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ORIGINAL ARTICLE

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Influence of wood wall panels on physiological and psychological responses

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Abstract The effect of visual stimulation from wood on the body was examined in a comparative study using full-sized hinoki wall panels and a white steel wall panel. Continuous blood pressure measurements were used as the physiological indicator. Sensory evaluation by the semantic differential (SD) method and the profile of mood states (POMS) test were performed to determine changes in psychological impression. Results showed that visual stimulation from hinoki wall panels had an emotional and natural impression upon humans. Blood pressure decreased significantly in subjects who liked them, and there was no significant increase in blood pressure in subjects who disliked them. Visual stimulation from the white steel wall panel made an unhealthy and closed impression and increased the sense of depression. In addition, there was stress and a significant increase in blood pressure in subjects who disliked them. Consequently, visual stimulation from hinoki and white steel wall panels had different physiological and psychological effects. Results also showed that the same visual stimulation induced different physiological responses depending on the values of the individuals.

Key words Wood · Wall panel · Blood pressure · SD method · POMS

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Introduction

Wood reflects long-wavelength light, which is mostly perceived by humans as yellow to red hues.[1] More intense reflection of light in the wavelength range from yellow and red to infrared makes wood feel "warm."[2] The effect of visual stimulation from wood on its subjective evaluation has been the topic of a number of studies in the fields of construction and wood design. Kunishima et al.[3] performed a quantitative determination of the effect of wall panel color on visual effects using slides and indicated that lightness, saturation, and hue had significant effects on "liveliness," "comfort," and "warmness," respectively. Questionnaire surveys have been conducted using panels with various types of grain created by computer graphics, and identified the intervals of grooves[4] and the size and arrangement of knots[5] that gave an "agreeable" impression.

However, the physiological effect of visual stimulation from wood has not been studied using a physiological indicator. When evaluating stimulation using subjective evaluation, results must be reinterpreted by recalling them. In addition, different persons assign different meanings to an expression.

A physiological indicator that allows objective and continuous evaluation of the status of the body under stimulation has been attracting attention as an essential evaluation method for interpreting the status of the body. When evaluating the physiological status of the body, autonomous nervous reflex has been commonly used as a useful indicator, including pupillary light reflex, blood pressure, and pulse rate.[6–9]

A feeling of real life is important for a sensory stimulation test. Tsunetsugu et al.[9] investigated the visual effects of wooden interiors in actual size living rooms on the autonomic nervous activity and found that pulse rate decreased in a standard living room (standard type of living room available in Japan) and increased in the designed living room. However, full-size stimulation has rarely been used in visual experiments to examine physiological effects in the field of wood science.

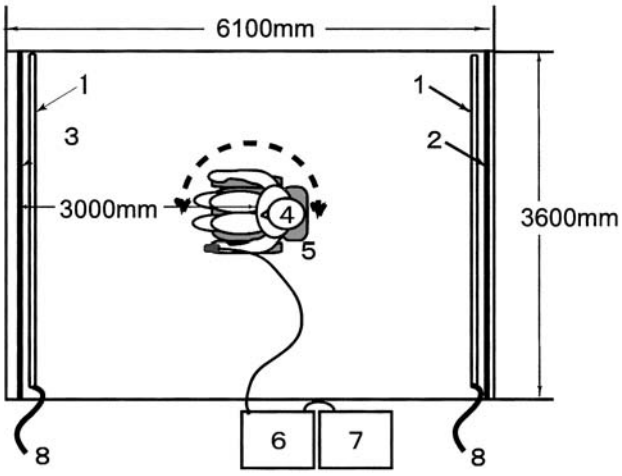

Fig. 1. Laboratory overview. *1*, Curtain (white); *2*, hinoki wall panels (2670 mm H × 3600 mm W); *3*, white steel wall panel (2670 mm H × 3600 mm W); *4*, subject; *5*, rotating chair; *6*, noninvasive continuous sphygmomanometer (Finapres, Ohmeda model 2300); *7*, computer for data storage; *8*, rope for opening/closing curtain

This study used full-sized hinoki wall panels and a white steel wall panel as stimulants to produce the sense of real life, and determined the effect of visual stimulation from wall panels on the body. As a physiological indicator, continuous blood pressure was measured by the Finapres method,[10,11] a simple method using the fingertips that places less of a burden on subjects. Blood pressure was used to check the state of relaxation. Sensory evaluation by the semantic differential (SD) method[12] and the profile of mood states (POMS) test[13] were performed to determine changes in psychological impression.

