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Bon Appétit! An Investigation About the Best and Worst Color Combinations of Lighting and Food*

Hyeon-Jeong Suk, Geun-Ly Park
KAIST (Korea Advanced Institute of Science and Technology), Daejeon, Republic of Korea

Yoonsook Kim
Korea Food Research Institute, Seongnam, Republic of Korea

We investigated an interaction effect between lighting color and food color that stimulates or discourages one's appetite. Facilitated by the LED (light-emitting diode) as an additional chromatic lighting source, observers selected the best and worst lighting colors by themselves using a "Mini Living Colors (Philips^{TM})" in the preliminary test (N = 30) and then color picker software in the main experiment (N = 30). Food stimuli were composed of two aspects, type—natural or processed—and complexity—low or high, and consequently they were grouped into four categories. We measured the selected lighting color in terms of chromaticity and illumination level, and analyzed the best and worst combinations based on these measurements. Throughout the two empirical studies, we found three tendencies: First, except for the white, yellow lighting stimulates while red and blue discourages one's appetite. Second, when color categories of lighting and food are similar to each other, it stimulates the appetite whereas complementary, it discourages it. Third, the type of food does not act as an influencing factor.

Keywords: food color, lighting color, appetite, color

Introduction

The quality of ambient lighting has been empirically proven as a directly influencing factor on stimulating one's appetite, and thus a large amount of attention has been paid to pronounce the importance of planning a proper lighting for dinning environment (Satyendra, 2012; Stroebele & De Castro, 2004; Wardono, Hibino, & Koyama, 2012). Concerning the appropriate brightness for dining, almost every industry standard proposes a certain range for illumination. The recommendation levels of illumination in Korea suggest that dining environments be illuminated between 60 and 150 lx (Korea Industrial Standards, 1998). In addition to the illumination, some studies have attempted to find the effect of hue aspect of lighting, and have revealed that

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Hyeon-Jeong Suk, associate professor at Department of Industrial Design, KAIST (Korea Advanced Institute of Science and Technology).

Geun-Ly Park, graduate student at Department of Industrial Design, KAIST (Korea Advanced Institute of Science and Technology).

Yoonsook Kim, principal researcher, Division of Metabolism and Functionality Research, Korea Food Research Institute.

warm looking lighting is more preferable than cool looking lighting. Accordingly, the affective quality of incandescent light has often been compared with that of fluorescent light, and the results show that incandescent light should be more proper than white lighting such as fluorescent lamp. It is due to the fact that the yellowish nuanced light is a more efficient stimulator for appetite than white light (Barbut, 2001). Nonetheless, in comparison to research in brightness, there have been little findings regarding the colorfulness of dining lighting, including dominant wavelengths and purity of lighting. This is mainly because none of the lighting types have a versatile characteristic in terms of varying its color.

However, since the LED (lighting emitted diode) has been applied to indoor lighting, the colorfulness of lighting is considered as a relevant attribute. The spectral characteristics of the light are critical for human to perceive object's color, and thus the appearance of food color is rendered differently depending on the light source. For example, a recent study of Hong, Park, and Seo (2010) revealed the best lighting color using LED for displaying breads in bakery. In this foregoing, we attempt to figure out the most appetitive lighting as well as the least appetitive lighting in relation to food color. Moreover, we intend to provide opportunities to explore and to choose the lighting color rather than to provide certain lighting settings. By doing so, we plan to observe the people's behavioral characteristics, who are searching for color of light.

Plan for Empirical Studies

In finding the empirical evidence of the best and worst matches between lighting color and food color, we first conducted a preliminary study using a "Mini Living Colors" (produced by Philips™; Mini lamp hereinafter), the product of Phillips Ltd.. Later, in order to assure the results in a more complex context, in terms of both lighting color and food color, we carried out the experiment after setting up a dining table with an LED lighting system.

Preliminary Study

In the preliminary study, we planned to observe whether there is a relationship between lighting color and food color.

Method

Observers. Thirty people made up of 14 male students and 16 female students participated in the preliminary study and their average age was 23.30 years old with a standard deviation of 3.05 years.

