https://doi.org/10.2352/CIC.2023.31.1.15

Usefulness of Saliency Map in Estimating Food Appearance Favorability

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Abstract

Saliency maps are widely known as a model for simulating visual attention and are also used in industry. They basically indicate whether target images have features that perceived, which predicts the region on which people's eyes focus. However, the saliency may also be related to the favorability perceived by observers [1]. Our goal examined if the saliency of the food product estimates the favorability. Specifically, we manipulated the saliency of hot snacks through the display case design and examined how the evaluation of favorability (the degree of tasty looking) changed. We expected that if we could estimate the favorability of the target product by only using the saliency map, which is an image to show locations with high saliency in images, it would be very useful to estimate the variables, which correlate with the favorability of the appearance of the hot snacks in a short time. Hence, in this study, the favorability of hot snack appearances was evaluated by participants, and the correlation between the favorability score and a saliency value that we defined was analyzed. The tendency of favorability against saliency was compared with that to color conditions of lighting or background of target objects. As a result, it has been indicated that there was the correlation between favorability of food appearance and saliency. Therefore, the possibility that the saliency map can be used as a tool to estimate favorability has been supported.

1. Introduction

The aim of this study was to examine if the saliency of the food product estimates the favorability. A more concrete goal was to enhance foods' tasty looking by designing more effective showcases for them. Although we focused on color effect first, there were some challenges in front of the goal.

It is well known that color affects to human appetite and favorability of food appearances [2-7]. Regarding appetite, warm color is known as the color to appetize [2-5]. Favorability of food appearances strongly depends on color of illuminations [5-8]. For example, Tsujimura et al. focused on memory color, and their results can be interpreted as meaning that foods with higher chroma color look tasty if it is within the range of lighting color temperatures that are possible in everyday life [8].

However, experience had shown that several factors, not just chroma, were involved in tasty looking. Such factors were not always clarified their relations with the tasty looking. Then subjective evaluating experiments with large man-hours were required for each product when we needed data that show relation between specifications of each product and favorability that users feel for the product.

From the favorability point of view, processing fluency is one of the important key factors. Processing fluency refers to the ease of processing in the human brain from perception to cognition. In this paper, processing fluency refers to only visual processing fluency.

Reber et al. indicate the contents with high luminance contrast as the contents with high processing fluency [9]. They have observed that the more visually perceptible contents with high luminance contrast, the more positive impression was left on the observer. Such an object with high luminance contrast on its outline must be easily precepted according to the mechanism of receptive fields in human visual system, which fire when the boundary of light and dark areas is seen [10]. On the other hand, saliency maps, which were suggested by Itti et al. [11] or Harel et al. [12], extract locations that are expected to be easily perceived in images by simulating low-leveled visual system based on the mechanism of the receptive field. Therefore, saliency value that is extracted from the saliency maps is expected to be correlated with visual processing fluency, which Reber et al. described as being reproduced by the presentation of easily perceptible visual stimuli. Considering that expectation, we assumed that objects with high saliency will give observers positive impression provided by high processing fluency.

The results reported by Miniukovich et al. [1] supported our assumption. They have conducted a practical validation, suggesting that saliency can predict liking to some extent. The stimuli they presented were the iconic images with distinctly different colors and patterns. However, our evaluation targets were hot snacks in a showcase, and their appearances don't change drastically like the iconic images with different colors and patterns. Hence, it was not possible to predict from the study by Miniukovich et al. [1] how sensitive the saliency would be to small changes, such as when the type of object under observation is fixed, and only the color appearance of the object changes. For example, it was difficult to predict that saliency of the hot snacks was higher when the hot snacks looked tastier by color effect from lighting.

Miniukovich et al. defines saliency as the different characteristic from processing fluency, and they focused on complexity, which was the characteristic based on special frequency of luminance or color distribution of images, as an important variable relating to processing fluency. However, we thought that saliency could be related to processing fluency considering the results by Reber et al. [9] and focused on the saliency map in this study.

Based on the above, we assumed that saliency was correlated with favorability of appearance of the foods under all possible conditions at the hot snack display case, and the hypothesis was verified in this study.

