Lighting Effects on Visual Impression of a Real-Room Space

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Abstract: A psychophysical experiment was carried out in a "shooting studio" to investigate visual impression of a real-room space induced by lighting conditions and the wall colours. Six lighting conditions were adopted, generated by two correlated colour temperatures (6500K and 2700K) and three lighting directions, including (A) light travelling up and sideway, (B) a non-directional floor lamp, and (C) light travelling down. Six wall colours were used: grey, white, black, light yellow, light blue and light green. Nineteen Chinese observers, including 8 males and 11 females, participated in the study. Each observer was asked to sit in the room, and for each experimental condition the observer rated the room using 10 scales: like/dislike, comfortable/uncomfortable, warm/cool, spacious/small, bright/dark, clean/dirty, relaxing/tense, elegant/inelegant, classical/ modern and harmonious/disharmonious. The experimental results show that the observers liked the room most when the room appeared warmth and spacious. The 6500K light source tended to induce bright or cool impression, while the 2700K tended to induce warm or dark feelings. Female observers tended to be more sensitive than male observers to changes in wall colours and lighting conditions, while the male observers tended to be more stringent when rating the experimental rooms.

Key words: visual impression, interior design, indoor lighting, real room, visual comfort

1. Introduction

Visual impression of an indoor environment has been of interest to researchers and related industries. Many existing studies, however, chose not to use real rooms for their experiments but rather tended to use computer-simulated indoor images as the stimuli. For instance, Shen et al. [1] used bedroom images shown on a computer monitor to study colour harmony and the exciting-calm response; as a result they developed a colour selection system based on fuzzy set theories. Brengman and Geuens [2] used store interior images to study colour emotion and found significant impact of colour on observers' responses in terms of pleasure, excitement and tension. The main reason for not using real rooms in the experiments was perhaps due to the difficulty in changing colour elements efficiently within a real room. It is unclear, however, as to whether the findings based on simulated images can also apply to a real indoor space.

Recent studies into colour harmony took advantage of modern colour science techniques. A number of quantitative models of colour harmony have been developed with satisfactory predictive performance using interior images [3-4]. The same question arises regarding whether such models can be applied in a real-room environment. In addition, it is still unclear whether and how the observer's visual impression of a room can be influenced by the lighting conditions. This is particularly essential for today's lighting industry given the continued increasing popularity of LED lighting in various areas.

To address these issues, a psychophysical experiment was carried out in the present study using a real-room space, in an attempt to investigate visual impression of a real room induced by lighting conditions and the wall colour.

2. Methods

A "shooting studio" was used as the experimental room, with a size of 3m (width) x 3m (depth) x 2.5m (height), as defined by three "walls" in the form of coloured cloth sets. The "wall colours" can be easily changed using a rail system that controlled the coloured cloth sets. A total of 6 wall colours were used: grey, white, black, light yellow, light blue and light green. The former three colours were achromatic but differed in lightness level; the latter three colours were selected to create "warm", "cold" and "medium" feelings. Table 1 shows CIELAB values of the 6 wall colours, determined by colorimetric measurement results using an X-Rite 962 Spectrophotometer.

Table 1. CIELAB specifications of the 6 wall colours

	L*	a*	b*	C^*_{ab}	h_{ab}
Black	16.8	0.1	-1.5	1.5	273.9
Grey	40.5	1.8	-11.2	11.4	279.2
White	93.8	2.0	-8.2	8.5	283.9
Light Yellow	88.4	2.1	14.4	14.5	81.6
Light Blue	54.7	-7.5	-2.8	8.0	200.5
Light Green	65.7	-14.7	43.0	45.5	108.9

Six lighting conditions were adopted, generated by two correlated colour temperatures (6500K and 2700K) and three lighting directions, including (A) light travelling up and sideway, (B) a non-directional floor lamp, and (C) light travelling down. This resulted in 6 (wall colours) x 2 (correlated colour temperatures) x 3 (lighting directions) = 36 experimental conditions, as illustrated in Figure 1.

