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Visual effects of interior design in actual-size living rooms on physiological responses

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Abstract

The aim of the present study was to clarify the effect of visual surroundings in the daily living environment by measuring the human physiological response. Two actual-size living rooms with different interior designs were created. Cerebral blood flow, pulse rate, and blood pressure were measured while the subjects spent 90 s in the rooms. There were no significant differences between the two rooms in subjective evaluation. However, the two rooms caused different physiological responses, i.e. the room with an ordinary interior design caused a calm and relaxed state, while the other room with visible wooden posts and beams caused an active and aroused state.

Keywords: Room interior; Wood; NIRS; Blood pressure; Pulse rate

1. Introduction

Experience tells us that visual surroundings can greatly affect our mood. Several studies have been done on the visual effects of room interiors, focusing on various aspects such as colors, patterns, or textures of materials. Kunishima et al. [1] investigated the visual effects of the wall colors of a living room, using slides and the semantic differential (SD) method. They clarified that the images of wall colors of living rooms were determined by three dimensions, which were "activity," "evaluation," and "warmness." They also clarified that "activity" was influenced by brightness, "Evaluation" by saturation, and "warmness" by the hue of wall colors. Nakamura and Masuda [2] studied the influences of groove intervals on the psychological images of wooden wall panels. They found that the interval of grooves that gave an "agreeable" image was near 1/6–1/10 of the geometrical average of the vertical and horizontal sizes of wall panels, and when there were ribbon figures on full-size panels, the interval most preferred was widened.

Recently, physiological surveys as well as psychological ones have increasingly been conducted, and have shown that visual environments may affect humans not only psychologically but also physiologically. There have been many studies concerning lighting. As Küller mentioned in his review paper on biological rhythms [3], it has been well known that light, both natural and artificial, has some influence on the human biological clock. A study by Kobayashi and Sato [4] was the first to recognize the effect of color temperature on blood pressure. Noguchi and Sakaguchi [5] clarified that low color temperature light lowered the values for alpha attenuation coefficient and mean frequency in the $\theta-\beta$ EEG bandwidth, and suggested the use of light with lower color temperature for bedrooms for this reason.

Regarding the physiological effects of the visual environment in an actual-size room, there have been few studies except those conducted by a group of the

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Lund Institute of Technology, Sweden. Küller [6] demonstrated the physiological impact of the total visual environment, focusing on colors and patterns, by creating two rooms (3.5 m × 4.3 m × 2.5 m) of totally different characters. In the room with many colors and patterns, the alpha component of the EEG was considerably lower than in the colorless (gray) room. Heart rate was also lower in the colorful room. They concluded that arousal was higher in the colorful room and visual overstimulation led to a compensatory autonomic response.

Summarizing these former studies, interiors of ordinary rooms have been evaluated only psychologically using pictures or small models. There have been many physiological studies on the effects of colors or illuminations but few studies on total surroundings except those investigating exaggerated designs.

What we attempted in this study was to clarify the visual effects of ordinary living rooms on humans. We focused on wooden interiors because wood is a common and preferred material for room interiors but its physiological effects are yet unknown. To investigate the situation closer to actual daily life, we created actual-size model rooms. The effects of the rooms were evaluated using physiological indices as well as psychological ones. It is often experienced that wooden interiors are pleasing to the eye, providing "comfortable" and "relaxing" feelings, but is the human body also led to a relaxed state?

2. Experimental method

Fifteen male students aged 19–25 years old participated in the experiment as subjects.

Visual stimulation was given using the two types of living rooms shown in Fig. 1. According to a survey on interior design types of living rooms in Japan [7], 77% of the investigated living rooms contained wooden flooring, and the walls and ceiling were covered with vinyl cloth or paper in 93% and 78% of the rooms, respectively. We created one of the rooms assumiing a standard type of living room commercially available in Japan (hereafter referred to as the "standard room"). The floor of the room is wood flooring and the walls and the ceiling are covered by off-white wallpaper. For the other room, wooden beams and columns were added so that the room looked different from ordinary living rooms (hereafter referred to as the "designed room"). We also prepared a room for practice for the subjects to become used to the procedure of the experiment. The sizes of the rooms were 13 m^2, and ambient conditions were controlled at 21–23 °C, 50–60% RH (relative humidity), and 40 lx.

