

Research paper

## Investigation of Color Images and Visual Responses of Electroencephalograms to Wooden Flooring

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### 【 Summary 】

Using wood as a flooring finish is a common and important selection for local interior decoration practice. Human's feelings and feedback from wooden flooring were investigated through psychological and physiological approaches in the study. A survey with a questionnaire was used to assess the preference of flooring materials among 5 major commercial wood species of various colors. Results indicated that the most favorite wood flooring was made of red incienso, i.e., 44% of interviewed adults, while the least favorite flooring was made of hard maple for 46% of interviewed adults. As to satisfaction with rooms in which different flooring material was installed, high scores were obtained for the psychological images of relaxation, comfort, warmth, and the first impression for wooden flooring compared to ceramic tile flooring. As to colorimetric characteristics of wood in a uniform color space, red incienso flooring material was close to a red color with a lower value of lightness, while hard maple was close to a yellow color with a higher value of lightness. From the electroencephalogram measurements when viewing a room in which different flooring materials were installed, major  $\alpha$  activity was found in the brain's occipital region, and the power of  $\alpha$  activity measured when subjects closed their eyes was 3 times that measured when the eyes were open. The  $\alpha$  activity measured when subjects were viewing a room in which wooden flooring was installed significantly differed from that when viewing a room covered with ceramic tile flooring. No significant difference in subjects'  $\alpha$  activity was found between rooms with red incienso and hard maple flooring materials, but there may have been different responses to flooring materials between males and females. It was found that the highest  $\alpha$  activity or amplitude occurred at 8 Hz when subjects were viewing rooms with different flooring materials, and shifted to around 11 and 12 Hz when subjects closed their eyes.

**Key words:** wood flooring, visual stimulation,  $\alpha$  activity, electroencephalogram.

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## 研究報告

## 木質地板之材色意象與腦電波視覺反應之探討

葉民權<sup>1,3)</sup> 蔡宇哲<sup>2)</sup> 林玉麗<sup>1)</sup> 曾偉菱<sup>1)</sup> 林以婷<sup>1)</sup>

## 摘要

使用木材作為地板裝修是國內室內裝潢常見且是很重要的選項，本研究進行心理及生理方法探討木質地板給予人的感受。首先選用五種主要商用地板區別其色彩，並進行問卷調查，結果發現以祕魯膠樹地板最受消費者喜愛佔44%，而最不喜歡的是硬木地板佔受訪人數之46%。在鋪設地板空間之滿意度方面，則木質地板相較於磁磚地板鋪設空間給予人在放鬆、舒適、溫暖等心理意象上及第一印象均有高滿意度之評價。在量化均一色彩空間中祕魯膠樹偏紅且明度較低、硬木偏黃且明度較高。受測者在觀察不同地板空間的腦電波圖顯示， $\alpha$ 波主要反應位置是在大腦枕葉區，且受測者在閉眼後之 $\alpha$ 波活動較睜眼期間增為3倍以上，具良好之反應性。在觀察木質地板空間時所產生的 $\alpha$ 波反應與磁磚地板空間有顯著的不同，但祕魯膠樹地板與硬木地板間之 $\alpha$ 波反應則無顯著差異，但男女受測者間略有不同。受測者在觀看不同地板時，其 $\alpha$ 波發生最大活動之頻率是在8 Hz，當閉眼後會移至11~12 Hz。

關鍵詞：木地板、視覺反應、 $\alpha$ 波、腦電圖。

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## INTRODUCTION

In general, recognition on an object such as a wood product is mainly based on the human visual sense from photoreceptors through the optic nerve to the cortex of the occipital lobe (Lou et al. 2006). Consequently, people may generate a physiological response to or psychological feelings about the object. However, it is not easy to properly identify the stimulation-response relationship for each case, since humans have various mental states when reacting or complicated thoughts when making a decision. Sohn (2005) tried to relate responses from a wood environment to brain activity. He found that the brain was more activated at the fusiform gyrus, posterior gyrus, parahippocampal gyrus, and frontal gyrus when subjects viewed a picture showing a room with 90% wood products. Some of those activated brain areas are especially

associated with positive sensibility. But no obvious brain activation was measured when subjects were exposed to the pictures containing 0, 30, and 45% wood products. On the other hand, Tsunetsugu et al. (2007) reported that subjects who had viewed a room without a wooden interior showed a small change in autonomic nervous activity, while subjects who had viewed a room with a 45% wooden interior had a significant increase in their pulse rate and had both the highest comfortable and restful feelings measured. In the case of the 90% wooden room, the systolic blood pressure of subjects decreased, but there were a rapid decrease in brain activity and an increase in the pulse rate due to the high coverage of wood. Although regional cerebral blood flow and cerebral activity basically increased, the results did not explain the

preference among interior wood ratios. Wang (2003) indicated that brain activities can be classified into different categories based on the frequency and may be located in different regions of the head for each category. Therefore, further identification of the corresponding brain response may be required for any specific stimulus during an investigation.

Tsai (2011) evaluated the recognition performance of hazard labels using both the event-related brain potential and a questionnaire. Based on the measured amplitude of a positive potential 300 ms after the stimulation, i.e., P300, a good correlation between physiological brain activities and psychological responses was only found in the frontal region, but not in the parietal, central sulcus, or occipital regions. This proved the necessity of selecting an adequate brain region to examine a specific mental state. Tsai also suggested that the gap between objective measurements and subjective measurements might be due to human learning experiences at the psychological level and specific functions among different brain regions.

In general, the color tone gives humans a psychological feeling, and the color of woods usually associated with positive impressions such as warmth, comfort, and calm (Wang 2003). Lin (2011) studied the visual evoked potential with 30 electrode locations using checkerboard patterns in young children. A significant change in the first negative amplitude occurred only in the prefrontal region ( $F_{p1}$ ). That report also indicated that children's brain responses differed among 4 major colors, with a magnitude order of responses to green, red, blue, and black colors. Further, Liu (1994) reported colorimetric characteristics of 22 softwoods and 88 hardwoods grown in China. The lightness or L values ranged 20–90 with most wood species within 50–80. Major wood species also showed 10–25 b\*

values, which indicated a tendency toward yellowish on the yellow-blue axis in the uniform color space. A relationship between colorimetric values of selected wood species samples and psychological visual responses of a subjective evaluation from questionnaires was established for possible furniture product development.

