Piers MacNaughton, John Spengler, Jose Vallarino, Suresh Santanam, Usha Satish, Joseph Allen, Environmental perceptions and health before and after relocation to a green building, Build. Environ. 104 (2016) 138–144.
[17] L. Lan, P. Wargocki, D.P. Wyon, et al., Effects of thermal discomfort in an office on perceived air quality, SBS symptoms, physiological responses, and human performance, Indoor Air 21 (5) (2011) 376–390.
[18] Z. Wang, H. Ning, Y. Ji, et al., Human thermal physiological and psychological responses under different heating environments, J. Therm. Biol. 52 (2015) 177–186.
[19] O.K.A.L. Rn, M.F. Chan, W.M. Chan, Music and its effect on the physiological responses and anxiety levels of patients receiving mechanical ventilation: a pilot study, J. Clin. Nurs. 14 (5) (2005) 609–620.
[20] X. Zhang, P. Wargocki, Z. Lian, Human responses to carbon dioxide, a follow-up study at recommended exposure limits in non-industrial environments, Build. Environ. 100 (2016) 162–171.
[21] L. Lan, Z.W. Lian, Y.B. Lin, Comfortably cool bedroom environment during the initial phase of the sleeping period delays the onset of sleep in summer, Build. Environ. 103 (2016) 36–43.
[22] X. Zhang, P. Wargocki, Z. Lian, et al., Effects of exposure to carbon dioxide and

bioeffluents on perceived air quality, self-assessed acute health symptoms and cognitive performance, Indoor Air (2016), http://dx.doi.org/10.1111/ina.12284.
[23] Li Lan, Zhiwei Lian, Use of neurobehavioral tests to evaluate the effects of indoor environment quality on productivity, Build. Environ. 44 (11) (2009) 2208–2217.
[24] Borong Lin, Zhe Wang, Hongli Sun, Yingxin Zhu, Qin Ouyang, Evaluation and comparison of thermal comfort of convective and radiant heating terminals in office buildings, Build. Environ. 106 (2016) 91–102.
[25] E. Finell, U. Haverinenshaughnessy, A. Tolvanen, et al., The associations of indoor environment and psychosocial factors on subjective evaluation of indoor air quality among lower secondary school students - a multilevel analysis, Indoor Air (2016), http://dx.doi.org/10.1111/ina.12303.
[26] Li Lan, Zhiwei Lian, Ten questions concerning thermal environment and sleep quality, Build. Environ. 99 (2016) 252–259.
[27] H.H. Liang, C.P. Chen, R.L. Hwang, et al., Satisfaction of occupants toward indoor environment quality of certified green office buildings in Taiwan, Build. Environ. 72 (1) (2014) 232–242.
[28] R.S. Ulrich, R.F. Simons, B.D. Losito, et al., Stress recovery during exposure to natural and urban environments 1, J. Environ. Psychol. 11 (3) (1991) 201–230.
[29] R. Mitchell, F. Popham, Effect of exposure to natural environment on health inequalities: an observational population study, Lancet 372 (9650) (2008) 1655–1660.
[30] C.D. Frenette, C. Bulle, R. Beauregard, et al., Using life cycle assessment to derive an environmental index for light-frame wood wall assemblies, Build. Environ. 45 (10) (2010) 2111–2122.
[31] F. Bob, Wood as a sustainable building material, For. Prod. J. 59 (9) (2009) 6–12.
[32] M.D. Burnard, A. Kutnar, Wood and human stress in the built indoor environment: a review, Wood Sci. Technol. (2015) 1–18.
[33] M. Nakamura, S. Nakagawa, T. Nakano, Evaluation of visual impact of multiple image characteristics observed in edge-grain patterns, J. Wood Sci. 61 (1) (2014) 19–27.
[34] A.Q. Nyrud, T. Bringslimark, K. Bysheim, Benefits from wood interior in a hospital room: a preference stud, Archit. Sci. Rev. 57 (2) (2014) 125–131.
[35] L. Tyrvinen, A. Ojala, K. Korpela, et al., The influence of urban green environments on stress relief measures: a field experiment, J. Environ. Psychol. 38 (6) (2014) 1–9.
[36] D. Fell, Wood in the Human Environment: Restorative Properties of Wood in the Built Indoor Environment, University of British Columbia, Vancouver, BC, Canada, 2010. PhD Dissertation.
[37] H. Ohta, Y. Tanabe, Y. Nishino, et al., Effects of summertime redecoration of a hospital isolation room on occupiers' physiological functions, Jpn. J. Biometeorology 45 (2008) 73–84.
[38] T.M. Tsao, M.J. Tsai, Y.N. Wang, et al., The health effects of a forest environment on subclinical cardiovascular disease and heath-related quality of life, Plos One 9 (7) (2014) e103231.
[39] E. Sonntag-Öström, M. Nordin, Y. Lundell, et al., Restorative effects of visits to urban and forest environments in patients with exhaustion disorder, Urban For. Urban Green. 13 (2) (2014) 344–354.
[40] E.M. Nordström, A. Dolling, E. Skärbäck, et al., Forests for wood production and stress recovery: trade-offs in long-term forest management planning, Eur. J. For. Res. 134 (2) (2015) 1–13.
[41] M. Masuda, Influence of color and glossiness on image of wood, J. Soc. Mater. Sci. Jpn. 34 (1985) 972–978.
[42] A.Q. Nyrud, T. Bringslimark, Is interior wood use psychologically beneficial? A review of psychological responses toward wood, Wood Fiber Sci. J. Soc. Wood Sci. Technol. 42 (2) (2010) 202–218.
[43] S. Sakuragawa, T. Kaneko, Y. Miyazaki, Effects of contact with wood on blood pressure and subjective evaluation, J. Wood Sci. 54 (2) (2008) 107–113.
[44] S. Sakuragawa, Y. Miyazaki, T. Kaneko, et al., Influence of wood wall panels on physiological and psychological responses, J. Wood Sci. 51 (2) (2005) 136–140.
[45] M. Masuda, Influence of color and glossiness on image of wood, J. Soc. Mater. Sci. Jpn. 34 (1985) 972–978.
[46] T. Baguley, Understanding statistical power in the context of applied research, Appl. Ergon. 35 (2) (2004) 73–80.
[47] L. Lan, Z. Lian, Application of statistical power analysis – how to determine the right sample size in human health, comfort and productivity research, Build. Environ. 45 (5) (2010) 1202–1213.
[48] Obesity WHO, Preventing and Managing the Global Epidemic. Report of a WHO Consultation, World Health Organization, 2000. Technical Report Series.
[49] D.M. McNair, M. Lorr, L.F. Droppleman, Revised Manual for the Profile of Mood States, Educational and Industrial Testing Services, San Diego, CA, 1992.
[50] H. He, G. Dong, Application study on Japanese "subjective fatigue Symptoms"(2002 version) in a chinese manufacter, Chin. J. Ergon. 15 (2009), 26e28 [In Chinese].