Fig. 1. Interiors of the rooms.

Three physiological indices were measured. Pulse rate and blood pressure were measured as indices of autonomic nervous activity on the left middle finger (Finapress, Ohmeda model 2300) [8]. Regional cerebral blood flow (rCBF) was measured as an index of central nervous activity on the right and left sides of the forehead (NIRO-300 Hamamatsu Photonics K.K.) by using near-infrared spectroscopy (NIRS) [9,10]. This index is thought to reflect mainly prefrontal area activity [11,12]. These two methods (Finapress and NIRS) are non-invasive and data for each index are available every second.

Sufficient information about the purpose and the procedure of the experiment was given to the subjects in advance. To eliminate the effect of walking, each subject was seated in a wheelchair which was custom-made for this experiment (Fig. 2). After attaching sensors for physiological measurement and instructing the subject to close his eyes, the experimenter pushed the wheelchair so that the subject entered one of the rooms, and then went out immediately. Physiological indices were monitored in real time from outside the room. After about 20 s of a stable state, an instruction for the subject to open his eyes was given from outside the room. The subjects were then exposed to visual stimulation for 90 s. All subjects started from the room for practice, and then the two other rooms (standard and designed) were shown in random order.

Fig. 2. Experimental subject being moved in a wheelchair with his eyes closed.

Sensory evaluation was conducted after 90 s of physiological measurement. The subjects were asked to evaluate the room using two 13-point scales along the following two dimensions: comfortable–uncomfortable and restful–restless. Their temporal mood states were also investigated by using profile of mood states (POMS) [13]. The approximate time required for these tests was 5 min. Then each subject was instructed to close his eyes again and was moved to the other room.

3. Data analysis

Data of all subjects were obtained for sensory evaluation and POMS. As for the physiological data, some were excluded from the analysis because of the artifact and other problems with measurement. Ten subjects' data were obtained for rCBF, and nine subjects' data were obtained for pulse rate and blood pressure.

To eliminate the effect of individual differences in baselines, the physiological data were processed as follows. The values of pulse rate and blood pressure of each second were converted to a value relative to the average value over 10 s before stimulation. The value of rCBF of each second was converted to the difference from the average value over 10 s before stimulation. A paired *t*-test was used to compare the physiological data after stimulation to the average value over 10 s before stimulation.

The scores for the questionnaire for the sensory evaluation were obtained by converting the points the subjects had marked into scores of -6 to $+6$. The scores of POMS were calculated in accordance with this method. The Wilcoxon signed rank sum test was used to compare these scores of the two rooms.

4. Results and discussion

Fig. 3 shows the scores of "comfortable" feelings for each room. Both rooms were evaluated almost equivalently as "slightly comfortable." Fig. 4 shows the scores of "restful" feelings. Both rooms were perceived as almost equally "slightly restful." There were no significant differences in "comfortable" and "restful" feelings between the two rooms ($p = 0.67$ and 0.61, respectively). Fig. 5 shows the scores of "vigor" in POMS. There was no difference between the two rooms in "vigorous" mood ($p = 0.95$), as well as the other five mood scales.