Brain activities can be monitored using electroencephalography (EEG) and can be classified into 4 major categories, i.e.,  $\alpha$ ,  $\beta$ ,  $\delta$ , and  $\theta$  activities, based on the detected frequency. Each brain activity category occurs in some specific regions and can represent different mental characteristics or clinical meanings. The  $\alpha$  activity is classified in the range of 8–13 Hz, and becomes active when humans stay aware and calm, in relaxed situations. It can be an index of comfort evaluation of the human body or the brain, or a calm state (Wang 2003). Cai (2010) used 2 different light pattern figures as visual stimuli for an investigation of brain activity changes in young children. Results indicated that 1 figure significantly affected the average powers of  $\alpha$ ,  $\theta$ , and  $\delta$  activities, while the other figure affected  $\beta$ ,  $\alpha$ , and  $\theta$  activities. The author tried to explain a child's mental states based on these brain activity changes and learning potentials from different light patterns of the visual stimulation. It is believed that different wood colors can cause certain physiological brain activities, which would give people different psychological positive feelings.

In this study, a survey of the preference for and psychological responses to wood species or colors for commercial flooring products was performed with a questionnaire. The physiological responses of people to the visual surrounding in rooms with different flooring materials were investigated using electroencephalograms. The  $\alpha$  activities in selected regions of the head were analyzed.

## MATERIALS AND METHODS

### Survey of flooring preferences

Two survey procedures were performed in the study. The first step was to investigate the preference for various wood species used as wood floor materials. Samples of 5 major commercial wood floor products ranging from light to dark colors were displayed during the survey. Samples of the wood floor products included hickory (*Carya* sp.), red incienso (*Myroxylon* sp.), red oak (*Quercus* sp.), hard maple (*Acer* sp.) and walnut (*Juglans* sp.). In total, 208 interviewed adults were randomly chosen including 100 males and 108 females, and the ages were identified. The second step was to investigate psychological feelings about the installed wood floorings after a visual reaction on an EEG test performed in the experimental room. Items of feeling responses included relaxation, comfort, warmth, preference, and first impression. The questionnaire for the survey was carried out

with a 1~5 Likert scale from the least to the most satisfaction for each item. Subjects were 13 male and 17 female college students aged 21~26 yr. They all had normal visual ability or normal after correction, no mental disease or wounds to the head, and were not taking medical prescriptions. Subjects were also requested to have a goodnight's sleep and wash their hair the day before the EEG test.

### Methods

An experimental room with dimensions of 3550 (width)×6130 (depth)×2500 (height) mm was furnished with desks, a single bed, a closet, a refrigerator, and an air conditioner for EEG data collection (Fig. 1). The walls and ceiling were painted white. The temperature was maintained at around  $27 \pm 1^\circ\text{C}$ . Three flooring materials, i.e., hard maple flooring products (light color), red incienso flooring products (dark color), and ceramic tile (gray color), were alternatively installed. Wood flooring strips were 15 mm

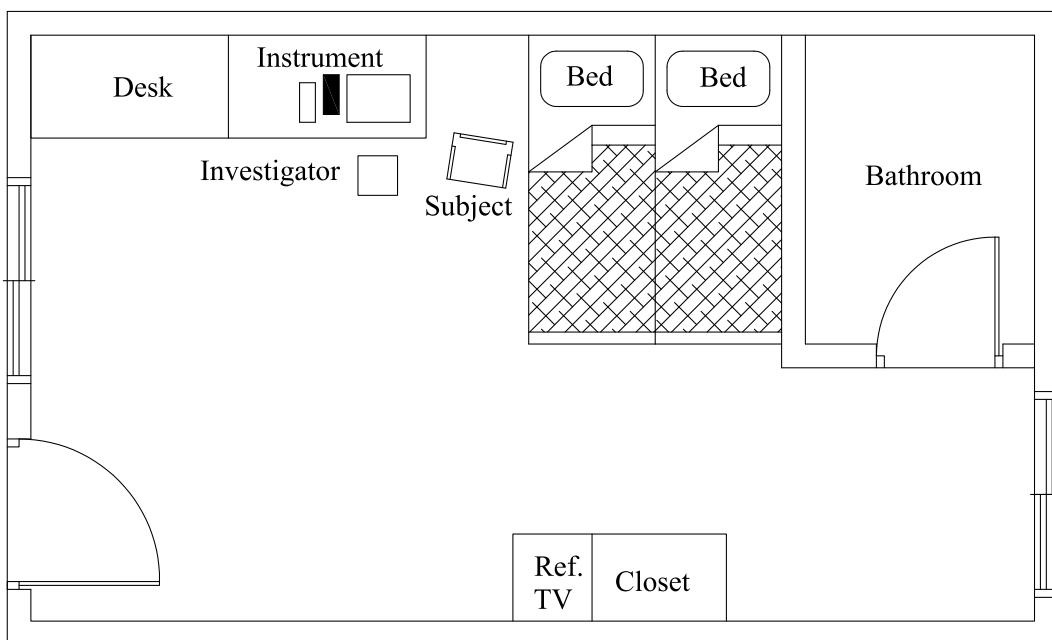


Fig. 1. Plane view of the experimental room for visual reaction to wooden flooring.

thick and 120 mm wide with a random length, and the size of the ceramic tiles was  $30 \times 30$  mm. The lightness and hue of the color measurements were tested using a CR-300 colorimeter (Konica Minolta, Tokyo, Japan) for all wood samples and ceramic tile.

