Causal relationship between lighting conditions and visual expectation of food products

A potential of memory color

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Abstract: A customer's satisfaction of a product depends on prior expectation as well as post experience of the product. Environmental factors such as lighting conditions potentially control the visual expectations of product goodness. Empirical techniques of lighting design have been applied to increase the visual expectation of a product (e.g., red lighting visually produces meat freshness). Although scientific studies on the partial dependence of visual expectation on lighting conditions have been done in various research fields, a cognitive structure of the relationship remains unexplained. In this paper, we propose a hypothetical model related to the effects of lighting conditions on a customer's visual expectation. The model consists of four layers: environmental factors (i.e., lighting conditions), visual features, cognitive factors, and visual expectations. We applied the model to illustrate a causal structural relationship between lighting conditions and visual expectation of a food product. For the food product application, we hypothesized that memory color and certain visual qualities such as freshness and hot-cold sensation affected the visual expectation. We successfully constructed the causal structure of the relationship between lighting parameters and a visual expectation "looks appetizing." We found lighting conditions in which observers judged a product to be more appetizing than under standard lighting conditions D50 and demonstrated that similarity to memory color is a key factor to increase the visual expectation.

Key words: Visual expectation, lighting design, memory color, food, LED.

1. Introduction

Disparity between prior expectation and post actual experience of a product has the potential to evoke both positive and negative emotions such as satisfaction and disappointment [1]. Excessive expectation may cause disappointment, whereas under expectation may not attract customers [2]. Thus, it is important to control expectation before experiencing a product. Customers often expect goodness of a product using visual information before experiencing it [3]. Examples of such situations include a vending machine, a show-window, catalog shopping, and online shopping. In these situations, customers do not experience a product before purchasing. Although techniques for maximizing visual expectation have been empirically developed and applied practically (e.g. raw meat with red colored lighting), scientific methodologies to control visual expectations have been largely neglected. LED (light-emitting diode) lighting that enables us to manipulate a variety of lighting conditions has the potential to control such visual expectation of a product. The aim of this paper is to illustrate a causal structure of the relationship between lighting conditions generated using LED and visual expectations. We used the visual expectation of foods for this study. For food products, it is known that prior expectation affects a customer's positive emotions such as pleasantness and satisfaction, as well as having experienced a taste [4, 5].

Several experimental studies have been performed on the visual expectation of food. For example, Suk et al. [6] investigated the best and worst combinations of lighting color and food color in terms of one's appetite. They conducted a sensory experiment using LED lighting and different kinds of food, and found that yellow lighting stimulates one's appetite except when the food is white colored, and similarity of color between lighting and food stimulates the appetite. Arce-Lopera et al. found that parameters of luminance distribution determined the perception of visual freshness using image analysis of a cabbage leaf [7].

Although conventional studies mainly investigated dualistic causality between partial factors, the overall structure of visual expectation involving multiple cognitive factors have been largely missing. In this paper, we propose a four-layer hierarchical model that illustrates a process using environmental factors (e.g. lighting conditions) and visual expectations. Based on the hierarchical model, we aim to illustrate a causal process using LED lighting parameters to the visual expectation "looks appetizing," which involves multiple factors with assumptions from partial findings of conventional studies and practice. Furthermore, we hypothesize that a similarity to "memory color" affects the visual expectation, which is a new aspect in the field of food lighting research. "Memory color" indicates the color of an object in reality that is in one's memory. It is known that memory color does not correspond to actual color [8]. Studies in memory color research have shown that people tend to prefer memory color rather than actual color and memory color tends to involve higher chroma than actual color [8, 9].

2. Proposal of visual expectation model

Figure 1 shows a hypothetical model of visual expectation (VEM) that illustrates a process involving environmental factors and visual expectation. The model consists of four layers viz. environmental factors, visual features, cognitive factors, and visual expectations. These layers are divided into physical phenomena and a cognitive structure. The cognitive structure depends on observers, whereas physical phenomena do not. In physical phenomena, an object in a certain environment generates a visual stimulus. Observers perceive that the visual stimulus involves certain features. For example, a food under certain lighting conditions (environmental factors) generates colors and observers perceive some color features such as luminance and chroma (visual feature). After perceiving the visual features, observers recognize the object and form an expectation pertaining to its quality.