Food stimuli. When preparing foods, we considered two aspects: type—natural or processed—and color complexity—low (single hue) or high (various hues), and thus, there were four categories of food stimuli as shown in Table 1.

Table 1
The Four Categories of Food Stimuli in Preliminary Test

Food type	Color complexity	
	Low	High
Natural food	Green salads, blueberry cake	Korean roll
Processed food	Sweets and beverages in seven hue categories: red, yellow, green, blue, purple, black, white	Mixed sweets

Lighting source. In order to set up the default light condition which is most similar to daylight, the Multi Light Viewing Booth from Botek was used. Additionally, as illustrated in Figure 1, the Mini lamp was fixed by a semi-circular stanchion made out of transparent acrylic so that observers could easily adjust colors. Then, foods were laid under the input light, and an observer added chromatic lighting by touching a point of the color wheel of the lamp.

Figure 1. The setting of the preliminary study.

Procedure. During the preliminary study, observers were asked to choose the best and the worst lighting for the food. They could either add any chromatic color of lighting generated from the Mini lamp or switch it off. Whenever an observer decided a certain lighting condition, an experimenter immediately positioned a Chroma Meter, CL-200A (Minolta) next to the food stimuli to measure the illumination level (lx) and x-y coordination in CIE1931 Chromaticity Diagram. In this way, the impact of light on appetite was basically determined by one’s emotional evaluation whereas the lighting color was assessed objectively. Each food stimulus was provided by the experimenter in a random order.

Results and Analysis

After plotting the chromaticity values into the CIE Chromaticity Diagram, we identified the color categories of lightings and then labeled them accordingly. The lighting category, “Orange”, was added. As shown in Tables 2-3, we found the most appetitive as well as the least appetitive combinations between lighting colors and food colors. We shaded cells when the color category of both lighting and food was identical. In addition, we bolded and underlined data when they exceeded 30.0%. Based on the frequency distribution, we conducted Chi-square analysis and found a statistical significance that the combinations are not random but they show some degree of tendency ($p < 0.05$). The major findings are as it follows: (1) In general, orange followed by yellow stimulates appetitive feeling whereas red followed by green and blue discourages it; (2) The combinations of identical color categories between lighting and food stimulate the appetitive feeling whereas combinations of complementary color categories discourage one’s appetite; (3) Observers would like to add chromatic light in order to create more appetitive lighting environment. When they made the least appetitive lighting environment, they often switched off the Mini lamp. We consider this as another tendency that lowers illumination which discourages one’s appetitive feeling; and (4) Observers applied similar lighting color to food color regardless of type of food—natural food or processed food. For example, for both green sweets and green salads observers selected yellow followed by orange and green as the appetitive lighting color.

Table 2

The Most Appetitive Color Combinations Between Lighting and Food in Preliminary Study (Unit: % (N = 30))

Lighting color	Food color										
	Low color complexity									High color complexity	
	Natural food		Processed food (sweets and beverage)							Natural food	Processed food
	Green (Green salads)	Purple (Blueberry cake)	Red	Yellow	Green	Blue	Purple	Black	White	Korean roll	Mixed sweets
D65 only	0.00	0.00	13.33	20.00	16.67	30.00	20.00	20.00	20.00	6.67	6.67
+ Red	0.00	3.33	6.67	0.00	0.00	3.33	16.67	3.33	0.00	0.00	0.00
+ Orange	33.33	53.33	66.67	33.33	26.67	13.33	26.67	43.33	23.33	53.33	43.33
+ Yellow	36.67	40.00	6.67	43.33	33.33	20.00	23.33	20.00	43.33	33.33	43.33
+ Green	30.00	0.00	3.33	3.33	23.33	13.33	3.33	10.00	6.67	6.67	6.67
+ Blue	0.00	0.00	0.00	0.00	0.00	10.00	3.33	0.00	6.67	0.00	0.00
+ Purple	0.00	3.33	3.33	0.00	0.00	10.00	6.67	3.33	0.00	0.00	0.00

Table 3

The Least Appetitive Color Combinations Between Lighting and Food in Preliminary Study (Unit: % (N = 30))