2. Objectives

The objective of this study was to verify the usability of saliency map as a tool to predict favorability of food appearance. Concretely, first, it was verified whether saliency value we defined becomes higher when color effect, which is known to affect favorability of foods' appearances, was better condition for the favorability. Second, the change of saliency value was verified in case other factors were varied. Finally, it was discussed whether the saliency map and saliency value we defined could be used to predict favorability of foods without subjective evaluations.

3. Experiment Procedure

First, models of hot snacks were displayed under controlled conditions in a laboratory, followed by the photos of the displayed hot snack models were taken by the experimenter. The photos were used as stimulus images to be evaluated on a display by participants. The displayed hot snacks were fried chickens, frankfurters, and fried potatoes. Fig. 1 shows an example of the stimulus. The conditions for the displaying are shown in Table 1. The experimental conditions were designed to be treated as a one-factor experiment in which only one variable was varied. The reason for this was to clarify when a saliency map is useful and when it is not, so that future issues were expected to be clarified. The images from No. 1 to 19 in Table 1 were evaluated. Those images were shown in Fig. 2.

The experiment was performed using the method of paired comparison (Scheffé's method). The advantage of this method is that it can reduce individual differences and can produce high reproducible results. The presented images were set assuming an observation distance of 3m at the store where the products are displayed. The observing distance was adjusted to around 33cm by the participants themselves. The observed image size was around 12 visual angle (7 ± 1 cm) in the short length of the image (Fig. 1).

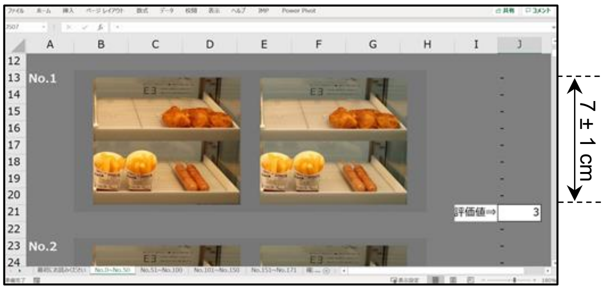

Figure 1. An example of presented images in the Experiment with the method of paired comparison.

The images were placed on an Excel file. The participants observed the images on their own display. They scored their favorability based on the criteria shown in Table 2. Besides, directions about the procedure and the criteria of the evaluation were shown on the side of images to be evaluated. Although such stimuli, which were not images to be evaluated, were included the displayed images, it was expected that the stimuli except images would not affect to the results because the evaluation was based on higher level cognition.

Seventy-four ordinary persons, ranging in age from teens to 50s, participated in the experiment. Of these, data from 63 who answered that they like hot snacks in advance were used in the analysis. As an ethical consideration, the purpose of the study was explained to the participants prior to their participation in the experiment, and their consent to the study was obtained freely and voluntarily. In addition, we ensured that the participants' personal information would not be identified.

This experiment was conducted online because of the pandemic in 2021. The experimenter couldn't control luminance and color space of the participants' displays and the environmental light condition. However, the noise which was coursed by the condition difference was expected to be small, because all experiment was relative evaluation based on the method of paired comparison.

Table 1: The condition of presented images. The numbers in () are the dummy values for statistical analysis.