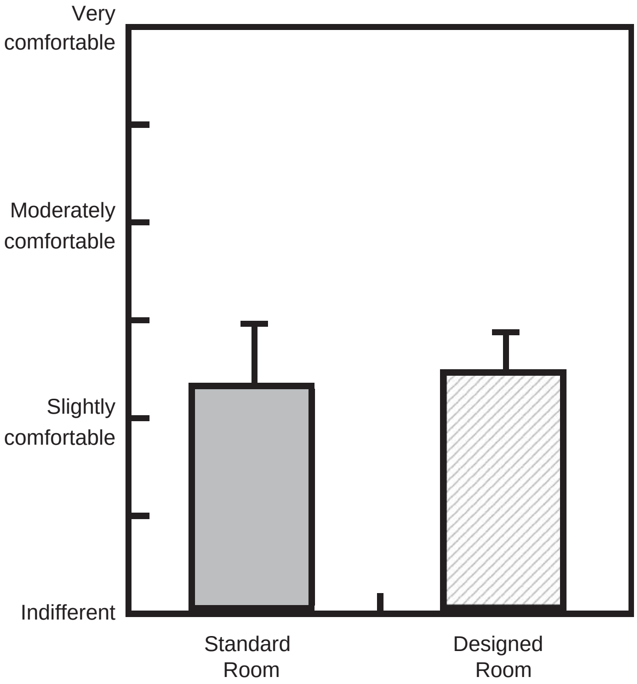

Fig. 3. Subjective "comfortable" feeling in rooms with different interior designs ($N = 15$ average ± SE).

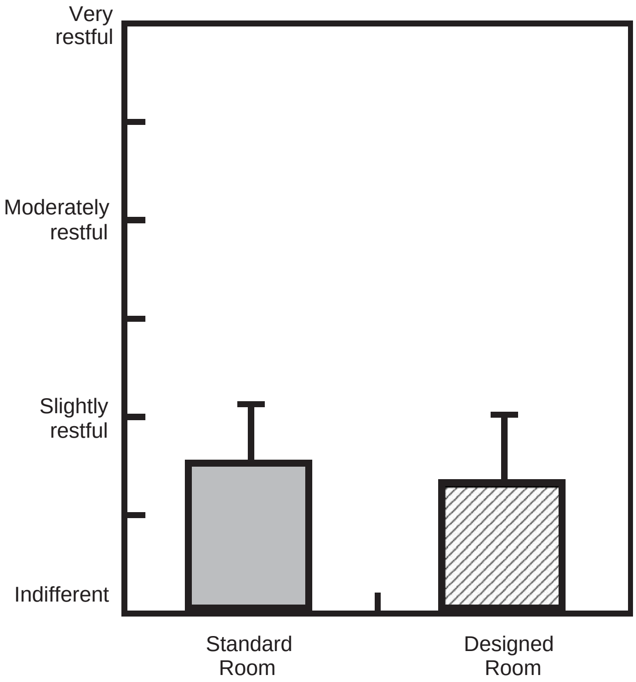

Fig. 4. Subjective "restful" feeling in rooms with different interior designs ($N = 15$ average ± SE).

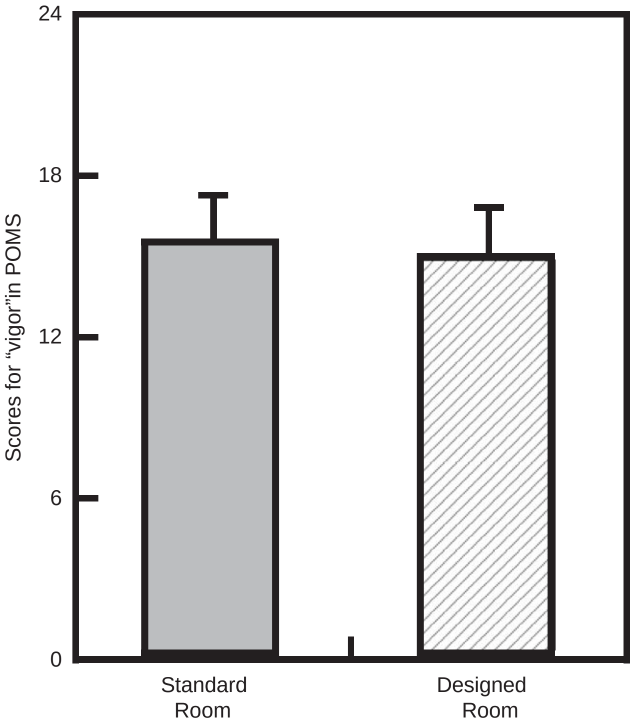

Fig. 5. Scores for feeling of "vigor" of POMS in rooms with different interior designs ($N = 15$ average ± SE).