The EEG acquisition procedure for viewing the flooring types is demonstrated in Fig. 2. Three days were required for each subject whose EEG data were recorded on 1 d for each flooring type. Locations of electrodes followed the international 10~20 system (Lüders and Noachtar 2000). Locations of  $F_3$  and  $F_4$  in the frontal region and  $O_1$  and  $O_2$  in the occipital region were selected for EEG response measurement acquisition (Fig. 3). An ipsilateral ear reference montage was employed at positions  $A_1$  and  $A_2$ . One electrode was mounted beneath an eye position to monitor eye movements. A ground line was attached to the forehead. EEG responses were measured using Neurolo EEG Systems E-series (Compumedics, Abbotsford, VIC, Australia) through an EEG64 control module and an EEG32 channel patient interface box. The subject was first told about the experimental procedure and signed an agreement to participate in the test. Then, the operators began to mount the electrode sensors on the subject's head. Ear plugs were used to block noise before monitoring the EEG. A subject was then asked to look around and feel the experimental environment for 3 min and close their eyes for another 3 min to detect the EEG responses. A questionnaire on satisfaction with the installed flooring materials was filled out at the end of the session.

An analysis of variance (ANOVA) and paired *t*-test were performed using SPSS statistical software (SPSS, Chicago, IL, USA) for the wood flooring preference survey and EEG responses of visual reactions to the different floor types.

## RESULTS AND DISCUSSION

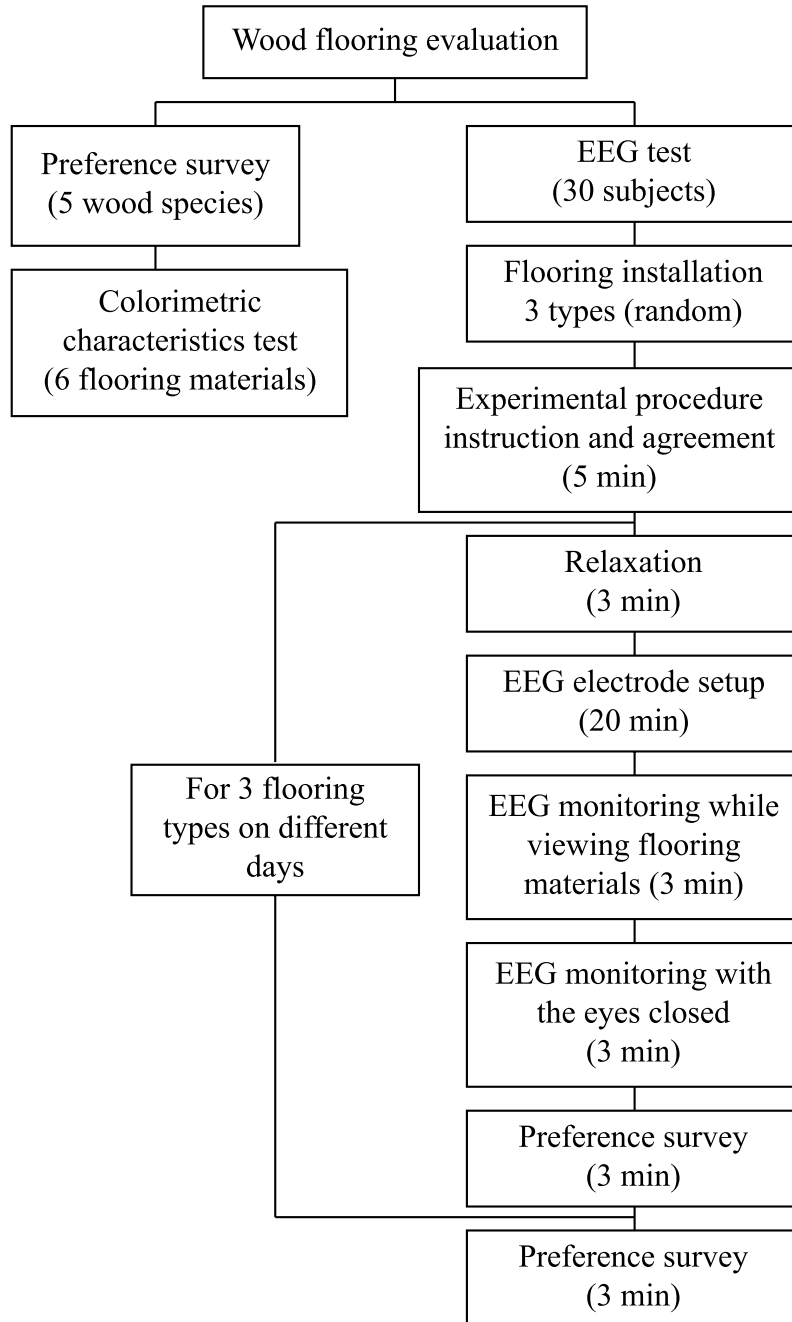
### Preference for wood flooring

There was 71% of interviewed people aged 20~40 yr in the first stage of the survey on the preference of wood flooring materials among 5 wood species. The most favorite wood flooring was made of red incienso, at 44% (Fig. 4). Red incienso wood exhibits a brownish-red appearance compared to the other wood species. A brownish-red color of wood materials can produce warm feelings in humans (Wang 2003). This suggested that red incienso is appropriate as a flooring product from a psychological point of view. The least favorite wood flooring was made of hard maple at 46%. Hard maple had a lighter appearance than the other wood species, which might have been counter to most people's choice for an indoor flooring application. It was noted that walnut flooring products were listed as the second rankings for both the most favorite choice (21%) and the least favorite choice (23%). Walnut exhibited a darker appearance compared to the other wood species. A darker color always gives humans a steady and calm impression and also has a masculine sense (Zheng 2011). It was also noted that the number of interviewed females aged 20~40 yr who liked walnut flooring was more than twice that of interviewed males. Only a few people showed little preference among the 5 observed wood flooring materials. Further, the interviewed persons aged 20~40 yr, who might be potential home buyers purchasing flooring products, also showed a similar preference trend. Both young females and males had the same choices for the most favorite and least favorite flooring products.