Materials and methods

Part of a laboratory was partitioned with a curtain to make a compartment that was 22 m^2 (3.6 × 6.1 m) in area with a ceiling height of 2.67 m, as shown in Fig. 1. The laboratory wall was used as-is (as the white steel wall panel), and six hinoki panels 2670 mm high (ceiling height) and 600 mm wide were arranged in front of the laboratory wall. The curtain (cotton, white) was closed when stimulation was not applied. At stimulation, the subject was instructed to pull the string to open the curtain and expose the wall (Fig. 2a). Three situations were provided: the curtain was closed (control), the white steel wall panel was exposed (Fig. 2b), and the hinoki wall panels were exposed (Fig. 2c). The order of presenting these situations was randomized. The experiment was performed at an ambient temperature of 21°–23°C, relative humidity of 50%–60%, and illumination of about 350 lx.

The subject population included 14 healthy male college students. The subjects were given sufficient information about the objective and procedure of the experiment. The subject was seated in a rotating chair in the center of the laboratory, made to face the wall to be exposed first, and a

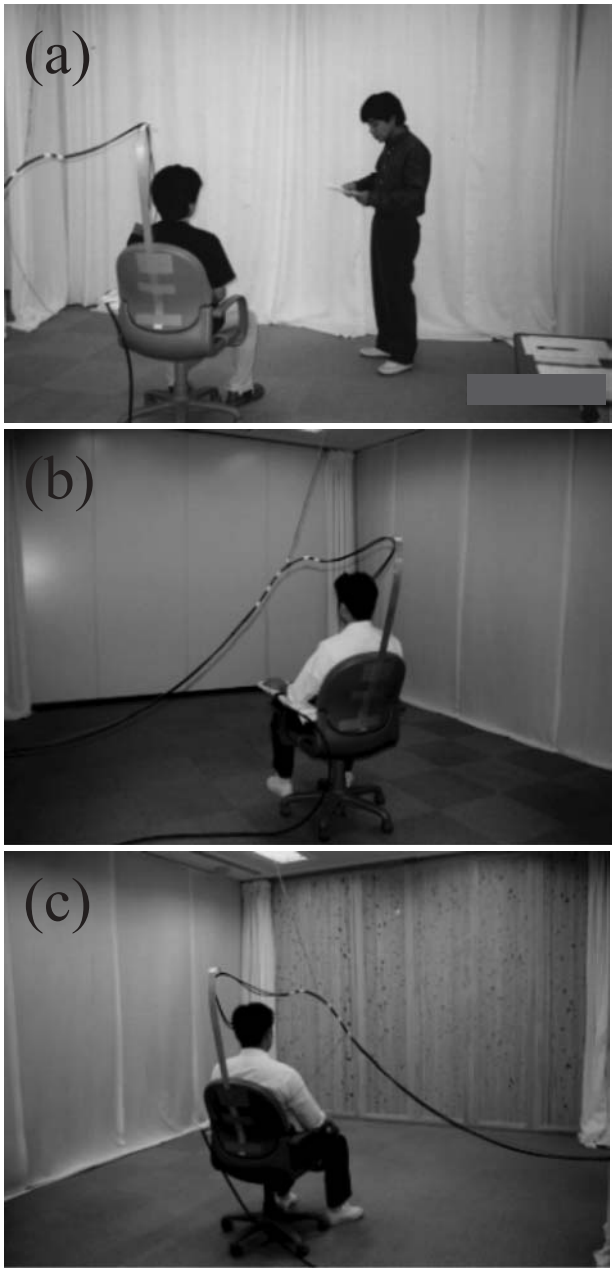

Fig. 2. **a** Instruction to subject when the curtain is closed, **b** white steel wall panel is exposed, **c** hinoki wall panels are exposed

