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Effects of lighting on impressions of popular music

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Abstract

This study focused on the effects of lighting colors on impressions of popular music in an actual room, in contrast to a previous study, in which impressions of classical piano music were evaluated for colored images of a piano player generated through computer graphics. The previous study did not clarify the effect of the lighting color on the difference in impression compared with that under normal white lighting. This study investigated the impressions of six pieces of popular music in a room under LED lighting in colors of white, red, yellow, green, and blue. The results of listening experiments conducted with 10 listeners were as follows: Red lighting induces strong and dirty impressions, and blue lighting induces dark and gloomy impressions. These results are consistent with those of the previous study. In addition, the finding of the previous study that appropriate matching between the music and the lighting color enhances the impression created by the music itself was generally observed. However, the degree to which this tendency holds true was found to somewhat depend on the lighting color.

Keywords: SD method, Factor analysis, Correlation, Relative impression

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1 Introduction

Impressions of music are known to be affected by the lighting in the listening environment. Lighting plays very important role in live performances of music. The lighting technicians can affect both hidden and obvious features of the music because the audience's impressions of the music will somewhat depend on the lighting.

The effect of the congruence between lighting and music was previously examined in experiments involving classical piano music played by a MIDI synthesizer and computer graphics of a piano performance under various colors of lighting [3, 2]. The lighting colors used were red, yellow, yellowish green, green, cyan, blue, violet and purple, which are equally spaced on the Munsell hue circle. The musical stimuli were eight short musical passages from popular classical piano tunes. The affective impressions of the music as a function of the lighting color used in the computer graphics and the degree of matching between the color of the lighting and the music were measured through rating experiments. The results showed that the impressions of the music pieces presented with red or purple colors were evaluated as powerful, whereas those presented with a cyan color were evaluated as powerless. Moreover, colors of green, yellowish green, yellow, and cyan enhanced bright impressions of the music, whereas colors of blue, violet, purple and red enhanced dark impressions of the music. In general, a color that matched the music enhanced the affective impression created by the music itself. Powerful music was matched with colors that made the music seem more powerful, and bright music was matched with colors that made the music seem brighter.

However, the previous study described above was conducted based only on a computer display. The performer and the piano were generated through computer graphics. Moreover, the impressions of the music in a normal white lighting environment were not measured. The impressions of the music under various colors were measured, but the baseline impressions of the music were unclear. Therefore, the affective impression created by the music itself, which was concluded to be enhanced by a color that matched the music, was not clear.

This study focused on the effects of lighting colors on impressions of popular music in an actual room, intended to be representative of typical situations of listening to music or to background music. LED (light-emitting diode) lighting, controlled by a computer, was illuminated in front of a listener sitting in the room. White lighting, which is the normal lighting color of a room, was examined in addition to blue, green, red, and yellow lighting. The impression that was reported for a given music under white lighting was treated as the reference. The variations in impression that were reported under other lighting colors were compared against the reference and were analyzed to elucidate the effect of lighting on music.

Table 1: **Intensities of illumination under the five lighting colors.**

Color (Abbrev.)	Intensity [lux]
Blue (B)	54
Green (G)	30
Red (R)	15
Yellow (Y)	51
White (W)	77

2 Experiment

2.1 Apparatus

A laboratory room, with approximate dimensions of 3.4 m × 5.4 m × 3.0 m in height, was used for the experiment. The room was sealed to avoid the intrusion of light from outside the room. Each listener sat on a chair located in the middle of the room. In front of the listener, a white table of 0.7 m in depth and 1.6 m in width was placed. Two LED lighting instruments (Fuloon Lighting, LED Flat Mini Par Light) were placed on both sides of the listener at a distance of 1.5 m. Two stereo loudspeakers (YAMAHA NS-1000MM), 2.8 m apart, were placed to the left and right front sides of the listener.

The light was produced by 1-watt LED bulbs in colors of red, green, and blue; there were six bulbs of each color. The lighting colors (blue, green, red, yellow, and white) were produced by lighting single bulbs (red, green, or blue), pairs of bulbs (yellow, generated by combining green and red), and all bulbs (white). A Tondaj LX-1010B digital luxmeter was used to measure the vertical intensity of the illumination at a point 2.3 m in front of the listener at a height of 1.2 m. Table 1 shows the intensities of illumination for the five lighting colors. Color temperature and chromaticity were not measured because no instrument was available to do so.

2.2 Musical pieces

Six pieces of music were selected from the RWC Popular Music Database [1]. A 30-second sample of each piece was extracted from the beginning of the tune. A-weighted equivalent sound pressure levels were measured at the listener's head position. The volume dial of the amplifier was fixed for all musical pieces. These pieces were also used in an initial informal experiment conducted to investigate the impressions of the music to allow a comparison of two independently collected sets of impressions of the music under white lighting conditions.