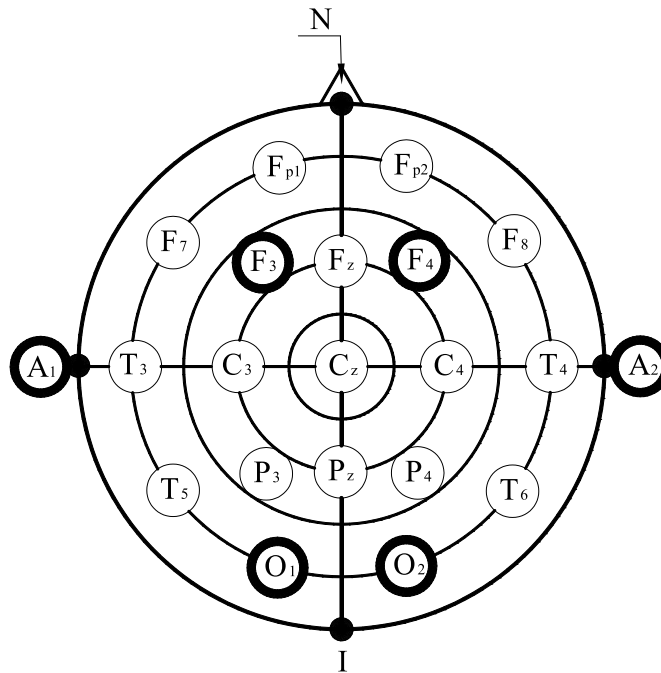
Satisfaction, i.e., expressed on a 1~5 Likert scale, with characteristic psychological descriptions of the different flooring materials in the experimental room is shown in Fig. 5.

These descriptions about the wood were chosen from correlations among lightness, color, saturation, and human impressions (Wang

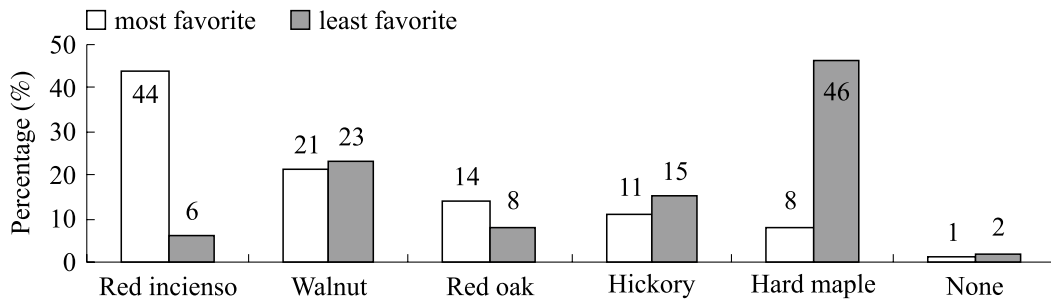
2003, Zheng 2011). Both the red incienso and hard maple floorings obtained high scores on satisfaction in terms of feelings of warmth,



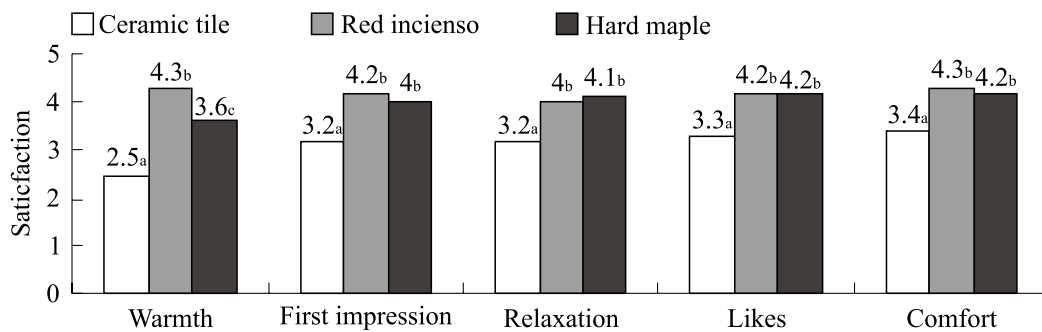
**Fig. 2.** Flow chart of experimental procedures for EEG acquisition with visual stimulus of wood flooring.



**Fig. 3.** Four locations in the frontal and occipital regions with an ear reference montage used for EEG responses.



**Fig. 4.** Survey of the most and least favorite wood species for flooring materials.



**Fig. 5.** Satisfaction with characteristic psychological feelings for different floorings. (Expressed on a 1~5 Likert scale, with Duncan's groupings at the 5% level, a < b < c).

relaxation, likes, and comfort. Only an average value on the satisfaction survey for those characteristic psychological responses was obtained for ceramic tile flooring. The wood flooring materials installed in the room also gave a more-satisfactory impression at first sight than the floor covered with ceramic tile. Saito et al. (2009) investigated the effects of Japanese cedar walls on human stress reduction using a profile of a mood states test. The negative psychological parameters included tension-anxiety, depression-dejection, anger-hostility, fatigue, and confusion. Scores showed significant alleviation after 30 min staying in the decorated room. Kimura et al. (2011) also reported that comfort feelings resulted when subjects entered 3 rooms covered with 20.2~97.7% hiba wood interior compared to a standard living room with 1.2% wood strips. This further demonstrates the comfort of a wooden living environment. Table 1 shows the subjects' preference ranking among the 3 installed flooring materials after finishing the EEG tests. Results indicated that the attendants significantly preferred wooden flooring among the psychological responses of warmth, relaxation, likes and comfort compared to the room in which ceramic tile flooring was installed. The red incienso flooring produced a warmer feeling than did the hard maple flooring. Subjects also more highly liked the red incienso flooring than the hard maple flooring, which is the same result as consumer's opinions shown in Fig. 4.