sensor for physiological measurement was attached to him. Continuous blood pressure and pulse rate were measured every second on the left middle finger by the Finapres method[10,11] (Ohmeda model 2300). After resting in a sitting position with the eyes closed, the subject was prompted to open his eyes and rest for an additional period of at least 20 s, and was then exposed to the wall for 90 s. When analyzing continuous blood pressure, the time required for opening the curtain (about 3 s) was omitted. After exposure, sensory evaluation by the SD method[12] and POMS test[13] were performed.

Eighteen epithet pairs (warm, carefree, comfortable, interesting, calm, tasteful, stable, natural, full of variety,

bright, soft, nonoppressive, friendly, healthy, beautiful, fresh, open, and sophisticated) were used for sensory evaluation by the SD method, consisting mainly of those used by Sato.[14] Almost all words were written in Japanese in the form. Evaluation was based on a seven-grade scale from −3 to +3. In addition, the like/dislike evaluation was also based on a seven-grade scale from −3 to +3. The POMS test followed the Japanese version of POMS described by Yokoyama et al.[13]

Wilcoxon's signed rank test was used for the test of significance regarding sensory evaluation and the POMS test. The test of significant differences in changes over time in systolic blood pressure was performed by the paired *t*-test based on the average values for 10 s before stimulation.

Results and discussion

Subjective evaluation

Principal component analysis (varimax method) was performed for sensory evaluation by the SD method. When the proper value was assumed to be 1 or more, seven repetitions resulted in an end of rotation and four factors were extracted.

When a factor loading of 0.7 or more was assumed, for the first principal component, "healthy" (0.88), "soft" (0.78), "nonoppressive" (0.77), "friendly" (0.76), and "open" (0.74) were extracted, and the first principal component was designated the "sense of health and openness." For the second principal component, "full of variety" (0.88), "interesting" (0.85), "warm" (0.83), and "natural" (0.73) were extracted and the second principal component was designated the "sense of variety and nature." For the third principal component, "stable" (0.86), "calm" (0.79), and "comfortable" (0.74) were extracted, and the third principal component was designated the "sense of stability and calmness." For the fourth principal component, "fresh" (0.80) was extracted, and the fourth principal component was designated the "sense of freshness."

Figure 3 presents the principal component scores upon visual stimulation by wall panels. The hinoki wall panels had significantly higher principal component scores for the "sense of variety and nature" than the control, and their visual stimulation was found to be full of variety and natural.

On the other hand, the white steel wall panel had a significantly lower second principal component score for the "sense of health and openness" and a significantly

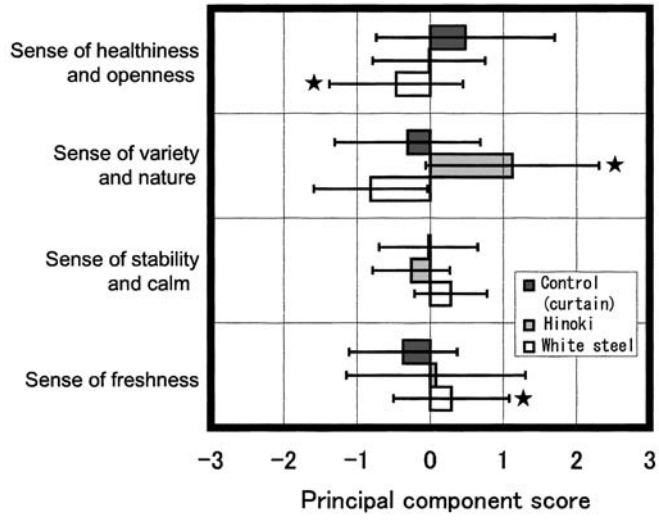

Fig. 3. Principal component scores for each wall panel, given as mean ± standard deviation. *Stars*, $P < 0.05$ (compared with control) for the Wilcoxon's signed rank test