No.	Lighting color tempe-rature	Tray color	Color render-ing	Net angle	Lighting angle	Hiding rear	Number on dis-play*3	Deploy-ment type
1	**3000K**	white	Ra90	flat (0)	horizon-tal (0)	w/o (0)	3	adja-cent (0)
2	**3500K*2**	white	Ra90	flat (0)	horizon-tal (0)	w/o (0)	3	adja-cent (0)
3*1	**4000K**	**white**	**Ra90**	**flat**	**hori-zonta**	**w/o (0)**	**3**	**adja-cent (0)**
4	**4500K*2**	white	Ra90	flat (0)	horizon-tal (0)	w/o (0)	3	adja-cent (0)
5	**5000K**	white	Ra90	flat (0)	horizon-tal (0)	w/o (0)	3	adja-cent (0)
6	4000K	**yellow**	Ra90	flat (0)	horizon-tal (0)	w/o (0)	3	adja-cent (0)
7	4000K	**orange**	Ra90	flat (0)	horizon-tal (0)	w/o (0)	3	adja-cent (0)
8	4000K	**red**	Ra90	flat (0)	horizon-tal (0)	w/o (0)	3	adja-cent (0)
9	4000K	**brown**	Ra90	flat (0)	horizon-tal (0)	w/o (0)	3	adja-cent (0)
10	4000K	**black**	Ra90	flat (0)	horizon-tal (0)	w/o (0)	3	adja-cent (0)
11	4000K	white	**Ra98**	flat (0)	horizon-tal (0)	w/o (0)	3	adja-cent (0)
12	4000K	white	**Ra80*2**	flat (0)	horizon-tal (0)	w/o (0)	3	adja-cent (0)
13	4000K	white	Ra90	**sloped (1)**	horizon-tal (0)	w/o (0)	3	adja-cent (0)
14	4000K	white	Ra90	flat (0)	horizon-tal (0)	**w/ (1)** *2	3	adja-cent (0)
15	4000K	white	Ra90	flat (0)	horizon-tal (0)	w/o (0)	**6**	adja-cent (0)
16	4000K	white	Ra90	flat (0)	horizon-tal (0)	w/o (0)	**1**	adja-cent (0)
17	4000K	white	Ra90	flat (0)	horizon-tal (0)	w/o (0)	3	**thinn-ing (1)**
18	4000K	white	Ra90	flat (0)	horizon-tal (0)	w/o (0)	3	**mirror-ed wall (2)**
19	4000K	white	Ra90	flat (0)	**verti-cal (1)**	w/o (0)	3	adja-cent (0)

*1) No.3 was default condition. Every effect by each variable was compared with No.3.
*2) The presented images were edited by image processing software: Photoshop CC (Adobe). In No. 2, 4, and 12, the presented images were images that were actually taken under illumination with color temperatures different from the set conditions and were edited so that the color temperatures matched the respective conditions. In No. 14, the shadow was drawn in Photoshop CC.
*3) The number indicates the number of fried chickens on a tray.

Table 2: The criteria for the method of paired comparison.

Criteria	Score
Right looks tastier than left.	2
Right looks slightly tastier than left.	1
No difference between right and left.	0
Right looks slightly less tasty than left.	-1
Right looks less tasty than left.	-2

Figure 2. *All evaluated images shown in Table 1.*

4. Analysis

4-1. Saliency Map Generating Algorithm

Saliency map is a heat map and a kind of simulation to show visual attention by image processing. The fundamental saliency map algorithm was suggested by Itti et. al. [11]. We used modified "Graph Based Visual Saliency (GBVS)" model [12], which is currently one of the most accurate models among rule-based models. The model visualizes bottom-up type saliency. Bottom-up type saliency can be rephrased to potential energy to attract visual attention when observers don't have any searching targets. Fig. 3 shows the algorithm to generate the saliency map based on our modified GBVS model. The basic procedure of the processing (1. extracting feature maps, 2. activating, 3. normalizing, 4. composing and 5. extracting a saliency map) is common among the model of Itti et al., GBVS and our modified GBVS.

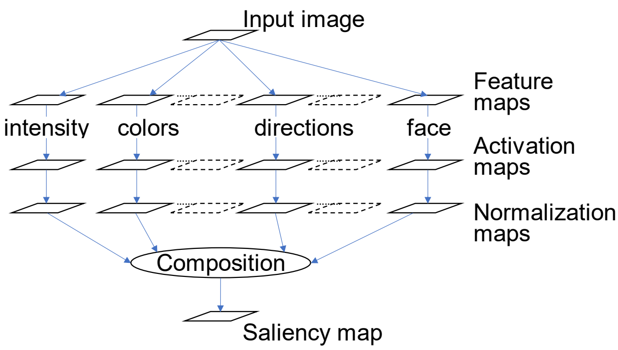

Figure 3. *The algorithm to generate a saliency map of our modified GBVS model.*

In this study, we implemented saliency map generating program based on the scripts that shown by Harel et. al. [13]. The difference between their scripts and ours are as follows. Extracted image characteristics from original images were luminance difference, color difference (Red – Green, Yellow - Blue), direction components (0°, 90°), and facial component. Luminance and color were described by L*a*b* (CIE1976). Although face detecting AI (retina-face: library for Python) was applied to our algorithm, it was applied for other studies and did not affect the results of this study, which did not include images with facial component. GBVS model requires "activation" process [12]. At the original way, each feature maps (Fig. 3) are changed into 2 different resolution images, the changed images with lower resolution were resized into the same as the higher resolution images, and the difference between those two types of 2D data is calculated for each feature. As a result, activation maps with enhanced contrast of the feature maps are obtained. We exchanged the activation algorithm to the method using max and minimum pooling from the original way.