**Table 1. Ranking of preference for different flooring types**

| Psychological description | Ceramic tile floor | Hard maple floor  | Red incienso floor |
|---------------------------|--------------------|-------------------|--------------------|
| Warmth                    | 1.03 <sup>a</sup>  | 2.10 <sup>b</sup> | 2.87 <sup>c</sup>  |
| Relaxing                  | 1.13 <sup>a</sup>  | 2.50 <sup>b</sup> | 2.37 <sup>b</sup>  |
| Likes                     | 1.17 <sup>a</sup>  | 2.27 <sup>b</sup> | 2.57 <sup>c</sup>  |
| Comfortable               | 1.10 <sup>a</sup>  | 2.37 <sup>b</sup> | 2.53 <sup>b</sup>  |

<sup>1)</sup> Values in the table are the average of 30 subjects' preference ranking from 1 (least preferred) to 3 (most preferred). Duncan's grouping,  $\alpha = 0.05$ ,  $a < b < c$ .

**Colorimetric characteristics of wooden flooring materials**

Colorimetric values of the uniform color space system for the 5 wooden flooring materials and ceramic tile were measured and are listed in Table 2. Lightness (L\* value) of wood samples was between 39.9 (walnut) and 77.5 (hard maple), and all values were lower than ceramic tile values. The red incienso floor had the highest a\* value which indicates a strong sense of a red color, while the hard maple showed the lowest value among the 5 wood species. The preference survey results also indicated a stronger warm feeling for the red incienso flooring material than for hard maple. In general, the walnut flooring material showed lower values for both red (a\* value) and yellow (b\* value) colors among the 5 wood flooring materials and were similar to values for ceramic tile but with very low

**Table 2. Colorimetric values of flooring materials**

| Floor type   | L                        | a*         | b*         |
|--------------|--------------------------|------------|------------|
| Hard maple   | 77.5 (2.8) <sup>1)</sup> | 8.1 (1.2)  | 21.5 (1.3) |
| Red incienso | 42.1 (2.4)               | 22.8 (1.7) | 15.9 (3.6) |
| Red oak      | 60.9 (3.4)               | 15.3 (0.9) | 26.9 (1.1) |
| Hickory      | 50.2 (5.6)               | 18.2 (1.6) | 25.6 (4.2) |
| Walnut       | 39.9 (2.9)               | 10.7 (1.6) | 11.6 (2.0) |
| Ceramic tile | 86.4 (0.2)               | 0.0 (0.0)  | 6.9 (0.4)  |

L, lightness; a\*, color index of red-green axis; b\*, color index of yellow-blue axis.

<sup>1)</sup> Data are presented as the mean (standard deviation).



lightness. Chen et al. (2009) reported the visual image of 5 wood species from Alisan had warm feelings except for Taiwania, which had lightness values of 60~65 and  $b^*$  values of 22~27 for softwood. Zheng (2011) suggested that hard maple fit the mental image of relaxation and brightness based on the  $L^*$  values, while red incienso corresponded to an image of luxury and passion based on the  $a^*$  values. Thus, different colorimetric characteristics of wood can influence a customer's choice for flooring products. Both studies showed some psychological images for wood materials, but they were not correlated to any specific end application for wood products. Lin (2011) reported that the brain activities responding to colors also differed based on the temperament of children. Black and red colors incurred the highest magnitude of the P300 amplitude for slow-to-warm-up children, while green color resulted in a highest value for intermediately difficult children.

### EEG analysis

Figure 6 shows typical results of brain EEGs monitored at selected locations for 1 subject subjected to the visual stimulus of

wooden flooring tests while in the closed-eye stage. A reference montage approach was used to find the real magnitude of signals in each channel instead of relative values. As the  $A_1$ - $A_2$  montage or unipolar recording was applied, the tendency of major  $\alpha$  activity ranging 8~12 Hz clearly appeared in both the  $O_1$ - $A_2$  and  $O_2$ - $A_1$  channels, while they were greatly reduced in both amplitude and occurrence in the  $F_3$ - $A_2$  and  $F_4$ - $A_1$  channels. The  $\alpha$  activity represents human's mental state especially in a calm, relaxed, and aware situation. Quan and Lin (2007) also suggested that a suitable region for observing  $\alpha$  activity or rhythm is in the occipital lobe. Figure 7 shows a brain coherence map example with a 1-s period for 1 subject who was given the visual stimulus of wooden flooring tests. It shows a 2-dimension (2D) brain map which indicated that strong  $\alpha$  activity or occurrence dominated in the occipital lobe, i.e.,  $O_1$  and  $O_2$ . A frequency power spectrum was used to identify the electronic frequency with the power peak. It also showed that brain activities in the  $O_1$ - $A_2$  and  $O_2$ - $A_1$  channels always had a high electric voltage peak or amplitude in a wave form around 8~11 Hz, which is

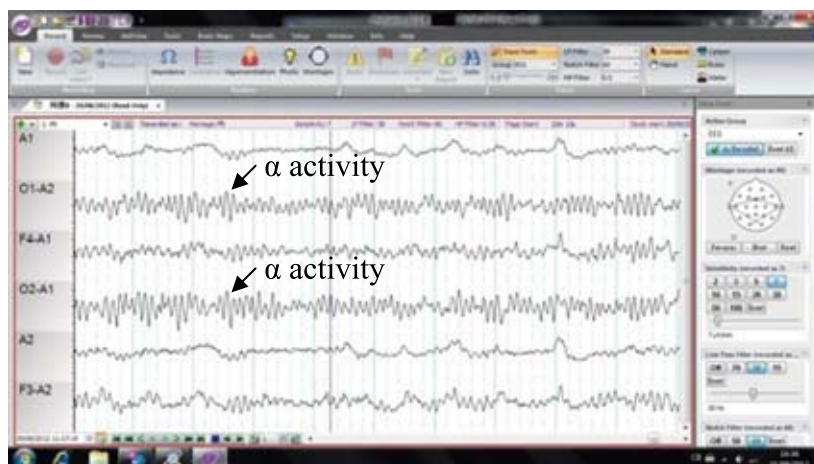
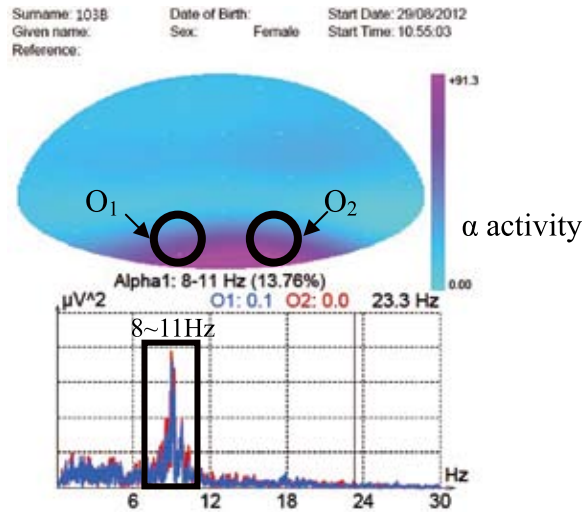