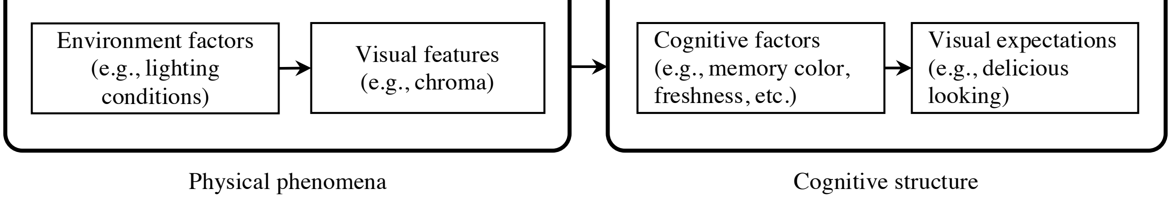

Figure.1 Hypothetical model of visual expectation with food lighting as an example

For example, for food, a customer may expect certain qualities of the food, such as freshness, as well as recognition of the food. In such a cognitive process, one refers to memory of concept and its typical quality as an attribute, and compares the quality in their memory with a quality perceived from a target object. For example, an observer's judgment "This apple looks dark in color" implies that the apple's color is darker than a typical apple's color in his/her memory. Therefore, the similarity to memorized concept and its typical quality is a key factor in recognition towards visual stimulus. Through such a cognitive process, observers finally judged the visual expectation such as "looks appetizing" in the case of food.

In this model, we assumed that environmental factors are manipulated variables, i.e. design parameters, and an object in the environment is constant. Thus, the model is intended to be used for designing a visual expectation by manipulating environmental factors based on illustrated causal structures.

3. Experiment

3.1 Overview

To extract the causal structure of the relationship between lighting conditions and visual expectation based on VEM, we conducted a sensory evaluation experiment using six kinds of food product and LED apparatus that enables us to manipulate several lighting conditions. We adopted illuminance and color temperature as lighting parameters to manipulate lighting conditions. We measured luminance and chroma of a food sample surface under different lighting conditions using Konica-Minolta CS-200 (Luminance and Color Meter). We obtained values of CIE L*a*b* color space as visual features for each food sample surface under each lighting condition. From findings of literature survey and lighting design practice, we hypothesized that the three factors affecting visual expectation are Hot-Cold sensation, Freshness, and similarity of memory color, which correspond to cognitive factors in VEM.

The experiment consists of three sets of assessments: firstly, similarity of memory color, secondly, visual expectation, and thirdly cognitive factors except memory color. To avoid participants' inference of our experimental hypothesis, we independently conducted each set of assessment. Using the measurements and assessment results obtained from the experiments, we analyzed causal relations between each level of VEM. The food samples, lighting conditions, and participants were identical for all sets of assessments. We selected all possible combinations of four levels of illuminance and five levels of color temperature as lighting conditions. In addition, we used D50 standard lighting (ISO 3664:2009) as the reference condition. As a result, the total number of lighting conditions was 21. Nine students from the University of Tokyo participated in this experiment. In each assessment trial, we showed a food sample under a lighting condition randomly selected from the 21 conditions and asked the participants to assess the appearance of the food sample. The order of the lighting condition used was random to eliminate the effect of order.

3.2 Experimental environment

To investigate the effect of only food surface color under a certain lighting condition, we need to eliminate the influences of other visual information such as the change in background color due to lighting conditions. Figure 2 and table 1 show the apparatus that has been developed for the purpose. This apparatus enables us to manipulate only food sample color by manipulating lighting parameters. We used JUST Color Viewing Light as the lighting source, which enables us to control certain illumination and color temperature using a combination of different

LEDs. The lighting box was covered by a black cloth. To eliminate the shadow of food on the bottom surface, we used a white styrene board as a reflector on the inner wall of the lighting box. We placed a diffusor between the LED and food sample to avoid a specular reflection of LED. We projected gray color onto a screen using a projector on the background surface, and placed a foreground window whose color corresponds to the background screen.

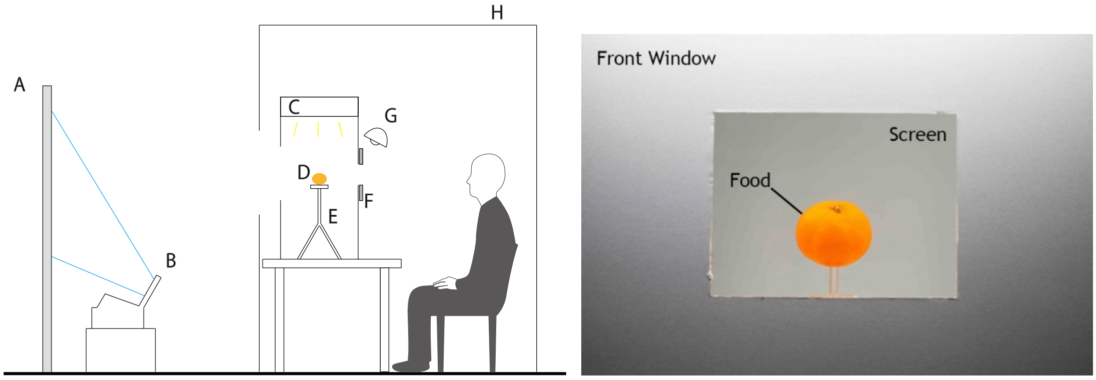

Figure.2 Experimental environment (on left) and front view of participant (on right)