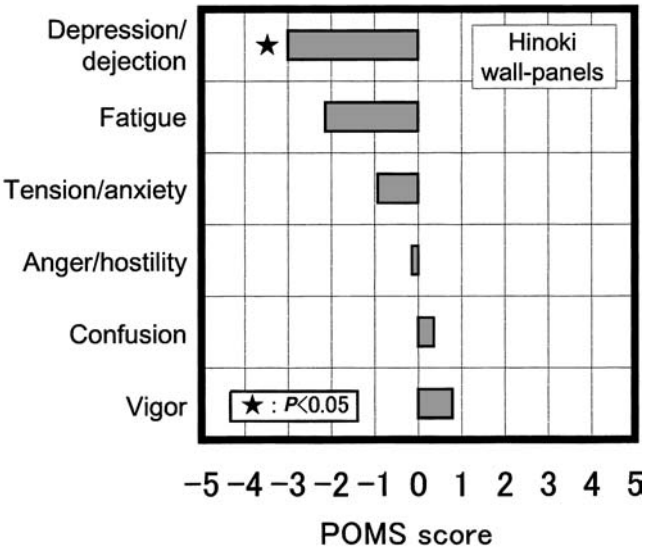

Fig. 4. Mood scale scores for hinoki wall panels. *POMS*, profile of mood states

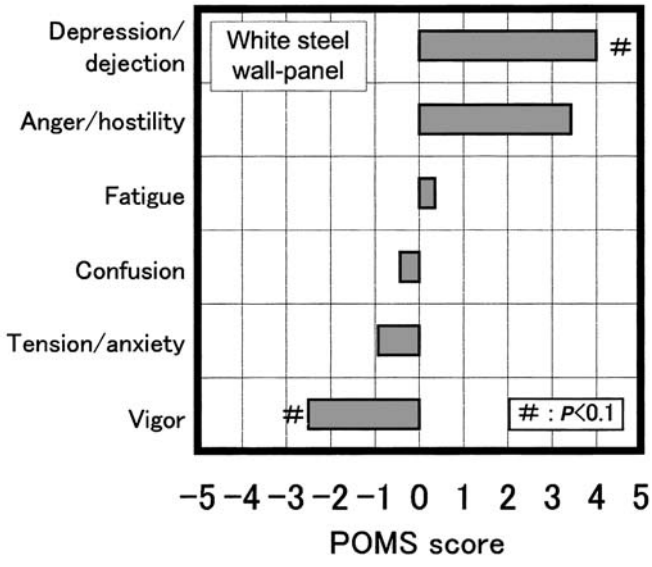

Fig. 5. Mood scale scores for white steel wall panel. *Hash*, $P < 0.1$ (compared with control) for the Wilcoxon's signed rank test

higher principal component score for the "sense of freshness." The visual stimulation of the white steel wall panel was found to be unhealthy and closed, while producing a feeling of freshness.

Figures 4 and 5 present mood scale scores from the POMS test upon visual stimulation by wall panels. The mood scale score represents the difference from the control.

The mood scale score of "depression/dejection" was significantly lower for visual stimulation by the hinoki wall panels than for the control. Visual stimulation by the hinoki wall panels was found to reduce depression.

For visual stimulation by the white steel wall panel, the mood scale score of "depression/dejection" was significantly higher, and the mood scale score of "vigor" was significantly lower, each with a level of significance of 10%. Visual stimulation by the white steel wall panel seemed to increase depression and reduce vigor.

The following findings were obtained from the results of subjective evaluation described above:

1. The hinoki wall panels produced natural and varied impressions and reduced depression/dejection.
2. The white steel wall panel produced an unhealthy and fresh feeling, and increased depression/dejection and reduced vigor.

Physiological responses

Figure 6 presents changes over time in systolic blood pressure before and after visual stimulation by the hinoki wall panels. Systolic blood pressure temporarily increased after stimulation and gradually returned to the original level (Fig. 6a). This temporary increase in blood pressure seems to have been caused by the removal of the curtain.