The accuracy of our modified model was confirmed on the three standards suggested by Riche et. al. [14]. The data set used for the confirmation was CAT2000 [15]. Table 3 shows the result and that the modified GBVS model was more accurate than original. Hence, we decided to use our modified model for the analysis in this study.

Table 3: The accuracy verification result of the saliency map applied for this study. (The less is the better in KL-div, the larger is the better in other standards.)

	NSS	KL-div	AUC-Borji	CC
Modified GBVS	1.335	0.804	0.817	0.532
Original GBVS	1.23	0.80	0.79	0.50

- NSS: the normalized scanpath saliency
- AUC-Borji: the Area Under ROC curve measure that based on Ali Borji's code, used in Borji et al. 2013 (ROC: Receiver Operating Characteristic.)
- CC: Pearson's linear coefficient, or the linear correlation coefficient

4-2. Quantifying Saliency of Target Objects

We defined quantitative value of saliency of each product: fried chickens, frankfurters and French fries. The tone value of each pixel on a saliency map means saliency intensity of the pixel. In this study, we manually selected target area first (Fig. 4), sum-up the tone value within the area in gray scale mode (A), sum-up the tone value of whole area of the image (B) and described saliency value of the selected area by the Equation (1).

$$\text{“saliency value of the selected area”} = A / B \times 100 \ (\%) \qquad (1)$$

A: the sum of the values in the target area
B: the sum of the values in the whole image

Plural areas such as boxes in Fig. 4 were selected on each image, and all the area had "saliency value of the selected area" in Equation (1). Eventually, "saliency of the hot snacks" of an image was defined as the sum of all "saliency value of the selected area" of the image.

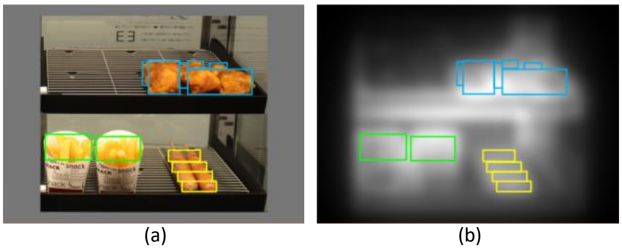

Figure 4. *An example of saliency map and the selected areas to calculate A in Equation (1). The boxes indicate areas for calculating A of each hot snack. The right image (b) is the saliency map. Saturation (chroma in HSV color space) of each hot snack was calculated from the same selected area.*

4-3. Statistical Analysis

The obtained score was calculated based on the method of paired comparison. First, all scores of each image were summed up, then it was divided by the number of original scores, which was directly obtained by the subjective evaluation. The result was defined as "favorability score". The number of the original scores for each image was 2394. That number can be calculated by the equation below.

$$\{(\text{the number of images})\times 2\}\times(\text{the number of participants}) \quad (2)$$

The value in { } means the number of evaluations that each participant performed. In this experiment, the number of images were 19 and participants were 63, hence the 2394 was calculated. Namely, the favorability score was the sum of all scores for each image in Fig. 2 divided by 2394. As a result, the obtained favorability score became within -1 to 1 although the original score range was -2 to 2.

Next, correlations between the evaluation of favorability (tasty looking) and the effect by each variable were confirmed individually. We focused on to confirm trend of favorability score against each variable based on regression analysis. However, the results of variables with levels under 3 were treated as hints for discussion because it was meaningless to apply regression analysis. Variable Importance in Projection (VIP) on PLS regression (NIPALS) was also calculated from the analysis including all data. The calculated VIPs were compared with each other, and the usefulness of each variable on predicting favorability was discussed.