Lighting color	Food color										
	Low color complexity									High color complexity	
	Natural food		Processed food (sweets and beverage)							Natural food	Processed food
	Green (Green salads)	Purple (Blueberry cake)	Red	Yellow	Green	Blue	Purple	Black	White	Korean roll	Mixed sweets
D65 only	30.00	26.67	23.33	16.67	30.00	33.33	36.67	36.67	20.00	16.67	30.00
+ Red	33.33	6.67	10.00	46.67	50.00	50.00	13.33	26.67	36.67	56.67	36.67
+ Orange	3.33	0.00	0.00	10.00	3.33	3.33	3.33	0.00	3.33	0.00	3.33
+ Yellow	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	0.00	0.00
+ Green	0.00	53.33	50.00	23.33	3.33	6.67	36.67	20.00	33.33	13.33	6.67
+ Blue	26.67	13.33	16.67	3.33	10.00	6.67	6.67	16.67	0.00	6.67	20.00
+ Purple	6.67	0.00	0.00	0.00	3.33	0.00	0.00	0.00	6.67	6.67	3.33

These findings were convincing the hypothesis that there is an interaction effect between lighting color and food color in encouraging and discouraging one’s appetitive feeling. In this foregoing, we planned a main experiment to improve experiment settings.

Experiment

As mentioned above, the experiment was an extended version of the preliminary study, and we tried to examine the best and worst matches between lighting color and food color in a more complex and realistic context.

Method

Observers. Thirty people made up of 14 male students and 16 female students participated in the experiment and their average age was 22.27 years old with a standard deviation of 6.62 years.

Food stimuli. Like in the preliminary test, four categories of food stimuli were prepared, so each category was characterized according to type of food and its color complexity (see Table 4). However, in the main experiment, we tried to test frequent dining contexts of Koreans. In category of natural food with low color complexity, we included five new items, such as Kimchi stew, ham and egg with a cup of orange juice, green salads, glasses of wine with cheese, and Bulgogi. Besides, we replaced Korean roll with Bibimbap, which represents more stereotypical contemporary Korean dish. Moreover, food mockups made of synthetic resin were used to avoid the smell of food as well as to keep the identical quality of the food stimuli.

Table 4

The Four Categories of Food Stimuli in Experiment

Food type	Color complexity	
	Low	High
Natural food (food mockups)	Kimchi stew, ham and egg, green salads, glasses of wine, Bulgogi	Bibimbap
Processed food	Sweets in seven hue categories: red, yellow, green, blue, purple, black, white	Mixed sweets

Lighting source. We prepared a dining table and a hanging LED panel in size of 40 cm × 40 cm for a more realistic context. Observers were seated at the dining table and selected and modified the color of LED panel using the software (see Figure 2). Moreover, since the experiment room was already lighted with ambient LED lighting, observer's selection resulted an additional lighting to render the appearance of the food.

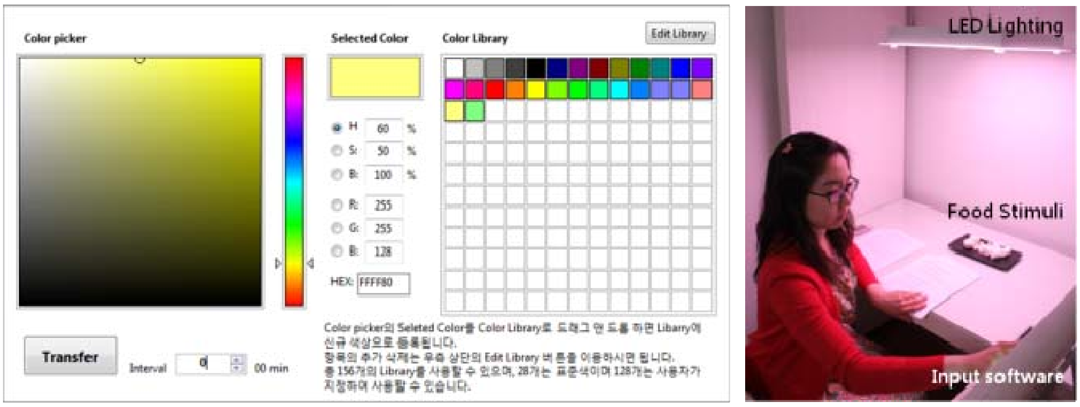

Figure 2. A lighting palette designed for main experiment (left); the setting of the experiment (right).