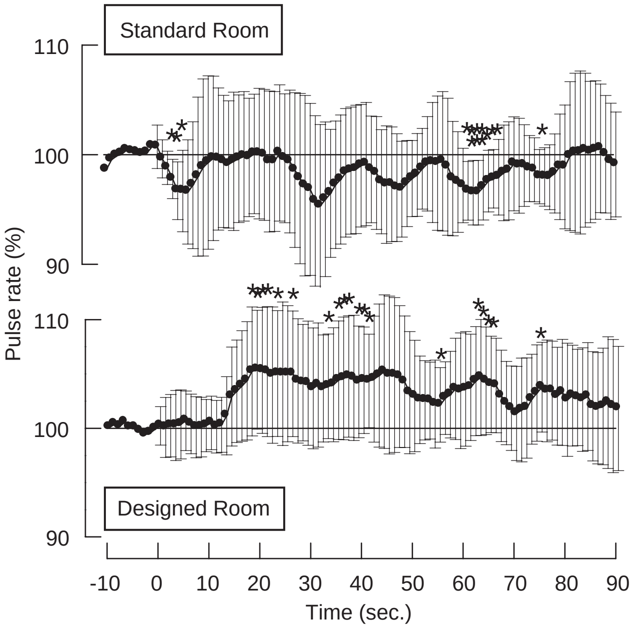

Fig. 6. Time-series variations in pulse rate in rooms with different interior designs ($N = 9$ average ± SD, $*p < 0.05$, $**p < 0.01$ by paired *t*-test).

Differences between the two rooms were observed in time-series variations of the indices of autonomic nervous activity. Fig. 6 shows the time-series variation of the pulse rate in both rooms. In the standard room, pulse rate significantly decreased soon after the beginning of exposure, and stayed lower than the average value over 10 s before exposure. This indicates that parasympathetic nervous activity was dominant in the standard room. In the designed room, however, pulse rate significantly increased from 19 s and remained high

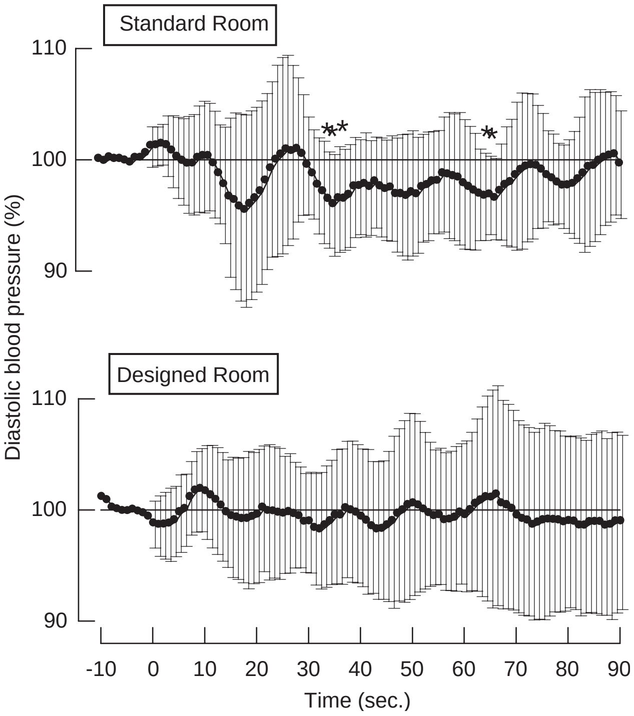

Fig. 7. Time-series variations in diastolic blood pressure in rooms with different interior designs ($N = 9$ average ± SD, $*p < 0.05$ by paired t-test).

compared to the state before stimulation. This shows that sympathetic nervous activity was dominant in the designed room and the subjects were in an aroused state physiologically.