Ten semantic scales were used in this experiment to measure the observers' visual impression of the room: like/dislike, comfortable/uncomfortable, warm/cool, spacious/small, bright/dark, clean/dirty, relaxing/tense, elegant/inelegant, classical/modern and harmonious/disharmonious. The 10 scales were selected based on results of a questionnaire. The questionnaire required 19 participants, including 8 males and 11 females, to write down 15 adjectives related to the impression of a "living room". As a result, 8 adjectives were selected as they were most frequently mentioned in the questionnaire. In addition to the 8 adjectives, "like" and "harmonious" were also used in this research to study colour preference and colour harmony in a real room environment. Thus, these adjectives were used to create the 10 bipolar scales.

Nineteen Chinese observers, including 8 males and 11 females, participated in the experiment. All observers were citizens of Taipei, Taiwan. Among the observers, 9 had professional design trainings. All observers have passed Ishihara's test for colour deficiency before the experiment.

Each observer was asked to sit in the experimental room, and for each experimental condition the observer rated the room using the 10 scales in Mandarin. Observers started rating after 30 seconds of adaptation to each experimental condition. The sequence of the 36 experimental conditions was randomised. Each of the 10 scales consisted of forced-choice 6 categories. Taking “spacious/small” as an example, the 6 categories included “very spacious”, “spacious”, “a little spacious”, “a little small”, “small”, “very small”.

