Effect of Interaction of Object Color and Lighting Color on a Person’s Impression of Interiors

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ABSTRACT
An experiment in which subjects rated their impression of 50 interior environments which were the contrasting combinations of two lighting colors, five wall and floor color combinations, and five furniture colors were performed. Three factors represented by harmony, warmth, and gaudiness derived from factor analysis of subject ratings. Ratings of harmony were influenced predominantly by the furniture color. Of particular significance was the higher harmony ratings assigned to color layouts presenting blue and green furniture colors when they are with similar wall and floor color hues than others. Likability ratings closely depend on the feelings of harmony. The ratings of harmony rose when the scale living room model presented bluish walls and floors and was illuminated by daylight fluorescent lamps rather than bulb color fluorescent lamps. However, the rating differences between the two lamps were not clear when assessing likability or comfort.

Keywords: Impression of Interior, Color temperature, Warm Colors, Cool Colors

1. INTRODUCTION
A well known study conducted by Kruithof [1] that deals with preferences for different combinations of lighting color and lighting illuminance tells of the existence of interactions between these two factors. In addition, a study in which subjects rated their impression of several contrasting lighting patterns with varying wall colors and wall materials has been conducted by the present author and his colleagues [2]. The results showed the influence of the interaction of three components of interior on the impression of beauty. Both these studies indicate the possibility of interactions of different interior lighting conditions and color choices influencing the impressions of people.

This study deals with interactions of contrasting interior lighting colors and wall, floor, and furniture colors, and details the influence of these contrasting conditions on the impressions of people. Specifically, this study aims to clarify whether interior lighting color and the color of walls, floors, and furniture act independently in influencing people’s impressions, or whether there is some interaction between the color elements.

2. EXPERIMENT
An experiment in which subjects rated their impression of 50 contrasting interior lighting and color conditions was conducted, and the design of the experiment is described below.
2.1 The scale model
A one-eighth scale model of a living/dining room was prepared. The scale model had a width of 450 mm, a depth of 900 mm, and a height of 300 mm. One of the shorter walls was removed to allow the observation of the interior. The interior was illuminated by two fluorescent lamps from above. A ceiling aperture corresponding to a width of 380 mm and a depth of 830 mm was covered with tracing paper to allow diffused light into the model.

Two types of fluorescent lamps exhibiting different lighting color characteristics were used. These were daylight color lamps (Ra = 84; color temperature: 7,200 K) and bulb color lamps (Ra = 84; color temperature: 2,800 K). The illuminance at the center of the floor of the model was approximately 1,050 lx. Six types of furniture were placed inside the scale model, as shown in Figure 1.

2.2 Contrasting arrangements of color stimuli
In the experiment, ratings of 50 contrasting light color and object color arrangements were collected; the arrangements were obtained by using the combination of two lighting colors, five wall and floor color combinations, and five furniture colors. The colors used for the interior components are shown in Table 1.

The Munsell values of the wall colors were high, and those of the floors lower. This was typical of the color combina-
tion of the walls and floor. The hue of the wall and floor colors in each experimental setting was the same. The three furniture colors consisted of a warm color, a neutral color, and a cool color. Two additional colors were included to give a warm or cool impression of not only the colors, but also the materials. This was done to test the hypothesis that warm light suits soft or natural materials such as wood and cloth, while cool light suits hard materials such as glass, metal, and stone. The natural furniture components were made with balsa board and cotton cloth, and the hard furniture components were made with an aluminum pipe, a transparent plastic board, an imitation stone sheet, and black leatherette. The shifts in wall color caused by changing the fluorescent lamp type diagram are indicated on xy-chromaticity in Figure 2.

2.3 Experimental procedure
Subjects rated their impression of each interior lighting and color pattern using ten 7-step bipolar scales after one-minute observation; this duration was set to ensure adaptation to the color and lighting conditions (see Figure 2). While 50 subjects (all were women students aged between 18 and 22) participated in the experiment, the number of subjects is corresponded to 25 persons because each subject rated 25 patterns. The presentation order was the same throughout the experiment and was chosen randomly. The time taken for each experiment was approximately 70 min.