Fig. 6. EEG responses indicating major  $\alpha$  activities in the  $O_1$ - $A_2$  and  $O_2$ - $A_1$  channels and less in the  $F_3$ - $A_2$  and  $F_4$ - $A_1$  channels.



**Fig. 7. Brain coherence map indicating major  $\alpha$  activity in both the  $O_1$  and  $O_2$  locations in a 2D brain map and activation in the 8~11-Hz range of the frequency power spectrum.**

classified as  $\alpha$  activity. All of the EEG measurements were first arranged by removing any potential artifact signals such as these caused by body movements or blinking. Then, a fast Fourier transformation was performed to obtain the brain electric power based on the frequency spectrum. Results for each brain location and 3 flooring types are listed in Table 3. It showed that subjects'  $\alpha$  activities occurring at  $O_1$  and  $O_2$  locations were 84.2%, on average, higher than those at the  $F_3$  and  $F_4$  locations when viewing the decorated floors. It also showed that  $\alpha$  activities occurring at the  $O_1$  and  $O_2$  locations were 4-times those at the  $F_3$  and  $F_4$  locations when subjects' eyes were closed. A paired or correlated  $t$ -test was performed to compare changes in  $\alpha$  activity before and after the eyes were closed. It indicated a significant increase in average  $\alpha$  activity values after the eyes were closed mainly in the occipital lobe ( $O_1$  and  $O_2$  locations) instead of the frontal lobe ( $F_3$  and  $F_4$ ) among the red incienso, hard maple, and ceramic tile flooring materials. In general, subjects'  $\alpha$  activity after viewing wood flooring did not show a significant difference from that after

viewing ceramic flooring based on the ANOVA. By combining the proper phenomena of the brain activity in the frequency range, head locations, and reactivity from the EEG, it was identified as an  $\alpha$  rhythm. Results in Table 3 also show that  $\alpha$  activity of the right brain ( $O_2$  location) was higher than that of the left side ( $O_1$  location). Small changes in  $\alpha$  activity in both the  $F_3$  and  $F_4$  channels might indicate that the frontal lobe is not a major area for  $\alpha$  activity observations.

In general,  $\alpha$  activities were more active in the occipital lobe and had about twice the calculated power as measured in the frontal lobe when the eyes were open during the visual stimulus in the testing room.  $\alpha$  activities were compared using paired  $t$ -tests as subjects viewed the rooms with different flooring materials while keeping the eyes open, and results are given in Table 4. Results showed a significant difference in  $\alpha$  activity in the occipital lobe of subjects who had viewed rooms in which ceramic tile flooring and wood flooring had been installed. It was noted that subjects had lower  $\alpha$  activities when viewing wooden flooring in the test

**Table 3. Average  $\alpha$  activity power measured in EEG tests when 30 subjects viewed a room with different flooring types installed**

| Floor type            | Location       | Degree of freedom | Eyes open stage ( $\mu V^2$ ) | Eyes close stage ( $\mu V^2$ ) | Paired <i>t</i> -test | Significance <i>P</i> |
|-----------------------|----------------|-------------------|-------------------------------|--------------------------------|-----------------------|-----------------------|
| Ceramic tile flooring | F <sub>3</sub> | 29                | 11.4 (6.1) <sup>1)</sup>      | 12.3 (6.5)                     | 0.64                  | 0.53                  |
|                       | F <sub>4</sub> | 29                | 14.0 (6.9)                    | 14.4 (7.9)                     | 0.28                  | 0.78                  |
|                       | O <sub>1</sub> | 29                | 24.0 (28.3)                   | 50.7 (45.0)                    | 4.45                  | 0.00**                |
|                       | O <sub>2</sub> | 29                | 29.0 (40.8)                   | 70.4 (67.0)                    | 4.95                  | 0.00**                |
| Maple flooring        | F <sub>3</sub> | 29                | 10.8 (4.7)                    | 13.6 (7.1)                     | 2.66                  | 0.01**                |
|                       | F <sub>4</sub> | 29                | 12.9 (6.9)                    | 15.5 (10.0)                    | 2.00                  | 0.05*                 |
|                       | O <sub>1</sub> | 29                | 17.3 (17.9)                   | 47.8 (35.8)                    | 6.59                  | 0.00**                |
|                       | O <sub>2</sub> | 29                | 21.8 (24.9)                   | 71.7 (71.1)                    | 4.44                  | 0.00**                |
| Red incienso flooring | F <sub>3</sub> | 29                | 9.9 (5.3)                     | 11.6 (7.1)                     | 1.39                  | 0.17                  |
|                       | F <sub>4</sub> | 29                | 13.1 (6.5)                    | 14.5 (8.6)                     | 0.84                  | 0.41                  |
|                       | O <sub>1</sub> | 29                | 18.4 (18.2)                   | 52.1 (44.8)                    | 5.27                  | 0.00**                |
|                       | O <sub>2</sub> | 29                | 22.0 (26.5)                   | 67.2 (68.1)                    | 4.58                  | 0.00**                |

<sup>1)</sup> Data are presented as the mean (standard deviation).