Procedure. Observers were provided with food stimulus in a random order, and they were asked to find the best as well as the worst lighting by using the provided software. Once a lighting color was decided, the experimenter measured the chromaticity and the level of illumination using the Chroma Meter.

Results and Analysis

Based on the chromaticity values measured with the Chroma Meter, we plotted the best and worst lightings of each food stimulus in the CIE Chromaticity Diagram. Then, we sorted out the data according to naming categories. Differently from the preliminary test, observers were able to control the illumination level and purity of the lighting. The selected lightings were scattered within the gamut. Consequently, lighting colors labeled as "White" were differently nuanced, such as yellowish white or bluish white. In Tables 5-6, we displayed the frequencies of both best and worst matches and summarized distinctive findings as follows: (1) Throughout the food colors, white lighting (low purity) was far more preferred than saturated lighting colors (Chi-square analysis, $p < 0.05$). This implies the need for investigating the effect of nuanced white lighting; (2)

High frequency of selecting purple or pink was observed. This was caused because the RGB (Red—Green—Blue) LED had the white point at x = 0.283, y = 0.221, which was leaning to purple segmentation. This purplish white was made when an observer selected white (R (red) = 255, G (green) = 255, B (blue) = 255) using the software. Therefore it was assumed that there was a discrepancy between selected digital color and resulted lighting color. Particularly the resulted lighting color was shifted to the direction toward purple; and (3) Lighter context stimulates one's appetite more than when it is in a darker context. The averaged illumination level for appetitive lightings was 192.40 lx and that for non-appetitive lightings was 75.40 lx, and the difference was statistically significant (*t*-test, $p < 0.05$).

Table 5

The Most Appetitive Color Combinations Between Lighting and Food in Experiment (Unit: % (N = 30))

Lighting color	Food color													
	Low color complexity												High color complexity	
	Natural food					Processed food (sweets and beverage)							Natural food	All dishes
	Kimchi stew	Ham & egg	Green salads	Wine & cheese	Bulgogi	Red	Yellow	Green	Blue	Purple	Black	White	Bibimbap	
White	66.67	50.00	80.00	30.00	80.00	56.67	56.67	53.33	70.00	50.00	80.00	66.67	70.00	86.67
Red	0.00	0.00	0.00	6.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orange	3.33	3.33	0.00	6.67	0.00	0.00	0.00	0.00	0.00	3.33	0.00	3.33	0.00	0.00
Yellow	10.00	13.33	3.33	6.67	6.67	6.67	20.00	3.33	10.00	3.33	10.00	10.00	16.67	3.33
Green	0.00	0.00	6.67	3.33	3.33	3.33	3.33	16.67	3.33	10.00	0.00	0.00	0.00	0.00
Blue	3.33	0.00	6.67	0.00	0.00	6.67	3.33	10.00	6.67	3.33	0.00	6.66	0.00	0.00
Purple	3.33	10.00	0.00	26.66	0.00	13.33	6.66	10.00	6.66	16.66	0.00	6.66	0.00	3.33
Pink	13.33	23.34	3.33	20.00	10.00	13.33	10.00	6.67	3.33	13.33	10.00	6.67	13.33	6.67

Table 6

The Least Appetitive Color Combinations Between Lighting and Food in Experiment (Unit: % (N = 30))