Table 1. Components of experimental environment

	Components	Specification
A	Screen	-
B	Projector	NEC Projector WT615J
C	LED lighting source	JUST LED Color Viewing Light
D	Food	70 cm distance between participant's eyes and food sample
E	Pedestal	Tripod
F	Foreground window	Material: styrene board Color: N4
G	Foreground lighting	Incandescent light
H	Dark room	-

3.3 Lighting conditions

It is well known that color temperature can be used as an indicator of how "warm" or "cool" the light is. Furthermore, color temperature can be utilized to create a spatial impression and atmosphere. For instance, the observer feels warm when the color temperature is set lower than 3300 K, moderately warm when the temperature is between 3300 k and 5300 K, and cool when the temperature is higher than 5300 K. Therefore, we used five level color temperature conditions viz. 2800 k, 3300 k, 4300 k, 5800 k, and 8300 K, so that the difference in chromaticity between adjacent slabs occurs at approximately equal intervals. Regarding selection of the levels of illuminance, we used four levels of illuminance based on JIS Z9110:2010 that provide recommendations of illuminance levels in shopping stores. We adopted four levels of illuminance: 1500 lx, 1000 lx, 500 lx, and 300 lx. We used all combinations of color temperature and illuminance as lighting conditions (4 * 5 = 20). As a reference lighting condition, we used an additional standard light source D50 based on ISO 3664:2009 in which illuminance is 2000 lx and color temperature is 5000 K. As a result, we prepared 21 lighting conditions in total.

3.4 Food samples

We selected six kinds of food as samples for evaluation viz. a sliced cucumber (cut diagonally every 1 cm), a slice of bread (cut thinly into six pieces), a hashed potato (toasted in a microwave oven), a mandolin orange (form, size, and color comparatively average), a packet of chocolates, and a packet of green tea. There are three aspects for selecting the six as shown in table 2. The first aspect is the temperature of the food at which it can be eaten with pleasure. The second aspect determines whether the food color is warm or cold. The third aspect gives information on whether the food is packaged or not. Before conducting the experiment, we confirmed that no participants disliked any of the food samples.

Table 2. Food samples used in the sensory experiment

Foods	Food type	Warm-Cold sense	Surface color	Packaged
Sliced cucumber	Vegetable	Cold	Cold	No
A slice of bread	Bread	Warm	Achromatic	No
Hashed potato	Side dish	Warm	Warm	No
Mandarin orange	Fruit	Cold	Warm	No
Chocolate	Confectionery		Warm	Yes
Green tea	Drink	Both	Cold	Yes

3.5 Procedure

We separately conducted three sets of assessments. Other than the evaluation method and evaluation items, the following procedure was identical for all the three assessments. We set a food sample in the lighting box and turned on the LED source under a certain lighting condition. In the first assessment, we adopted the magnitude estimation (ME) method to evaluate similarity in memory color. In the ME based evaluation, firstly, we showed participants a food sample under a lighting condition as a reference (color temperature at 4300 K with an illuminance of 300 lx) for about five seconds. After that, we changed the light to a lighting condition that was randomly selected from the 21 prepared conditions as a target. We asked participants to score the food appearance under a target condition in terms of similarity to memory color of a food when the score of the reference was 100%. For the second and third experiments, we adopted the semantic differential (SD) method to evaluate visual expectation and cognitive factors as shown in table 3. In the SD method, we showed the participants a food sample under a target lighting condition randomly selected from the 21 conditions, and asked them to score using five level bipolar scales. We repeated the above assessment trial for the 21 lighting conditions. We conducted the set of assessment trials for all the food samples. The participants were given breaks of a few minutes between each set.