**Table 4. Paired *t*-tests for the  $\alpha$  activity of subjects who viewed rooms with different floorings with their eyes open**

| Comparison                                      | Location       | Power difference ( $\mu V^2$ ) | Paired <i>t</i> -test | Significance <i>p</i> |
|-------------------------------------------------|----------------|--------------------------------|-----------------------|-----------------------|
| Ceramic tile flooring vs. maple flooring        | F <sub>3</sub> | 0.58 (0.97) <sup>1)</sup>      | 0.60                  | 0.56                  |
|                                                 | F <sub>4</sub> | 1.14 (1.08)                    | 1.06                  | 0.30                  |
|                                                 | O <sub>1</sub> | 6.66 (2.41)                    | 2.76                  | 0.01**                |
|                                                 | O <sub>2</sub> | 7.21 (3.35)                    | 2.15                  | 0.04*                 |
| Ceramic tile flooring vs. red incienso flooring | F <sub>3</sub> | 1.56 (1.27)                    | 1.23                  | 0.23                  |
|                                                 | F <sub>4</sub> | 0.84 (1.34)                    | 0.63                  | 0.54                  |
|                                                 | O <sub>1</sub> | 5.62 (2.43)                    | 2.31                  | 0.03*                 |
|                                                 | O <sub>2</sub> | 7.01 (3.38)                    | 2.08                  | 0.05*                 |
| Red incienso flooring vs. maple flooring        | F <sub>3</sub> | -0.97 (0.85)                   | -1.14                 | 0.26                  |
|                                                 | F <sub>4</sub> | 0.29 (1.12)                    | 0.26                  | 0.80                  |
|                                                 | O <sub>1</sub> | 1.04 (1.19)                    | 0.87                  | 0.39                  |
|                                                 | O <sub>2</sub> | 0.20 (1.81)                    | 0.11                  | 0.92                  |

<sup>1)</sup> Standard deviation.

room. Also, only small  $\alpha$  activity changes in the frontal lobe were observed when subjects viewed different flooring types. No further difference in  $\alpha$  activity between rooms with 2 wooden floors, i.e., red incienso and hard maple, was found. Saito et al. (2009) examined concentration changes of biochemical parameters included chromogranin A, cortisol, and

immunoglobulin A in saliva when subjects stayed in a room finished with Japanese cedar walls. The results showed that the excited sympathetic nervous system after taking an Uchida-Kraepelin test tended to gradually subside. This stress reduction originally came from the visual stimulus and should have induced certain brain activity. Kimura et al.

(2011) also found sympathetic nervous activities when subjects entered rooms with hiba wood walls and floors in various coverage, including decreases in systolic and diastolic blood pressures and a change in the salivary  $\alpha$ -amylase. According to our survey results, subjects gave high values for relaxation and comfort descriptions when they viewed both wooden floors. This feeling may have further incurred a reduction in  $\alpha$  activity. The  $\alpha$  activity in the occipital lobe was further analyzed based on subjects' gender, and results are given in Table 5. In the case of male subjects, a significant difference in  $\alpha$  activity was found only at  $O_2$  when they viewed the ceramic tile floor and red incienso floor. While in female subjects,  $\alpha$  activity at  $O_1$  significantly differed when they viewed the ceramic tile floor and hard maple floor. This may indicate that males prefer the red incienso floor, while females prefer the hard maple floor compared to the ceramic tile floor.

A test of independence between subjects' psychological perceptions and changes in  $\alpha$

activity was performed using a non-parametric Chi-squared test and bivariate correlation test. Preferences in psychological responses of warmth, relaxation, likeness, and comfort parameters with the wooden flooring and ceramic flooring were identified with 3 categories of least preference as 1, similar as 2, and most preference as 3. Corresponding subject's  $\alpha$  activity was coded as 1 for an increase and 2 for a reduction. Even though 75 and 67% of subjects felt relaxation with the incienso flooring and showed reductions in  $\alpha$  activities at  $O_1$  and  $O_2$ , respectively, statistical results did not show a significant relation between the attendant preference of relaxation feeling for flooring types with  $\alpha$  activity changes. Similar results were also found for the other psychological responses of warmth, likes, and comfort. Again, averages of 74, 68, and 67% of subjects, respectively, had a preference for the incienso flooring and showed reductions in  $\alpha$  activity in the occipital lobe compared to the room in which ceramic tile flooring was installed. In the case of viewing the maple

**Table 5. Paired *t*-tests for the  $\alpha$  activities of male and female subjects who viewed rooms with different floorings with their eyes open**

| Gender | Comparison                                      | Location | Power difference<br>( $\mu V^2$ ) | Paired<br><i>t</i> -test | Significance<br><i>p</i> |
|--------|-------------------------------------------------|----------|-----------------------------------|--------------------------|--------------------------|
| Male   | Ceramic tile flooring vs. maple flooring        | $O_1$    | 5.91 (3.47) <sup>2)</sup>         | 1.70                     | 0.11                     |
|        |                                                 | $O_2$    | 4.07 (2.85)                       | 1.43                     | 0.18                     |
|        | Ceramic tile flooring vs. red incienso flooring | $O_1$    | 6.35 (3.47)                       | 1.83                     | 0.09                     |
|        |                                                 | $O_2$    | 6.46 (2.70)                       | 2.39                     | 0.03*                    |
|        | Maple flooring vs. red incienso flooring        | $O_1$    | 0.44 (1.80)                       | 0.24                     | 0.81                     |
|        |                                                 | $O_2$    | 2.39 (1.48)                       | 1.62                     | 0.13                     |
| Female | Ceramic tile flooring vs. maple flooring        | $O_1$    | 7.24 (3.42)                       | 2.12                     | 0.05*                    |
|        |                                                 | $O_2$    | 9.60 (5.52)                       | 1.74                     | 0.10                     |
|        | Ceramic tile flooring vs. red incienso flooring | $O_1$    | 5.06 (3.46)                       | 1.46                     | 0.16                     |
|        |                                                 | $O_2$    | 7.43 (5.68)                       | 1.31                     | 0.21                     |
|        | Maple flooring vs. Red incienso flooring        | $O_1$    | -2.17 (1.58)                      | 1.38                     | 0.19                     |
|        |                                                 | $O_2$    | -2.17 (2.95)                      | 0.74                     | 0.47                     |