5. Results

Fig. 5 shows the results of the effects by each variable individually. The higher favorability score means the tastier the hot snacks looked. The error bars indicate standard error. Those that could not be meaningfully regressed because there were only under 3 levels are shown in bar graphs.

To focus on the color temperature and Ra (mean of color rendering index) of the lightning, the conditions that have obtained higher favorability were the levels with lower color temperature or higher Ra. In both cases, when the favorability is higher, saturation (chroma in HSV color space) of presented food products were roughly higher (Fig. 5 (3)).

Regarding the tray color (Fig. 5 (4)), lower L* was favored. Moreover, lower ΔC* from red was favored when the plots of achromatic or nearly achromatic colors like white, black, and brown were ignored.

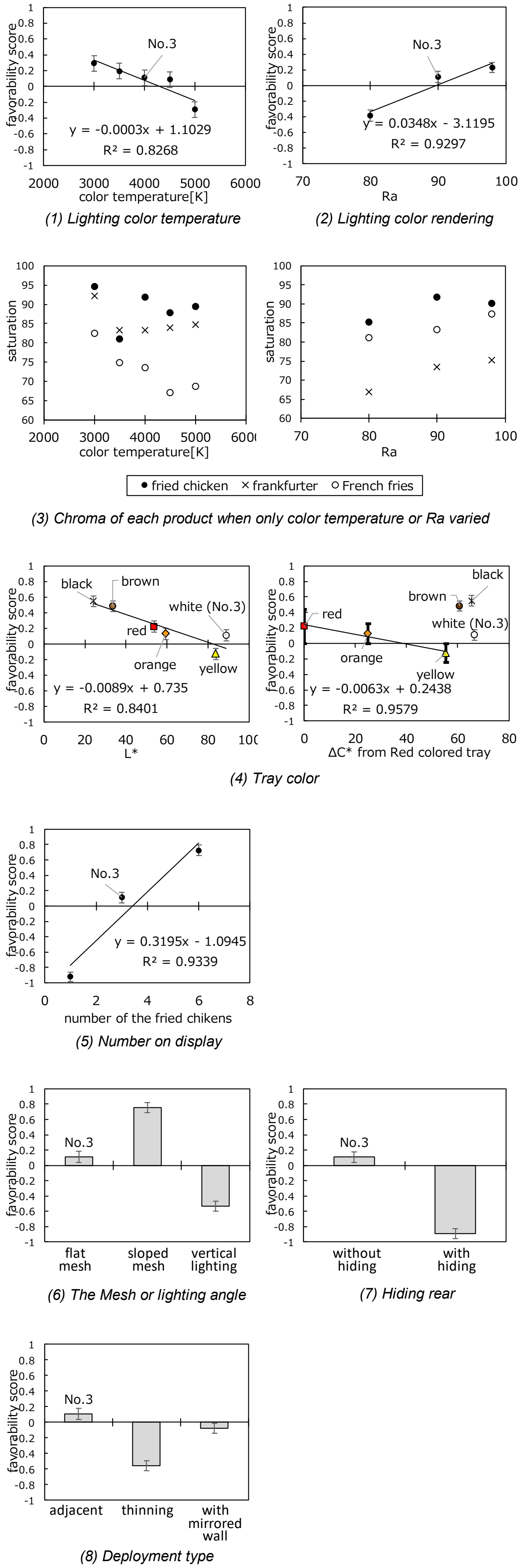

Figure 5. *The results of favorability scores for each variable.*

The greater number on display of the food products, the greater favorability score was obtained (Fig. 5 (5)). Among the variables that shown in (6), (7) and (8) in Fig. 5, the image, which the products were displayed on the sloped mesh and their appearance was shown with larger area in the area than other image samples, obtained greater favorability score. Besides, among (6), (7) and (8), the image in which shadow was added behind the products, and another image in which the products were placed with a space between them, were obtained especially negative favorability scores.

Table 4 shows the correlation coefficients R between "saliency of the hot snacks" and "favorability score" when each main variables were varied, and p-values of the Rs. The data from which each R was calculated was limited to the data obtained when each variable written in the first row in Table 4 were varied.