Table 3. Evaluation items for each level of the hypothetical model

Level	Evaluation items	Assessment order
Cognitive factors	Similarity to memory color	First
	Freshness	Third
	Warm-cold sense	
	Particular evaluation item for each food Juicy (cucumber), puffy (bread), freshly-fried (potato), sweet (orange), vivid (package)	
Visual expectation	Looks appetizing	Second

4. Result and Discussion

4.1 Semantic dimensions of cognitive factors

Cognitive factors such as freshness, warm-cold sensations, and similarity to memory color may involve personal differences in terms of their interpretations of the meanings. To evaluate the commonality of meanings [10] for each cognitive factor, we conducted a cluster analysis using a correlation distance between participants for each evaluation item used in the experiment and for each food sample. The correlation distance is defined as $1-r_{ij}$, where r_{ij} is a correlation coefficient between the evaluation scores obtained from participant i and j for a certain evaluation item. We divided participants into few clusters (i.e. groups) using a cluster analysis with a threshold of distance where r_{ij} was statistically significant ($p<0.05$). If a large cluster including a majority of participants was obtained for a certain evaluation item, then most of the participants shared a common meaning for the item. As a result, we confirmed that most of the evaluation items formed a large cluster involving a majority of the participants. For later analysis, we used an average score of the largest cluster in each combination of evaluation item and food sample. We did not use "warm-cold sensation" of the mandarin orange because it involved many small clusters.

Evaluation items of cognitive factors may correlate with each other and involve a few potential factors. To extract independent evaluation factors, that are dimensions of the cognitive factor, we applied principal component analysis (PCA) for each food sample. PCA is a statistical analysis that extracts a few independent dimensions called principal components (PC) from multivariate data. The i^{th} PC z_i is defined as $z_i = \sum_j k_{ij} x_j + \varepsilon_i$, where x_j is the i^{th} evaluation item, k_{ij} is PC loading, and ε_i is the error. Each PC involves the contribution ratio representing how much the PC explains the original data. We conducted PCA using four evaluation items: freshness, warm-cold, similarity to memory color, and particular items for each food as parameters for each food sample. We confirmed that the cumulate contribution ratio was more than 90% using the 1^{st} and 2^{nd} PC in all the food samples. Therefore, we concluded that two dimensions are sufficient to explain the cognitive factors.

Table 4 shows the PC loadings for the two PCs of the evaluation items for each food sample. The PC loadings represent how much each evaluation item affects each PC. The negative value of PC loading represents negative relations between a PC and an evaluation item. To interpret the meaning of each PC, we focused on the evaluation items involving significant PC loadings denoted by '**' in table 4. For the 1^{st} PC, memory color, freshness, and particular evaluation commonly affected the 1^{st} PC in most of the evaluation items. On the other hand, warm-cold sensation commonly affected the 2^{nd} PC in all the food samples. Thus, we can interpret that the 1^{st} PC represents memory color and freshness and the 2^{nd} PC represents warm-cold sensation. As exceptions, memory color belongs to the 2^{nd} PC in packaged chocolate and freshness belongs to the 2^{nd} PC in mandarin orange.

Table 4. Principal component loadings for the 1st and 2nd PC of cognitive factors (** denotes 1% significance level)

Cognitive factors	Freshness		Warm-cold		Memory color		Particular evaluation	
Principal components	1^{st} PC	2^{nd} PC	1^{st} PC	2^{nd} PC	1^{st} PC	2^{nd} PC	1^{st} PC	2^{nd} PC
Sliced cucumber (106.6)	0.57**	0.37	-0.34	0.90**	0.46**	-0.096	0.59**	0.23
Sliced bread (92.0)	0.71**	0.073	-0.18	0.77**	0.61**	-0.16	0.31	0.61**
Hashed potato (80.1)	0.71**	0.014	-0.15	0.9**	0.61**	-0.014	0.41**	0.34
Mandarin orange (60.2)	-0.057	0.99**			0.82**	-0.028	0.57**	0.16
Packaged chocolate (34.7)	0.66**	-0.011	-0.075	0.89**	0.38	0.43**	0.64**	-0.14
Packaged tea (126.0)	0.56**	0.42	-0.34	0.82**	0.55**	-0.21	0.52**	0.32

4.2 Effect of cognitive factors on visual expectation

The next question that arises is how cognitive factors affect the visual expectation. To answer this question, we conducted a multiple-regression analysis (MRA) using the extracted PCs as explanatory variables and the average score of "looks appetizing" as an objective variable. A model of an MRA is defined as $y = \sum_i w_i x_i + \varepsilon$, where y is an objective variable, x_i is the i^{th} explanatory variable, w_i is the partial regression coefficient of x_i, and ε is an error. Table 5 shows the result of MRA for each food sample. The coefficients of determination R^2 were significantly high in all food samples. It indicates that the formed MRAs could well estimate the scores of "looks appetizing" using the two PCs of cognitive factors. The partial regression coefficients of both PCs are significant in all food samples (p<0.05). The 1st PC and the 2nd PC are independent of each other. Thus, the two PCs independently affected the visual expectation. By comparing the standardized partial regression coefficients between the two PCs, the 1st PC is higher than the 2nd PC in most of the food samples. This result suggests a potential of "similarity to memory color" as a key factor for stimulating visual expectation. As an exception, the regression coefficient of the 2nd PC is higher than the 1st PC in sliced bread. The surface color of sliced bread is close to white, so that it can be largely affected by color temperature that may express the 2nd PC as involving "warm-cold sensation."