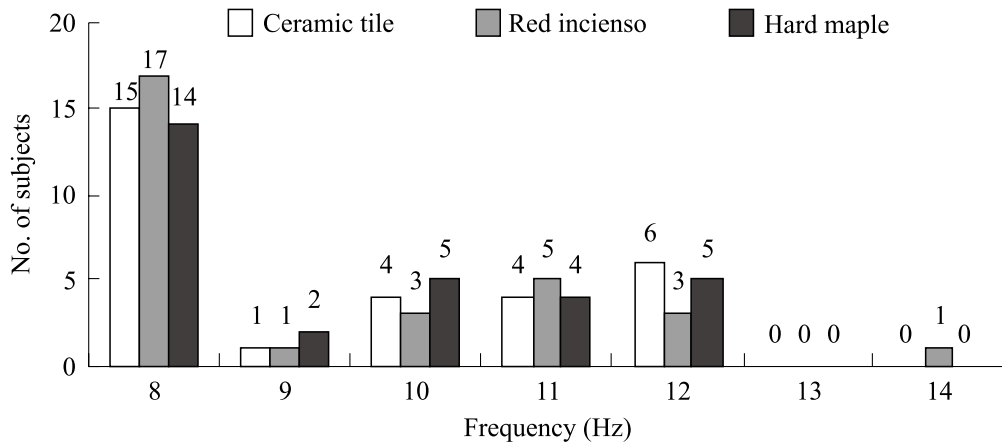
<sup>1)</sup> The degrees of freedom for male parameters was 12, and for female parameters was 16.

<sup>2)</sup> Standard deviation.

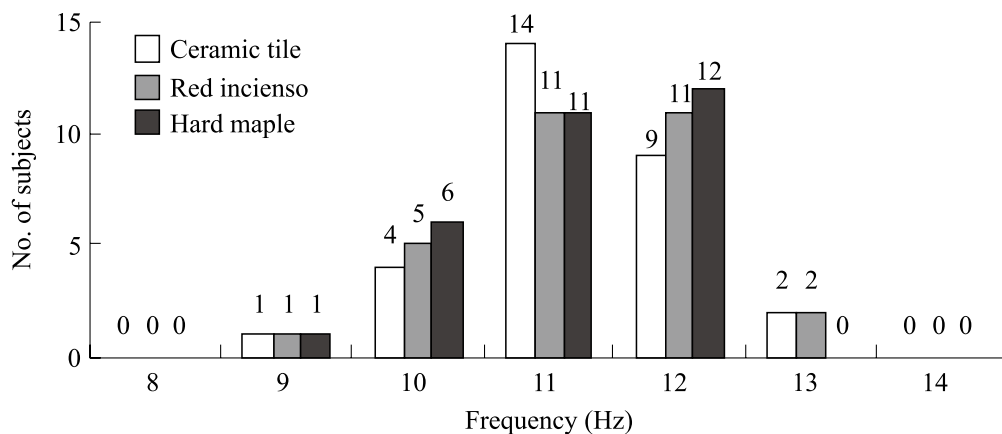
flooring, there was a tendency for a high percentage of subjects to have a preference for viewing wood flooring, and reductions of  $\alpha$  activity were also found. However, the low Spearman's rho values also indicated an insignificant correlation between the preference of those psychological responses for maple flooring and corresponding reductions in  $\alpha$  activity.

$\alpha$  activities in the occipital lobe were analyzed based on the frequency domain

through a fast Fourier transformation procedure. Each subject showed different brain activity powers at each frequency from 8 to 14 Hz. Figure 8 shows that most subjects had the highest  $\alpha$  activity or amplitude at 8 Hz when they viewed rooms with different flooring materials. It was found that when subjects closed their eyes, the highest  $\alpha$  activity shifted to 11 and 12 Hz (Fig. 9). Usually,  $\alpha$  activity appears in the occipital lobe when humans stay calm and may possibly change to a major



**Fig. 8.** Occurrence distribution of 30 subjects based on the frequency of the highest  $\alpha$  activity in the  $O_2$  region when viewing a room with different flooring materials.



**Fig. 9.** Occurrence distribution of 30 subjects based on the frequency of the highest  $\alpha$  activity in the  $O_2$  region after a visual stimulus in the test room and then the eyes were closed.

frequency because of day or night differences or female's menses (Zhang 2004). Zhang also reported average  $\alpha$  activity commonly at 10 Hz for adults and 8.5 Hz for children. In this study, subjects were college students aged 21~26 yr. Further study may be required to identify possible causes of the frequency shift.

## CONCLUSIONS

Customers preferred using red incienso as wood flooring materials among 5 major commercial products, and hard maple was the least favorite for this application based on a survey comprising mainly 20~40-yr-old interviewed adults. Compared to the ceramic tile floor, both rooms installed with red incienso and hard maple floorings showed higher satisfaction in psychological feelings in terms of comfort and relaxation. The room in which red incienso flooring was installed had the highest score in providing a warm feeling and had the most satisfactory impression at first sight.

The red incienso floor with high  $a^*$  value in colorimetric characteristics gave a strong sense of red color while the hard maple showed a low value among the 5 wood species. A stronger warm feeling of red incienso flooring material was indicated than that of hard maple. From the EEG testing, high  $\alpha$  activities were found in the occipital lobe instead of in the frontal lobe when the eyes were open and became influential when the eyes were closed after receiving visual stimuli. Subjects viewing the room in which hard maple flooring was installed had higher  $\alpha$  activities in the  $F_3$ ,  $F_4$ , and  $O_2$  regions when the eyes were closed, and in the  $O_2$  region for red incienso flooring.  $\alpha$  activities of subjects as stimulated by both wood flooring materials significantly differed from ceramic tile

flooring, meaning a wooden environment can induce certain physiological responses in the human body.

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