3. RESULTS AND DISCUSSION

3.1 Factor analysis
Factor analysis (principal component solution, varimax rotation) was carried out on the obtained data after the mean value of each pattern was calculated. From the analysis, three factors represented by harmony and beauty, warmth

<table>
<thead>
<tr>
<th>Scales</th>
<th>Fac. 1</th>
<th>Fac. 2</th>
<th>Fac. 3</th>
<th>Communality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well harmonized - Poorly harmonized</td>
<td>0.96</td>
<td>0.18</td>
<td>0.10</td>
<td>0.97</td>
</tr>
<tr>
<td>Beautiful - Ugly</td>
<td>0.95</td>
<td>0.22</td>
<td>0.17</td>
<td>0.98</td>
</tr>
<tr>
<td>Focussing - Distracting</td>
<td>0.89</td>
<td>0.27</td>
<td>0.31</td>
<td>0.97</td>
</tr>
<tr>
<td>Tranquil - Restless</td>
<td>0.87</td>
<td>0.31</td>
<td>0.33</td>
<td>0.96</td>
</tr>
<tr>
<td>Like - Dislike</td>
<td>0.86</td>
<td>0.40</td>
<td>0.28</td>
<td>0.98</td>
</tr>
<tr>
<td>Comfortable - Uncomfortable</td>
<td>0.81</td>
<td>0.53</td>
<td>0.23</td>
<td>0.98</td>
</tr>
<tr>
<td>Bright - Dark</td>
<td>0.39</td>
<td>0.87</td>
<td>-0.13</td>
<td>0.92</td>
</tr>
<tr>
<td>Warm - Cool</td>
<td>0.22</td>
<td>0.92</td>
<td>0.06</td>
<td>0.90</td>
</tr>
<tr>
<td>Soft - Hard</td>
<td>0.21</td>
<td>0.96</td>
<td>0.09</td>
<td>0.97</td>
</tr>
<tr>
<td>Gaudy - Modest</td>
<td>-0.42</td>
<td>0.04</td>
<td>-0.90</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Table 2
Factor coefficients

Factor Coefficient (%) 51.99 32.15 12.08 96.22
and softness, and gaudiness were obtained (Table 2). This is a typical structure for evaluating the impressions people display to interior environments.

3.2 Relationship between stimulus pattern and recorded impressions
Line graphs using the average ratings of scales were plotted for harmony, warmth, and likability (see Figures 3, 4, and 5). The relationship between stimulus pattern and recorded impressions is discussed below.

3.2.1 Harmony and beauty
The lines plotted in Figure 3 show the average rating values for harmony. Each line is related to a furniture color pattern.
In general, the order of the lines, from well harmonized to poorly harmonized, is natural, YR, hard, B, and G, with a large separation between the first three and last two. Interestingly, the B and G harmony values rise remarkably when the wall and floor colors have similar hues. This tendency is also apparent with warm furniture and warm wall-floor combinations, but is not so pronounced.
These results suggest that feelings of harmony are defined predominantly by furniture color and that the matching between furniture and wall-floor color has a small effect when warm-colored furniture is present and a large effect when cool-colored furniture is present.
Ratings of beauty display tendencies similar to those of harmony, even though the harmony values of the G and B furniture are not so prominent when plotted against similar wall-floor colors (graph not shown). The correlation between harmony and beauty is very high (0.97).

3.2.2 Warmth and softness
Figure 4 displays the impressions of warmth, from cool to warm, and shows the large influence of lamp color on warmth. Although there are large variations in warmth impressions with changes in the lamp color, the lines generally remain parallel. The order of the plots from warm to cool is natural, YR, G, hard, and B. The curves slope from
3.2.3 Gaudiness

The shifts in the average gaudiness ratings are very small and therefore not shown in graph form here. The lines are horizontal and crowded at values of 3 to 4 (slightly modest to neutral). Considering that the Munsell chroma of walls and floors are constant and that those of furniture vary from low to high in this experiment, the gaudiness ratings are likely to be influenced predominantly by the wall and floor colors.

3.2.4 Likability and comfort

The lines plotted in Figure 5 show the average rating values of likability. Generally, the lines are horizontal, suggesting that likability is predominantly defined by furniture color. The order of lines, from high to low likability, is natural, YR, hard, B, and G. The G-G and B-B combinations of furniture color and wall-floor colors mentioned above in the section on harmony also appeal here, but the rise are smaller. Ratings of comfort have a tendency very similar to the likability ratings (this graph is also not included). The correlation between likability and comfort is 0.97.