Table 5. Result of multiple regression analysis where explanatory variables are principal components of cognitive factors and the objective variable is the visual expectation "looks appetizing." (** and * denote 1% and 5% significant level, respectively.)

Food sample (hue)	Standardized partial regression coefficients		R^2
	1st PC	2nd PC	
Sliced cucumber (106.6)	0.89**	0.31**	0.90
Sliced bread (92.0)	0.47**	0.6**	0.92
Hashed potato (80.1)	0.58**	0.39*	0.88
Mandarin orange (60.2)	0.58**	0.12*	0.88
Packaged chocolate (34.7)	0.50**	0.49**	0.81
Packaged tea (126.0)	0.81**	0.48**	0.89

4.3 Effect of lighting conditions on visual features

For designing visual expectation with lighting conditions, we need to analyze the effects of lighting parameters on visual features and the obtained cognitive structure. We conducted the two-way analysis of variance (ANOVA) to analyze effects of lighting conditions (i.e., illuminance and color temperature) on a visual feature for each food sample. For the visual features, we used CIE L*, c*, and h* to represent the luminance, chroma, and hue, respectively. We derived L*c*h* based on the surface L*a*b* values measured by using the color meter. Table 6 shows the contribution ratio and significant levels of the ANOVA results. Illuminance was a dominant factor of L*, whereas color temperature was dominant in c*. We did not find any interaction effects, so that the effect of each lighting parameter was independent.

Table 6. Results of the two-way ANOVA using lighting conditions as explanatory factors and visual features as objective factors. The values represent contribution ratios [%] of each lighting condition. ** and * denote 1% and 5% significant level, respectively.

Food sample (hue)	Illuminance	Color temperature	Illuminance	Color temperature	Illuminance	Color temperature
	Luminance (L*)		Chroma (c*)		Hue (h*)	
Packaged tea (126.0)	99**	0	99**	0	0	100**
Sliced cucumber (106.6)	100**	0	35**	60**	0	100**
Sliced bread (92.0)	100**	0	11**	83**	0	100**
Hashed potato (80.1)	100**	0	28**	67**	0	100**
Mandarin orange (60.2)	97**	0	63**	32**	7	36*
Packaged chocolate (34.7)	94**	6	55**	42**	0	100**

The illuminance was positively correlated with L*. The relations between color temperature and h* are different, depending on the surface color of the food samples as shown in figure 3. For c*, both the illuminance and color temperature involved significant main effects. The illuminance positively affected c*, whereas the color temperature negatively affected c*. For sliced cucumber, sliced bread, and hashed potato, the effect of color temperature was higher than the effect of illuminance. These food samples have a similar value of h* of around 90. This result suggests that the dominance of effects of illuminance and color temperature depend on the hue of the sample's surface color.

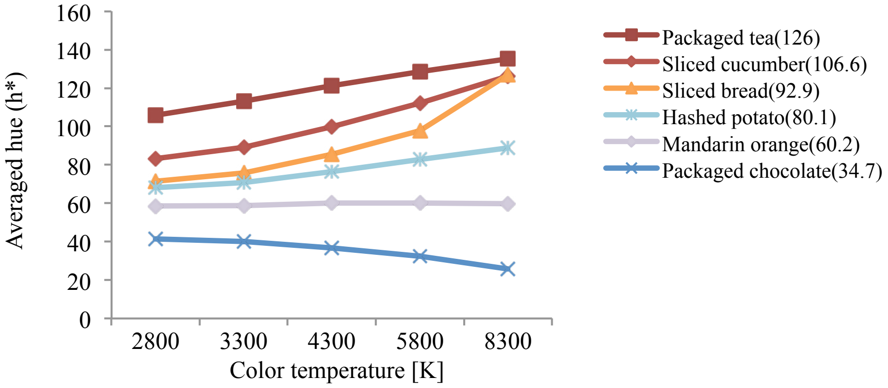

Figure 3. Effect of lighting color temperature on hue of sample surface color for each food sample.