The visual impression of the hinoki wall panels was also examined according to the subject group that evaluated them as either "like" or "dislike." For this like/dislike evaluation, subjects with ratings of −3 and −2 were classified as the "dislike" group, subjects with ratings of −1 to +1 as the "neither like nor dislike" group, and subjects with ratings of +2 and +3 as the "like" group. For the hinoki wall panels, the "like" group included five subjects, the "neither like nor dislike" group included four subjects, and the "dislike" group included five subjects. Blood pressure decreased significantly after 67–73, 79, 81–85, and 88–89 s of stimulation in subjects of the "like" group (Fig. 6b). On the other hand, there was no significant difference in the "dislike" group (Fig. 6d). Consequently, visual stimulation by the hinoki wall panels was found to result in relaxation in subjects who evaluated it as "like" and did not cause stress in subjects who evaluated it as "dislike."

Figure 7 presents the changes over time in systolic blood pressure when visual stimulation by the white steel wall panel was applied. Systolic blood pressure increased temporarily after stimulation and returned to the original level, and then started to increase gradually (Fig. 7a).

For the results of the "like/dislike" evaluation of the white steel wall panel, the "like" group included two subjects, the "neither like nor dislike" group included three subjects, and the "dislike" group included nine subjects. Blood pressure increased significantly after 38–44, 46, 53, 55–60, and 74–89 s of stimulation in subjects in the "dislike" group (Fig. 7d). Blood pressure tended to decrease in subjects in the "like" group, as shown in Fig. 7b, although the results were not statistically tested because the number of subjects included was too few. The white steel wall panel was found to cause stress in subjects who evaluated it as "dislike."

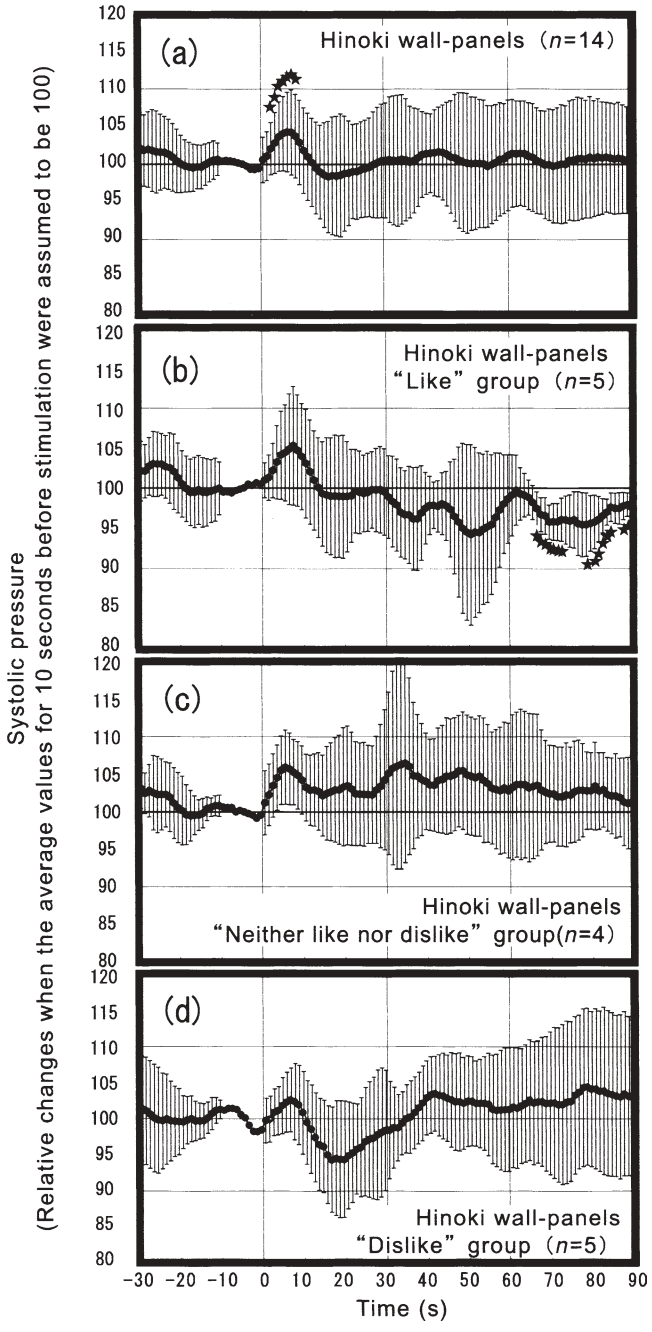

Fig. 6. Changes in systolic blood pressure after visual stimulation by hinoki wall panels, given as mean ± standard deviation. *Stars*, $P < 0.05$ (paired *t*-test)