2.3 Method

The listeners were 10 young adults of 20–22 years in age. All 30 possible combinations of the six musical pieces and the five lighting conditions were presented in a random order. The participants evaluated their musical impressions on 11 bipolar, 7-point semantic differential (SD) scales and assessed the degree of congruence between the music and the lighting. The adjective pairs used to assess the impressions were 'dirty — clean', 'obscure — clear', 'unemotional

Table 2: **Musical pieces used in the experiments.**

No.	RWC-MDB-P-2001	Tempo	A-weighted equivalent SPL [dB]
1	No. 96	130	69
2	No. 79	92	66
3	No. 40	122	65
4	No. 25	103	69
5	No. 24	130	73
6	No. 21	98	66

Table 3: **Pearson product-moment correlation coefficients between two experiments conducted under white lighting.**

Piece No.	1	2	3	4	5	6
Coefficient	0.909	0.964	0.828	0.555	0.952	0.739

— emotional', 'dislike — like', 'gloomy — cheerful', 'dark — bright', 'weak — strong', 'common — unique', 'ungraceful — graceful', 'calm — excited', and 'soft — hard'. Each bipolar item was scored on an SD scale of –3 to +3.

3 Analysis

3.1 Comparison of impressions under white lighting

In the initial informal experiment, 83 young adult listeners evaluated their impressions of the same six musical pieces using nine bipolar, 13-point SD scales under fluorescent lights of 350–500 lux. The nine adjective pairs that were used for these SD scales were a subset of the adjective pairs that were used in the current experiment. The Pearson correlation coefficient for the average evaluation of the listeners of the nine scores between the initial and current experiments was calculated for each musical piece.

The results are shown in Table 3. The correlation coefficients between the two experiments under white lighting indicate a high degree of significance, except for musical piece No. 4. This exception is due to the difference in the scores for cheerfulness; the initial result was slightly gloomy, and the current result was neutral. The initial gloomy impression of musical piece No. 4 may have been caused by the contrast between the well-lighted room and the gloomy lyrics of the piece. In general, however, the impressions of the musical pieces under white lighting did not considerably differ between the initial well-illuminated condition (350–500 lux) and the less illuminated condition (77 lux). Moreover, the average impressions reported by the current participants did not considerably differ from those reported by a number of other young adults.

Table 4: **Factor loading determined in the factor analysis.**

Adjective			Communality	Factor 1	Factor 2
-		+		Clearness	Cheerfulness
Dirty	—	Clean	0.943	0.820	–0.520
Obscure	—	Clear	0.941	0.970	–0.0055
Unemotional	—	Emotional	0.368	0.600	–0.111
Dislike	—	Like	0.356	0.595	0.0476
Gloomy	—	Cheerful	0.972	–0.021	0.986
Dark	—	Bright	0.852	0.093	0.918
Weak	—	Strong	0.588	–0.491	0.589
Common	—	Unique	0.478	–0.439	0.534
Variance [%]				46.0	22.8

3.2 Effects of lighting colors on music

The variation of music impressions depending on lighting colors is observed from the differences between the impression scores reported under white lighting and those reported under other lighting colors. Henceforth, these differences in score are called ‘color effect scores’. A three-way analysis of variance (ANOVA) in which the factors considered were the four colors (blue, green, red, yellow), the six musical pieces, and the 10 listeners was conducted using the color effect score for each impression. No significant difference was found in the interactions between music and color. Significant differences were found in the listeners for all impressions. The significant effects of the colors were as follows: red lighting causes the impressions of a piece of music to become stronger and dirtier, whereas blue lighting causes these impressions to become darker and gloomier. These results are approximately consistent with those of the previous study [3].

3.3 Factor analysis

The correlation coefficients between the scores of the graceful, calm, soft, and clear impressions averaged among the listeners that were obtained for the 30 combinations of stimuli were highly significant, that is, greater than 0.8 for all combinations of impressions. Therefore, of these four impressions, only the results for clear impressions were employed for the factor analysis; the graceful, calm, and soft impressions were not considered.

Thus, a factor analysis using eight SD scales was conducted via the principal factor method, and varimax rotation was applied to the obtained factor loadings. Because an eigenvalue of the first two factors exceeded unity, a two-dimensional solution was adopted. Table 4 shows the factor loadings determined in the factor analysis. Factor 1 and factor 2 are named ‘Clearness’ and ‘Cheerfulness’ respectively, based on the corresponding adjectives that showed the maximum factor loading.

Figure 1 shows the two-dimensional factor scores for the 30 experimental conditions. The abbreviations B, G, R, Y, and W represent the lighting colors, and the numbers 1—6 represent the numbers of the music pieces. The same musical pieces under different lighting colors tend to form groups in the factor space, indicating that the variation of the impression depending on the lighting color is not strong.