4.4 Effect of lighting conditions on cognitive factors

In VEM, we assumed that visual features affect cognitive factors. However, values of L*c*h* (visual features) correlate with each other because L*c*h* values are the results of manipulating the two lighting parameters. In order to avoid multicollinearity, we used the two lighting parameters to explain the PCs of cognitive factors. The results of this analysis enabled us to interpolate the effect of visual features on cognitive factors with relations between visual features and lighting parameters (discussed in 4.3).

We conducted two-way ANOVA to analyze the effect of illuminance and color temperature on the 1st and 2nd PC of cognitive factors. No interaction effects were found, so that the main effects were independent of each other. Table 4 shows the F-values and significant levels of the lighting parameters on each PC for each food sample. In most food samples, the effects of both illuminance and color temperature were significant on both PCs (*p*<0.01).

Table 4. F-values and significant levels of lighting conditions towards principal components of cognitive factors

F-value		Packaged tea	Sliced cucumber	Sliced bread	Hashed potato	Mandarin orange	Packaged chocolate
1st PC	Illuminance	76.0**	35.8**	26.9**	39.4**	34.8**	45.8**
	Color temperature	63.6**	16.8**	0.3	25.1**	61.7**	9.0**
2nd PC	Illuminance	25.4**	19.0**	44.2**	80.6**	35.2**	6.6
	Color temperature	23.2**	61.2**	35.2**	141.7**	1.2	42.0**

Figure 4 shows the effects of the lighting parameters on the 1st PC, which involved meanings of "freshness" and "memory color," for each food sample. Illuminance positively correlated with 1st PC, although the gradients were slightly different among the samples. On the other hand, the relations between the color temperature and the

1st PC involved some patterns depending on the food samples. These relations tend to be positive for a cold hue sample such as packaged tea (green) and sliced cucumber (green), and negative for a warm colored sample such as hashed potato (yellow) and mandarin orange (orange). These results suggest that, in order to increase the degree of the 1st PC, we need to select the lighting color temperature that corresponds to the color temperature of the food surface. Packaged chocolate exhibited a deviation from this tendency. This is because the meaning of the 1st PC in packaged chocolate was different from that in the other food samples.

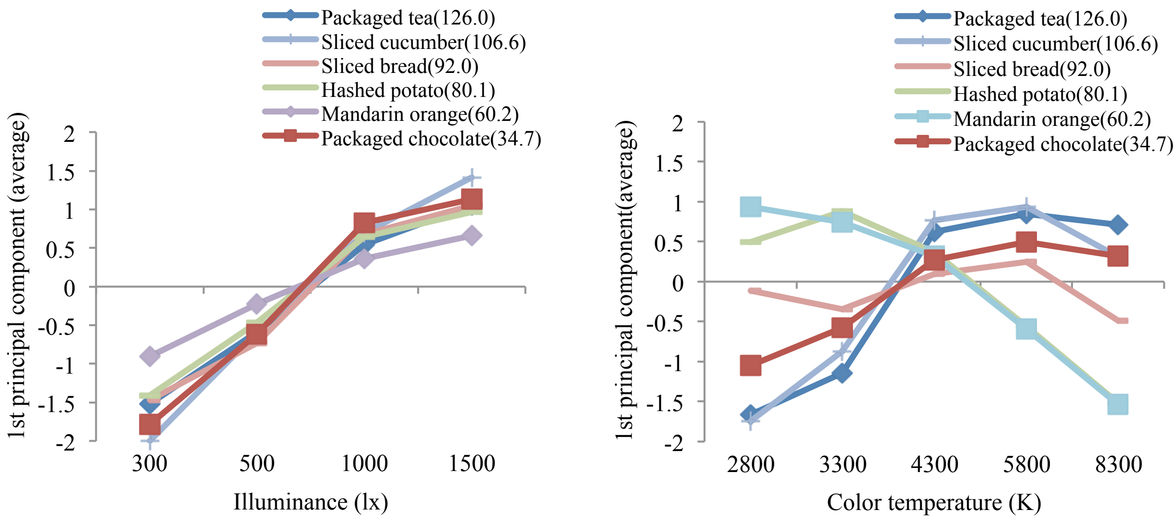

Figure 4. Effect of lighting conditions on first principal component of cognitive factor

Figure 5 shows the effects of illuminance and color temperature on the 2nd PC, which involved the meanings of "warm-cold sensation," for each food sample. The relation with the 2nd PC tends to be positive for illuminance, and negative for color temperature. Thus, regardless of the kinds of food, "warm-cold sensation" can be controlled using the two parameters. As an exception, color temperature did not affect the 2nd PC for mandarin orange. This is because the meanings of the 2nd PC correlate with "freshness" which differed from other food samples.