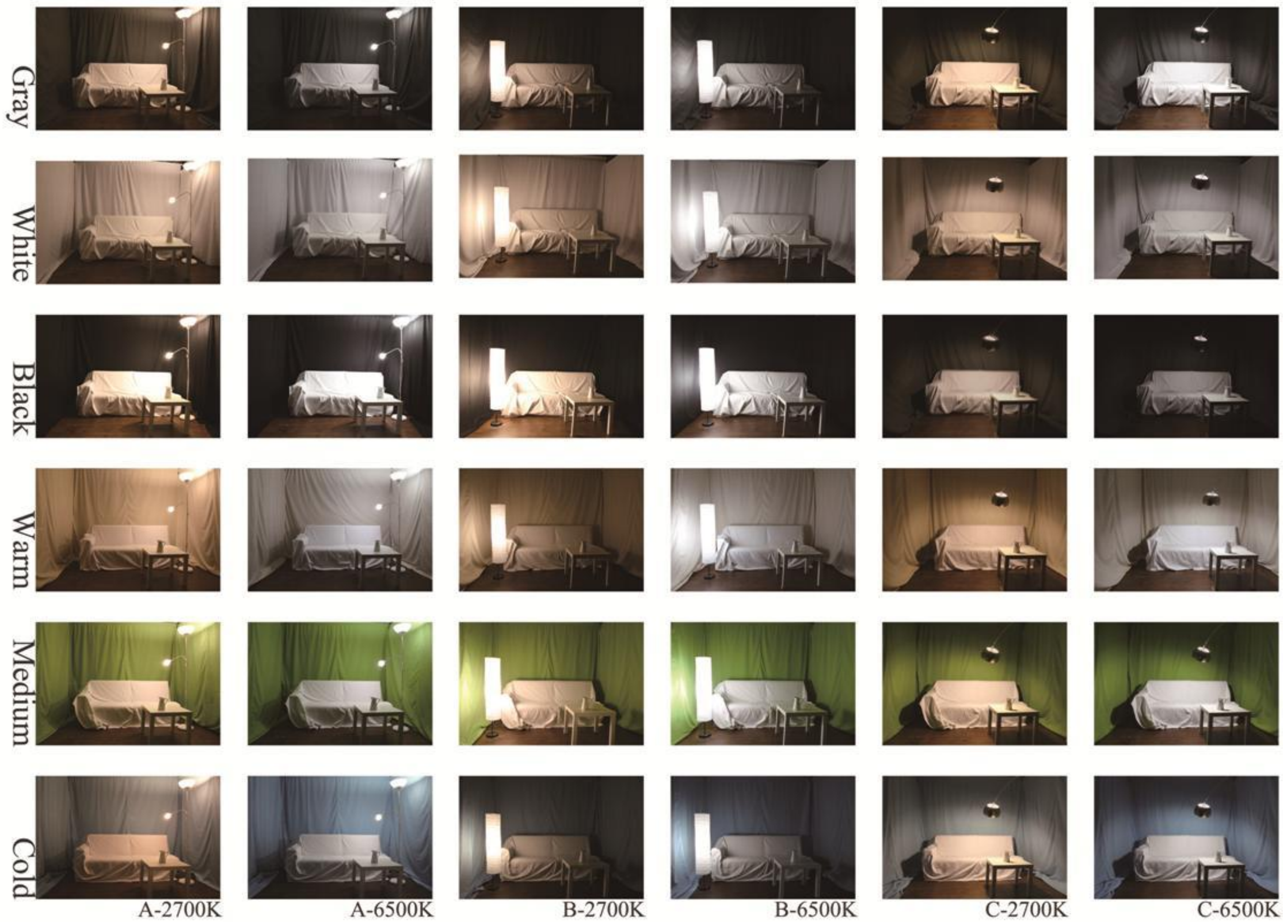


Figure 1. The 36 experimental conditions

3. Results

The aim of the study was to investigate visual impression of a real room induced by lighting conditions and the wall colour. To see whether there was any gender difference in the observer responses, the experimental data were divided into the two gender groups. For each of the 10 scales, Torgerson’s Law of Categorical Judgement [5] was used to convert the experimental data of each gender group into an interval scale related to the z-score.

To see whether or not the three variables (i.e. the wall colour, the lighting direction and the correlated colour temperature of the light source) had significant effects on the experimental results and whether the three variables interacted with each other, the analysis of variance (ANOVA) were conducted. As shown in Table 2, there seems to be significant interactions between wall colour and correlated colour temperature. According to the experimental data, the 6500K light source worked quite well with the blue wall colour, but showed the worst impression of the room with the black walls. The 2700K light source worked well with the yellow walls, but showed the worst impression with blue walls.

Table 2. Three-way analysis of variance (ANOVA) for visual impressions of the experimental room induced by wall colour, lighting direction and correlated colour temperature

	F-value	p-value
Wall colour	11.303	.000
Lighting direction	8.454	.000
Correlated Colour Temperature (CCT)	10.582	.001
Wall colour x Lighting direction	.898	.535
Wall colour x CCT	4.571	.000
Lighting direction x CCT	2.518	.081
Wall colour x Lighting direction x CCT	.611	.805

To see whether the experimental results were influenced by observer gender, the experimental data for male and female groups were compared in terms of correlation coefficient. Table 3 shows comparison results between the two gender groups. Most of the semantic scales, including warm/cool, spacious/small, comfortable/ uncomfortable, relaxed/tense and classical/modern, show high correlation coefficients, suggesting good consistency in the observer responses between the two genders. "Harmonious/disharmonious" and "like/dislike" show the lowest correlation coefficients, suggesting strong effect of observer gender on the two scales.

Table 3. Correlation coefficients between the two gender groups for the 10 semantic scales

Like/dislike	Bright/dark	Warm/cool	Spacious/small	Comfortable/uncomfortable
0.50	0.56	0.94	0.72	0.73
Clean/dirty	Relaxed/tense	Elegant/inelegant	Classical/modern	Harmonious/disharmonious
0.61	0.78	0.52	0.83	0.46

Principal component analysis was used to classify the 36 experimental conditions and create a semantic map where the interrelationships between these experimental conditions are demonstrated. Two principal components "warmth" and "spaciousness", were extracted, as demonstrated in Table 4 and Figure 2. The two principal components, accounting for 86.7% of the total variance, were regarded as the underlying factors for the experimental data. The "warmth" factor was found to correlate closely with classical/modern, relaxed/tense, comfortable/uncomfortable and elegant/rough. The "spaciousness" was highly correlated with spacious/narrow and clean/dirty. Note that like/dislike was correlated moderately with both factors, with a component loading of 0.752 for the "warmth" factor and 0.452 for the "spaciousness" factor. This suggests that the observers liked the experimental room most when the room appeared both warmth and spacious.

Figures 3 (a) and (b) show distribution of the 36 experimental conditions in the component plot, based on the component scores for male and female observers, respectively. As both graphs demonstrate, the correlated colour temperature seems to have a strong impact on visual impression of the room, although both wall colour and lighting direction appear to play a part too. The 6500K light source tended to induce either bright or cool impression, while the 2700K tended to induce either warm or dark feelings. As the two graphs show, the correlated colour temperature seems to have strong impacts on the results for both male and female groups.