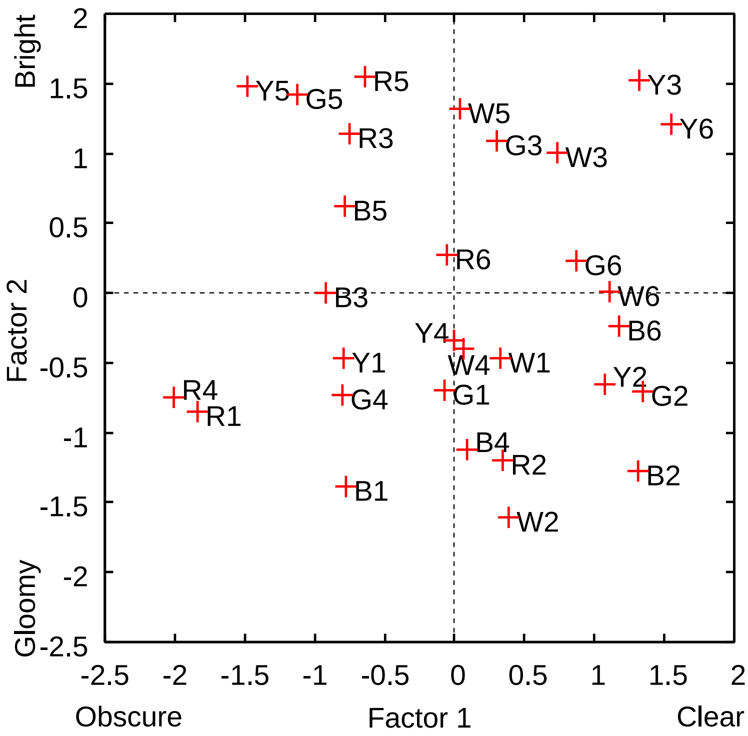

Figure 1: **Two-dimensional factor scores for the experimental conditions. The letters B, G, R, Y, and W represent the lighting colors. The numbers 1—6 represent the numbers of the music pieces.**

3.4 Enhancement of musical impression by lighting

Previous studies [3, 2] have argued that the appropriate matching of music with colors enhances the affective impression created by the music itself. However, in these studies, the affective impression created by the music itself was not clear because the musical impressions under normal white lighting were not measured.

This section focuses on the relationship between the relative changes in the impressions of music in the factor space (Fig. 1) and the evaluations of the congruence between lighting and music.

Let $C_i = (C_{i1}, C_{i2})$ represent a vector of the stimuli in the two-dimensional factor space, where i represents the ith piece of music ($i = 1, 2, ..., 6$) and C represents the color abbreviation (B, G, R, Y, W). The strength of impression λ_{Ci} of the stimulus C_i is expressed as the length of the vector C_i:

$$\lambda_{Ci} = \sqrt{C_{i1}^2 + C_{i2}^2}, \tag{1}$$

where C_{i1} is the first factor score and C_{i2} is the second factor score. Then, the strength of impression of the ith piece of music under white lighting is denoted by λ_{Wi}. Therefore, the strength of impression λ'_{Ci} relative to the impression under the white lighting is calculated by obtaining the length of the vector C_i projected onto the direction of the vector W_i:

$$\lambda'_{Ci} = \lambda_{Ci} \cos(\alpha_{Ci} - \alpha_{Wi}), \tag{2}$$

where α_{Ci} is the angle of the vector C_i. A graphical representation of this conversion process in the factor space is shown in Figure 2.

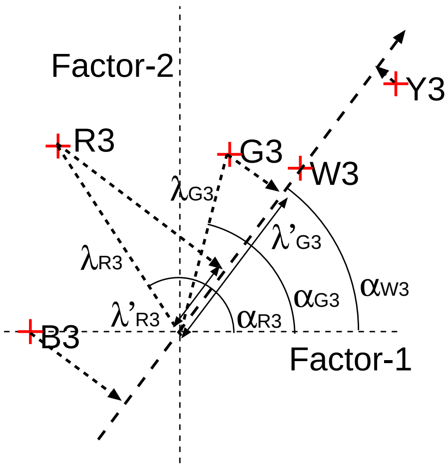

Figure 2: **Graphical representation of the projection of the impression vector for each lighting color C_i onto the axis of the white lighting vector W_i.**

Finally, $\lambda'_{Ci} - \lambda_{Wi}$, where C =B, G, R, Y and $i = 1, 2, ..., 6$, is derived as the enhancement effect on the impression that is induced by the lighting color compared with white lighting conditions. Positive values indicate enhanced impressions, and negative values indicate diminished impressions.