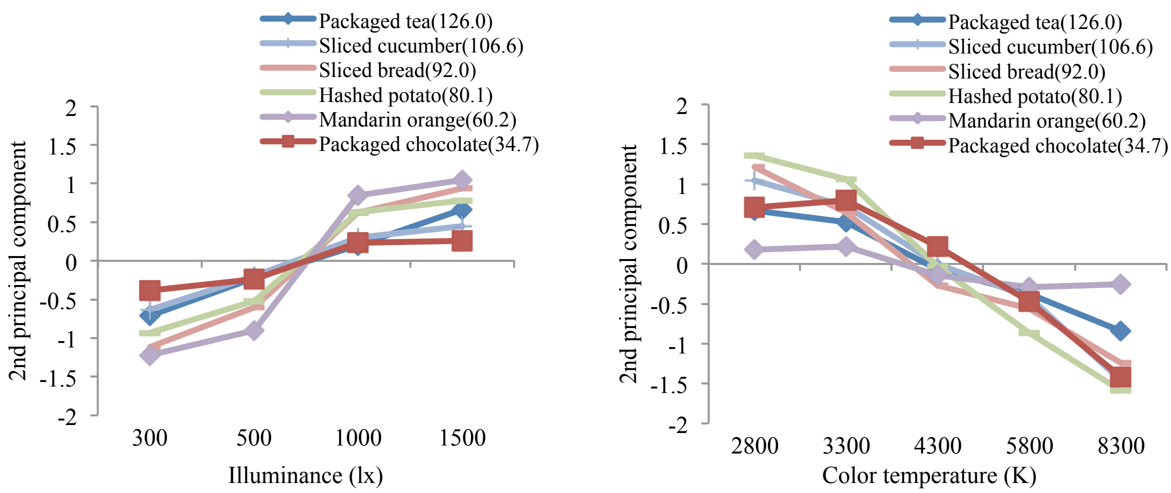

Figure 5. Effect of lighting conditions on the second principal component of cognitive factor

4.5 Relations of memory color and visual expectation

The 1st PC involved "similarity of memory color" that is a new aspect of a cognitive factor, and positively affected the visual expectation, as discussed in sections 4.1 and 4.2. We further analyzed the direct effects of the memory color on visual expectations in detail. Figure 6 shows a scatter plot of the combinations of food samples under different lighting conditions on color-opponent dimensions using CIE a* and b*. Each sign of plot denotes each kind of food sample. For simplicity, we plotted only two levels of illuminances, 1000 lx and 1500 lx. The size of balloons for each plot represents the averaged score of similar memory color. The black circles denote the colors of each food under D50 lighting condition, which represents the standard color of the food. Red balloons are for lighting conditions where the participants judged that the food color was more similar to a memory color than the one with D50. The blue balloons show the opposite cases. Balloons filled with yellow color depict conditions where the average score was higher than the ones with D50.

Interestingly, we obtained some lighting conditions that realized higher visual expectation than D50 standard lighting, which expresses the actual color. This finding indicates a potential to design higher visual expectation by manipulating illuminance and color template than a standard lighting, which is often regarded as an ideal lighting condition.

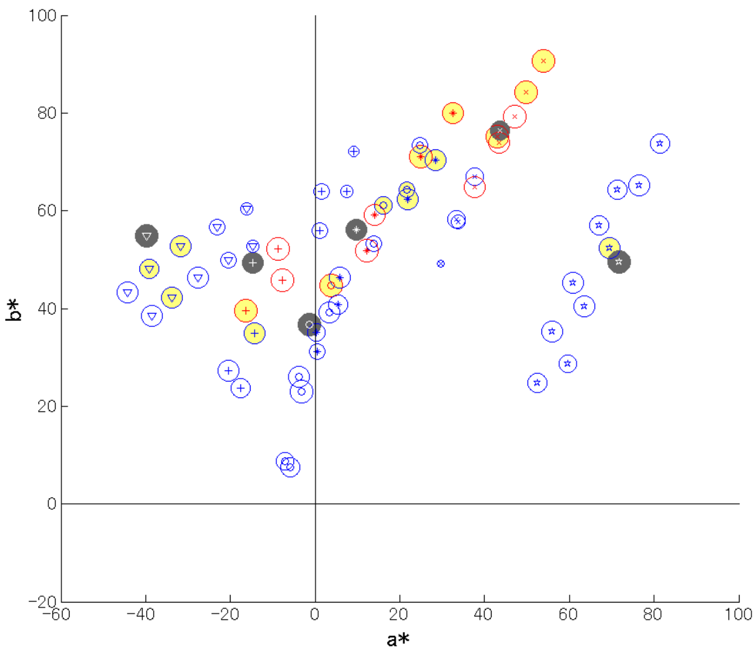

Figure 6. Scatter plots of food samples under each lighting condition on color space (a* and b*). The signs of plots denote food samples (+: cucumber, o: bread, *: potato, x: orange, star: chocolate, triangle: green tea). The black circles denote the standard lighting condition D50. The sizes of the balloons represent the score of memory color. Balloons filled with yellow depict the lighting condition for which the average score of visual expectation was higher than the one for D50.