The distribution of the 36 experimental conditions appears to be wider in the graph for female observers than for male observers. This suggests that female observers were more sensitive than male observers to the changes in wall colour and lighting conditions of the room. In addition, the distribution of the 36 experimental conditions seems to be more towards the positive side of the graph for female observers than for male observers. This indicates more positive visual responses by female observers than by male observers, suggesting that when rating the experimental rooms, more stringent criteria were adopted by male observers than by female observers.

Table 4. Component loadings for the 10 semantic scales used in the experiment

	Principal component 1 (Warmth)	Principal component 2 (Brightness)
Warm/cool	**.963**	-.050
Classical/modern	**.904**	.270
Relaxed/modern	**.852**	.436
Comfortable/uncomfortable	**.833**	.427
Like/dislike	**.752**	.452
Elegant/inelegant	**.736**	.570
Bright/dark	-.002	**.978**
Spacious/small	.377	**.855**
Clean/dirty	.456	**.748**
Harmonious/disharmonious	.620	**.659**

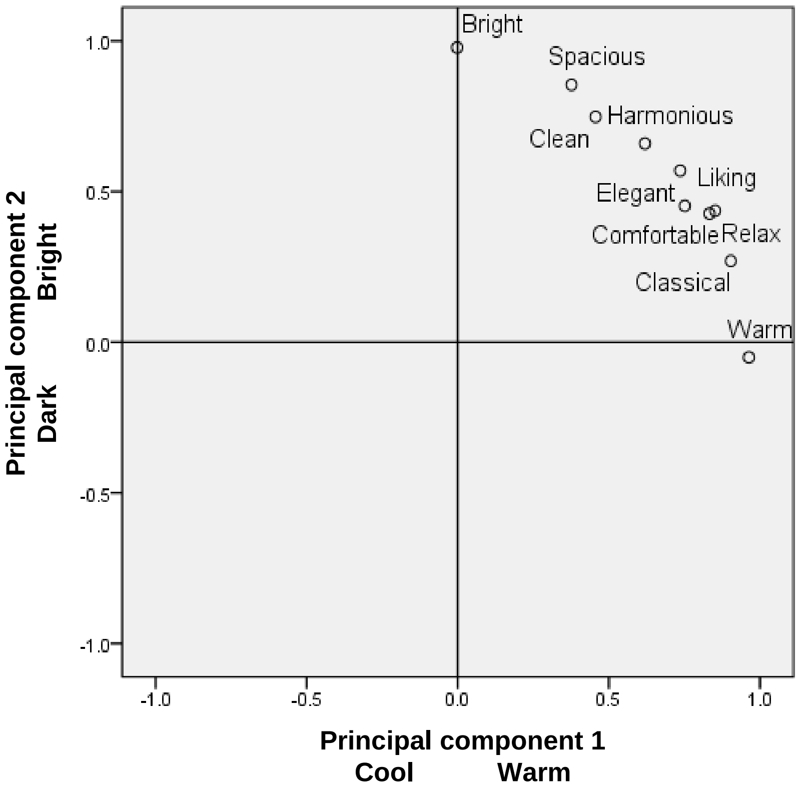
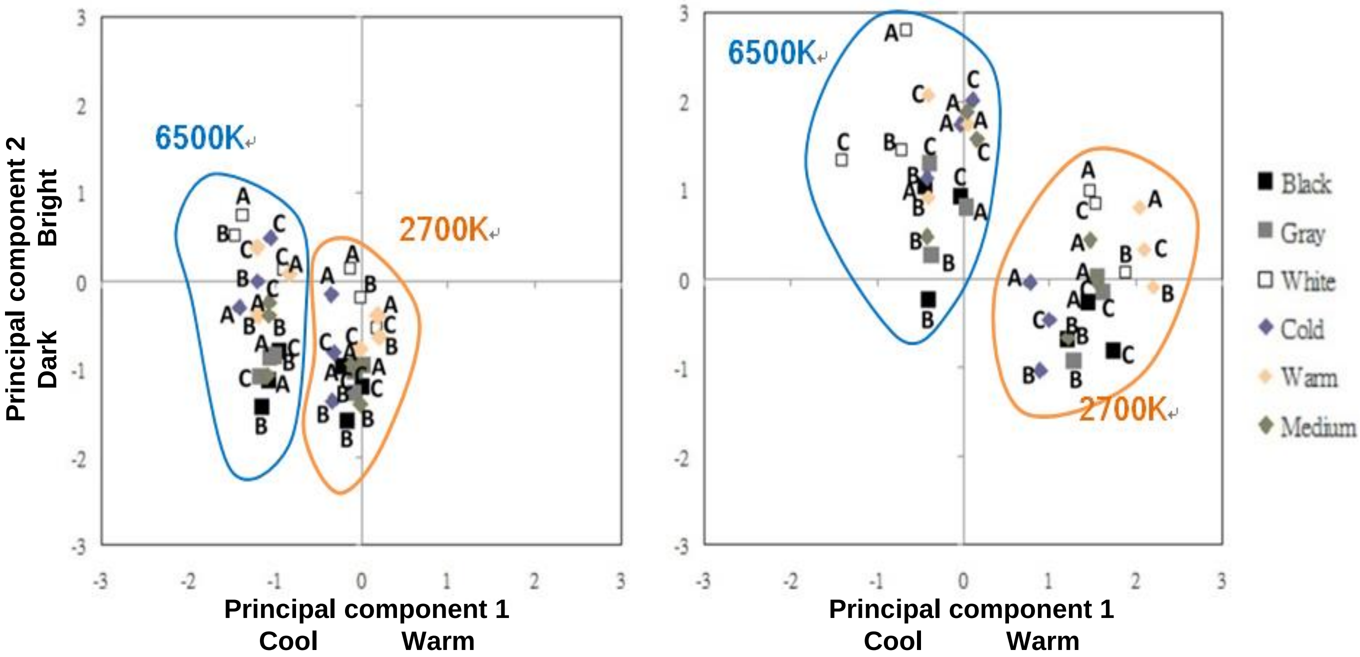