A scatter plot of the relative enhancement effect and the relative congruity between lighting and music is shown in Figure 3. The correlation coefficient between the relative impression enhancement and the congruity is 0.607 ($N = 24$), which is highly significant. The correlation coefficients were calculated separately for each lighting color, resulting in values of 0.930 for blue, 0.483 for red, 0.406 for yellow, and –0.668 for green. Thus, the general tendency that appropriate matching between the music and the lighting color enhances the impression created by the music itself is confirmed. However, this tendency is strong for blue lighting, small for red and yellow, and opposite for green. Note that the opposite tendency observed for green lighting is vague because the values for both indices, the relative impression enhancement and the congruity, are small.

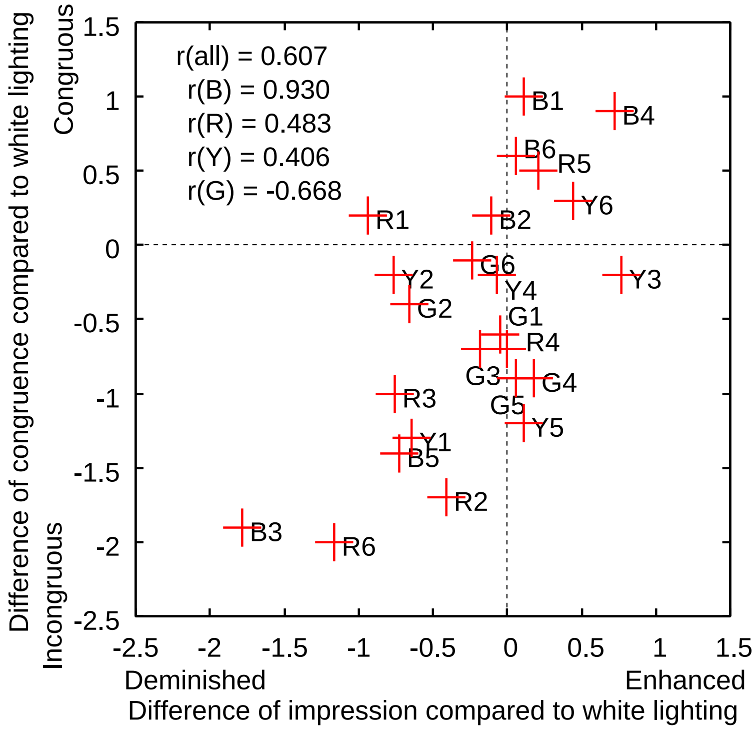

Figure 3: **Relationship between relative enhancement of impression and congruence between lighting and music.**

4 Discussion

The results of this study are broadly consistent with the results of the previous studies [3, 2] despite the differences in the experimental conditions, that is, the music genre (popular contemporary music versus popular classical music) and the lighting environment (actual lighting in a room versus simulated lighting in computer-generated graphics).

The previous study extracted three principal components, namely, powerfulness, brightness, and emotion, through a principal component analysis using 15 SD scales. This study did not extract the factor of powerfulness because the SD scales included few adjective pairs that are usually classified together into the powerful factor. The 'strong — weak' impression, which is usually included in the powerful factor, was approximately equally loaded into the two extracted factors of clearness and cheerfulness. When all 11 SD scales were used for the current factor analysis, the three factors of brightness, emotion, and clearness were extracted. Again, the 'strong — weak' impression was found to be loaded into all three factors approximately equally.

The listening experiments were conducted under less strongly illuminated conditions (below 77 lux) compared with the informal experiments, which were performed under well-illuminated conditions (350–500 lux). The reported profiles of the impressions of the music did not considerably differ under these two conditions. However, the extent to which the impressions of music remain the same under darker conditions, such as in the pitch dark, is not clear. The dependence of musical impressions on the intensity of illumination will be a future subject of research.

5 Summary

This study focused on the effects of lighting colors on impressions of popular music in an actual room, in contrast to a previous study in which impressions of classical piano music were evaluated based on the presentation of a colored image of a piano player generated through computer graphics. LED lighting, controlled by a computer, was illuminated in front of a listener sitting in a room. White lighting, which is the normal color of room lighting, was presented in addition to blue, green, red, and yellow lighting while the listener was listening to a music piece. The impressions of the music pieces under white lighting were treated as the references. The variations in impression that were reported under other lighting colors were compared against the corresponding reference and were analyzed to elucidate the effect of lighting on music. Red lighting was found to induce strong and dirty impressions, and blue lighting was found to induce dark and gloomy impressions. These results are consistent with those of the previous study. In addition, the finding of the previous study that appropriate matching between the music and the lighting color enhances the impression created by the music itself was generally observed. However, the degree to which this tendency holds true was found to somewhat depend on the lighting color.

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