For the mandarin orange and hashed potato, lighting conditions representing higher chroma (distances from the zero-point) tend to show greater similarity to memory color and visual expectation than with D50. This tendency corresponds to literature where memory color tends to be of higher chroma than the actual color [9]. For sliced cucumber, the lighting conditions involving higher hue than D50 tend to be judged as higher visual expectation. The color of cucumber is green, which corresponds to the direction of higher hue. This result implies an influence of color typicality. For sliced bread, we could not find an influence of memory color. This may be because the 2nd PC affected the visual expectation rather than the 1st PC in a result of the MRA.

5. Conclusion

Visual expectation is an essential factor to achieve customer's positive emotions such as satisfaction and pleasantness. In order to control visual expectation, the key issue is to understand a cognitive structure of visual expectation. In this paper, we proposed a four layer hierarchical model that illustrates a causal process between external environment as a design parameter and visual expectation. We applied the model for designing visual expectation of food, i.e. appetizing, by manipulating LED lighting parameter. Figure 7 shows a causal structure extracted from analysis of experiment using combinations of six kinds of foods and 21 lighting conditions consisting of different luminances and color temperatures. We obtained the following findings regardless of the kinds of food product.

- Two cognitive dimensions independently affected the visual expectation "looks appetizing." One was related to memory color and freshness (the 1st PC) whereas another was related to cold-warm sensation (the 2nd PC).
- Illuminance and color temperature independently affected the two cognitive factors. Combinations of the lighting parameters and the two cognitive dimensions had common relations. The gradient of relations between color temperature and the 1st PC depended on hue color of the food surface.
- Illuminance and color temperature had strong causal relations with CIE L*c*h* of the food surface.
- Lighting conditions where chroma saturation (i.e. c*) of food surface was higher than the actual one tend to present memory colors for non-packaged food. Food samples corresponding to memory color tend to exceed the one under ideal standard lighting.

These findings will work as indicators to manipulate visual expectation of food using the LED lighting parameters. Although this work has a limitation of sample size, we believe that the proposed model and analytical method used in this study is applicable to further research.

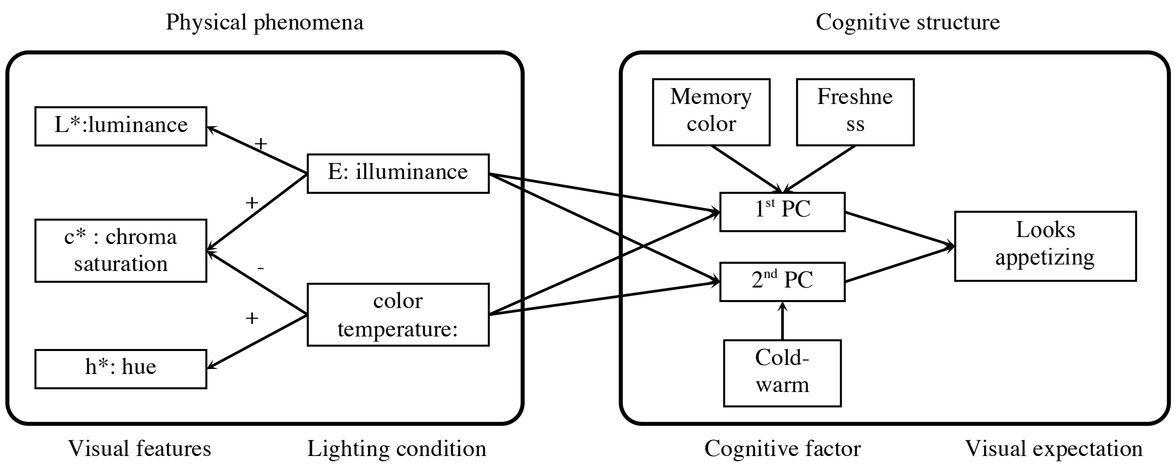

Figure 7. Extracted structure on how lighting conditions affect visual expectation of food samples

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