Figure 2. The component plot for the 10 semantic scales used in the experiment



(a) (b)

Figure 3. Distribution of the 36 experimental conditions for (a) male and (b) female observers, in the factor plot where A, B and C represent the three lighting directions: A. light travelling up and sideway, B. a non-directional floor lamp, and C. light travelling down.

4. Conclusion

This study aimed to investigate the influences of lighting conditions and wall colour on the visual impression of a real-room environment. The ANOVA results show that the 6500K work worst with black walls, while the 2700K light worked best with yellow walls. Table 3 shows high correlation coefficients for the 10 scales between the two gender groups, suggesting good agreement between the two gender groups regarding their impressions of a real-room space induced by various lighting conditions. According to Figures 3 (a) and (b), however, the female observers tended to be more sensitive than male observers to the changes in wall colour and lighting conditions.

On the basis of the experimental results, a number of design guidelines regarding interior lighting are proposed, as follows:

- Lighting conditions and wall colour were found to have a significant interaction regarding their influences on the visual impression of a room.
- The visual impressions of a real-room space can be determined by two underlying factors, “warmth” and “spaciousness”.
- The correlated colour temperature of the light source has a dominant impact on the visual impression of a real-room space. A light source with a high correlated colour temperature tends to give a spacious and bright impression, while a light source with a low correlated colour temperature tends to give a warm and relaxing feeling.

These guidelines can be followed when designing a specific environmental space by considering appropriate colour temperature with a proper choice of lighting in various colours of walls so that we can get the desired affective effect, e.g. making people feel relaxed, enlarging the perceived spaciousness of the room, or increasing the brightness of the space. For instance, it may be more appropriate using low colour temperature with darker lighting type for darker or achromatic wall colours than high colour temperature with brighter lighting type for brighter or vivid wall colours to create a more comfortable environmental space.

5. Acknowledgement

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6. References

[1] Shen, Y., Yuan, W., Hsu, W. and Chen, Y. (2000) *Color selection in the consideration of color harmony for interior design,* Color Research and Application, vol. 25, pp 20-31.

[2] Brengman, M. and Geuens M. (2005) *Assessing the impact of color in the store environment – an environmental psychology approach*, in Proceedings of 10th Congress of the International Colour Association, pp 551-554.

[3] Ou, L. and Luo, M. R. (2006) *A colour harmony model for two-colour combinations*, Color Research and Application, vol. 31, pp 191-204.

[4] Ou, L., Chong, P., Luo, M. R. and Minchew, C. (2012) *Additivity of colour harmony*, Color Research and Application, vol. 36, pp 355-372.

[5] Torgerson, W. S. (1958) *Theory and Methods of Scaling,* John Wiley & Sons, New York.