Lighting color	Food color													
	Low color complexity												High color complexity	
	Natural food					Processed food (sweets and beverage)							Natural food	All dishes
	Kimchi stew	Ham & egg	Green salads	Wine & cheese	Bulgogi	Red	Yellow	Green	Blue	Purple	Black	White	Bibimbap	
White	0.00	0.00	0.00	3.33	0.00	3.33	6.67	0.00	6.67	0.00	0.00	3.33	0.00	0.00
Red	6.67	20.00	20.00	3.33	6.67	13.33	13.33	26.67	33.33	16.67	13.33	13.33	10.00	6.67
Orange	0.00	0.00	0.00	6.67	0.00	3.33	0.00	0.00	3.33	3.33	3.33	0.00	0.00	0.00
Yellow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	3.33	0.00	0.00
Green	20.00	6.66	6.67	36.66	20.00	26.67	20.00	6.66	10.00	20.00	10.00	10.00	20.00	13.33
Blue	56.66	56.67	30.00	50.00	56.66	36.67	40.00	23.33	16.66	3.33	33.33	36.66	60.00	60.00
Purple	16.67	6.66	36.67	0.00	16.67	13.33	20.00	23.33	23.33	23.33	40.00	23.34	10.00	20.00
Pink	0.00	10.00	6.67	0.00	0.00	3.33	0.00	0.00	6.67	6.66	0.00	10.00	0.00	0.00

Despite the new observations caused by the new experiment settings, we observed the three tendencies that are replicated in main experiment: (1) In general, yellow stimulates one's appetite. However, blue, green, and red lightings make food not delicious; (2) When color categories between lighting and food match, it increases one's appetite. When they are complementary, one loses the appetite; and (3) Regardless of the type of food, whether it is natural or processed, there is no particular impact on interaction effect between lighting color and food color.

In addition, when we displayed glasses of wine, we asked observers to find the light that makes the experimenter, who was seated across the table, look the most attractive. They were also asked about what factor they considered a greater priority; the appropriate lighting color for an appetitive appearance of food (wine & cheese) or the appropriate lighting color for highlighting a partner's attractive features. 73.33% of observers answered that lighting that makes their partner's look more attractive is more important. This suggests the implication that another context related factor to dining should be considered in finding lighting color.

General Discussion

Prior to the discussion session on empirical evidence of this study, we initially intended to explore the potential benefit that can be gained from the LED, not only in terms of pragmatic values such as energy efficiency or safety, but also its affective value. In this foregoing, we attempted to investigate the effect of interaction between lighting color and food color, especially because now we have a greater freedom of creating lighting colors by mixing R, G, and B values of RGB LED. In the preliminary test with a simple lighting facility ("Mini Living Colors" from Philips™), we obtained convincing results based on which we set forward to the main experiment. In the main experiment, we tried to observe the selected lighting color not only in terms of dominant wavelength (hue category) but also purity. The color picker software enables observers to select and to modify digital colors and then to realize it as a lighting color. However, there is a noticeable discrepancy between the digital color and lighting color since the gamut of each system is not properly matching with each other. For example, when an observer selected bright yellow by giving input values, R = 255, G = 255, and B = 128, the RGB LED resulted in purplish pink (x = 0.338, y = 0.299). Due to this technical limitation in main experiment, the result demonstrates that purple as a preferable appetitive lighting color. Nevertheless, we can conclude that three tendencies consistent throughout the two studies. In addition, we found that the contextual factor related to mood of dinning situation should be in a considerable factor. The lighting influences not only the appearance of the food but also that of people seated together. The affective effect of LED needs to be further explored, such that designers may refer to the empirical results when they create user-centered lighting environment.

Conclusions

In this study, we conducted two empirical studies supposing that there would be an interaction effect between food color and lighting color, and one's appetite should increase or decrease caused by this interaction effect. For the preliminary test, the observers were able to add only a certain lighting hue to the given context that was already lit with daylight. In the main experiment, the lighting facility was improved, so that observers might control not only hue aspect but also chroma and illumination. Throughout both empirical studies, we draw three major findings: First, among chromatic lighting, yellow stimulates while red and blue discourages one's appetite. However, as shown in the main experiment, the purity matters a lot in particular as the lighting very low purity (i.e., white lighting with nuances) is overall preferred. Second, when both food color and lighting color are similar, the lighting color generally stimulates appetite, whereas when they are dissimilar, particularly when the colors are complementary, the lighting color discourages appetite. Lastly, the type of food does not act as an influencing factor of the interaction effect between food color and lighting color, presenting consistent trend regardless whether the food is natural or artificial. Since the RGB LEDs become increasingly popular in interior design, the empirical evidence provided in this study is expected to be implemented in new dining environment. As far as the lighting quality affects one's mood and appetitive feeling, the attractive color contents facilitated with RGB LEDs will result the market success.

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