3.3 Influence of lighting color on impression ratings

The differences between the patterns that have the same furniture and wall-floor color combinations but different lighting color were calculated to verify the hypothesis that left to right, indicating the “cooling” influence of the wall-floor colors from R through P. These results suggest that the three components of the interior scale model effect warmth.

Softness ratings have a tendency similar to the warmth ratings. The correlation between these two scales is 0.89. The influence of wall and floor color and lighting color on softness is lesser than that on warmth.
warm light suits warm or natural colors and materials and cool light suits cool or hard colors and materials. Table 3 shows the differences between the patterns that share the same feature colors, but not lighting color. A positive value indicates that the color pattern under the bulb color lighting is rated higher than that under the daylight color lighting.

### 3.3.1 Likability and comfort
The differences between the average ratings of likability and comfort, which depend on lighting color, are shown in part (1) of Table 3. This indicator shows that bulb color lighting makes the overall evaluation greater than 0.4 when YR and natural furniture are matched to the R, B, and PB wall-floor. The B and PB wall and floor must be darker when they are illuminated by the bulb color lamp. This may reduce the vividness of the wall and floor color. Conversely, the R wall and floor must be brighter under bulb color lighting. These color changes would make the scene appear warmer and more intimate, increasing the impression rating.

Hard furniture matched with warm key room results in positive readings, but when it is matched with cool key room, it results in negative readings. Achromatic color should accept the influence of lighting color directly.

The remaining combinations corresponding to a difference of more than 0.4 are (1) G furniture and YR and (2) G furniture and B wall-floor combinations. The reason for this large difference is not clear, but G and YR and G and B are pairs of small color differences including neutral colors; therefore, it is possible that the increased color similarity leads to high values.

### 3.3.2 Harmony and beauty
The differences between average ratings of harmony and beauty are shown in part (2) of Table 3. Part (1) and part (2) show similar values, except for B, hard furniture and G, B, and PB wall and floor combinations, for which the differences are more than 0.5 as shown in part (3). The values are negative, and therefore cool furniture and cool wall-floor color combinations produced higher ratings of harmonization than likability when cool color lighting was used. Therefore cool color lighting rises impression of harmony than warm color lighting, but lighting color has no influence for likability rise for cool color furniture, wall and floor combination.

A difference of 0.3–0.5 is evident in part (3) when furniture and wall-floor warmth are opposed. For example, the natural furniture and B wall-floor (warm vs. cool) combination. This suggests the likelihood that bulb color lighting might rise likability and comfort ratings more than harmony and beauty ratings when furniture warmth are opposed to wall and floor warmth.

### 3.4 Discussion
The average values of G, B and PB wall and floor with B or hard furniture indicate higher values of harmony and beauty under the daylight color florescent lamp than the bulb color florescent lamp. The average of R wall and floor with YR and natural furniture indicate higher values of harmony, beauty, likability and comfort under the bulb color florescent lamp than the daylight color florescent lamp. These results support the hypothesis concerning the matching of lighting color warmth and object color warmth. However, the former tendency described above is not shown on lik-
ability and comfort, and the latter tendency described above is not clear for YR wall and floors. These results suggest the hypothesis is an oversimplification.

One explanation for these results is that people prefer warm atmospheres over cool ones. This tendency should become apparent when object color and lighting color are bluish. The reason for the pattern involving the YR wall and floor is not clear, but adaptation makes the look difference smaller is available.

Future experiments involving more stimuli variations such as white objects, more warm object colors, and a middle color temperature lighting should be incorporated into the experiment to further develop and justify these arguments.

4. CONCLUSIONS

The findings derived from the impression rating experiment can be summarized as follows:
- Impressions of harmony rise remarkably when both the lighting color and object color or material are cool.
- Such a tendency is not evident in the case of likability and comfort.
- Impression ratings of likability and harmony are greater for bulb color lighting than for daylight lighting when natural and YR furniture are matched to the R, B, and PB walls and floors.

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REFERENCES