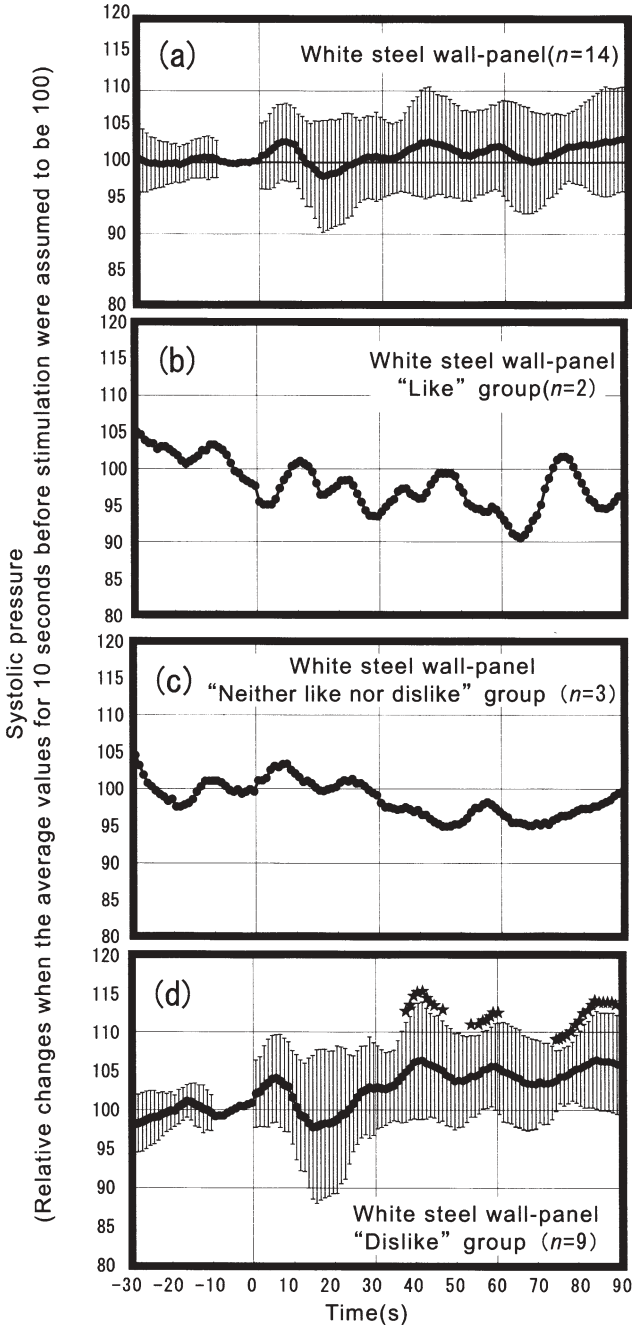

Fig. 7. Changes in systolic blood pressure after visual stimulation by white steel wall panel, given as mean ± standard deviation

Conclusions

The following conclusions were obtained:

1. Visual stimulation by the hinoki wall panels produced natural and varied impressions in a subjective evaluation study and was found to reduce feelings of depression/dejection. In addition, systolic blood pressure decreased significantly in the subject group that evaluated the hinoki wall panels as "like," and no stress was caused in the subject group that evaluated them as "dislike."
2. Visual stimulation by the white steel wall panel produced an unhealthy and fresh feeling and was found to increase depression/dejection and decrease vigor. Systolic blood pressure increased significantly in the subject group that evaluated the white steel wall panel as "dislike," resulting in typical stress.

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