Fig. 7 shows the time-series variation in diastolic blood pressure. Diastolic blood pressure went down in the standard room and there were significant differences between the values from 35–38 s, 66–67 s, and the average value before exposure. The designed room did not cause significant change. The significant decrease in blood pressure in the standard room supports the presumption that the subjects were in a calm state in the room.

Fig. 8 shows the time-series variations in the rCBF on the left frontal area. The rCBF significantly increased in both rooms. Increase in cerebral blood flow has been reported in several studies as a response to a mental arithmetic quiz or other mental task [12]. We also have observed an increase in rCBF during a visual stimulus of green color or a cherry tree in full blossom (unpublished data). The increase in the present study as well as in the previous cases is typical evidence of increased activity in the left frontal area of the subjects. We therefore assumed that the subjects were interested in the interiors of the rooms.

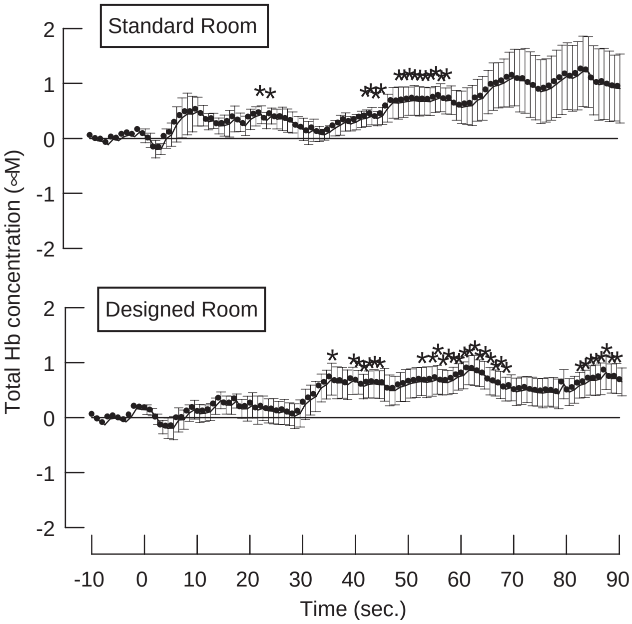

Fig. 8. Time-series variations in regional cerebral blood flow on the left frontal lobe in rooms with different interior designs ($N = 10$ average ± SE, $*p < 0.05$ by paired t-test).

The results above can be summarized as follows. The two rooms caused no differences in sensory evaluation but did cause significant differences in dynamic states of autonomic nervous activity. Generally, when we are required to express feelings, we try to interpret the feelings and find appropriate words to fit them. However, there may be some feelings that people cannot interpret and express linguistically, or even recognize. The physiological measurement in this study is thought to be able to detect the unexpressed or unrecognized effects of visual surroundings. To evaluate the states of humans, information provided by physiological examination should be considered, with psychological information as supporting evidence.

5. Conclusion

We investigated by physiological and psychological indices the visual effects on humans of two actual-size living rooms with different interior designs. The findings were as follows: (1) Although differences in the interior designs caused no significant differences in sensory evaluations, pulse rate and diastolic blood pressure significantly decreased in the standard room, whereas pulse rate significantly increased in the designed room. The room with the common interior caused a calm state of the body, while the room with a design different from ordinary living rooms caused an active state. The physiological investigation was able to reveal an effect of the room interiors that could not be detected by the sensory evaluations. (2) Both rooms caused a significant increase in rCBF, which showed that the subjects were interested in the interiors of the rooms.

The present study clarified that differences in the designs of living rooms cause different physiological responses. It is essential to consider the physiological effects of the visual surroundings when designing housing environments, with information from psychological investigations as supporting evidence. Further study is necessary to detect the factors that cause individual differences in physiological responses, and reflect those individual differences in the designing of artificial environments.

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