Fig. 6 shows "variable importance for projection" (VIP) obtained from NIPALS analysis. The data to extract the VIP included data of all image samples. Saliency of the hot snacks showed the highest VIP. Fig. 7 shows the relation between favorability score and saliency of the hot snacks in case that includes data of all image samples.

Table 4: The correlation coefficients R between "saliency of the hot snacks" and "favorability score" when each main variables were varied, and p-values of the Rs.

Varied variables	Color temperature	Ra	Tray L*	Number on display
R	-0.673	0.323	0.848	0.987
p-value	0.106	0.383	0.016	0.052

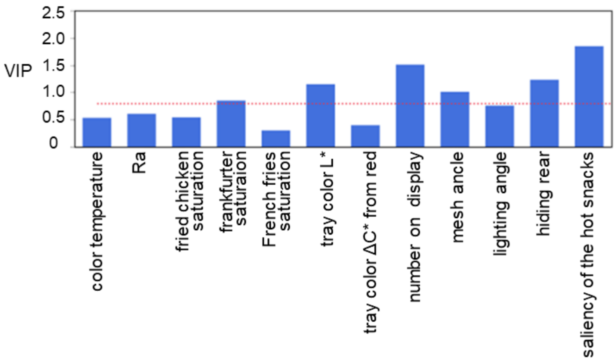

Figure 6. *VIP of PLS regression obtained by the analysis including all data. The dushed line represents the line at VIP=0.8.*

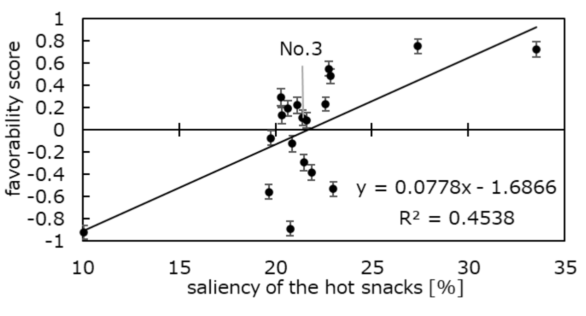

Figure 7. *The relationship between the favorability scores and "saliency of the hot snacks". The correlation coefficient R was 0.668, and p-value of the R was 0.0002*

6. Discussion

6-1. Lightning Color Effect and Saliency

For the hot snacks with brown color and warm temperature, lower color temperature and higher Ra were favored (Fig. 5 (1), (2)). Hence, the effects of parameters about color showed the results as expected from the past studies [5-8]. Although there are some limitations that we mention in section 7, General Discussion, the results that reproduced the predicted tendency indicate that the experiment were likely performed properly.

When color temperature of the lighting was varied, the saturation (chroma in HSV color space) of each hot snack was roughly increased, and the favorability was also increased (Fig. 5 (1), (3)). At this time, it is assumed that the saturation was closer to the memory color, making it more favorable. On the other hand, Table 4 indicates that there was negative correlation between saliency of the hot snacks and favorability, when color temperature was changed. However, the p-value of this correlation was greater than 0.05 and it means the shown correlation was not reliable. Besides, the indicated tendency didn't match our assumption that the higher saliency enhances the better favorability. Therefore, saliency value that we defined was not suitable for predicting color temperature effect.

Regarding Ra, the correlation coefficient between the saliency and the favorability has shown weak correlation, and the p-value has indicated low reliability on the indicated correlation. Taken together with the discussion of color temperature, we concluded that our definition of saliency values was not suitable as an alternative variable for lighting-induced color effects.

6-2. Tray Color Effect and Saliency

Although the warm color is said to affect appetize and we expected it would enhance the favorability, even red and orange trays resulted in lower favorability scores than black and brown trays. The R^2-value for the correlation between L* of tray and favorability score was greater than that between ΔC*, which was difference of chroma compared with the used red tray, and favorability (Fig. 5 (4)). Hence, L* of the trays was found that it affected to favorability stronger than the chromatic effect by the trays. To see the correlation coefficient in Table 4, R between the saliency and the favorability, when L* of the tray color was varied, indicates strong correlation with low enough p-value. Since the saliency value basically increases when the luminance contrast around the focused area increases based on the algorithm to extract the saliency map, it would be natural that the saliency value increases when L* of the tray decreases. Therefore, the results indicated the possibility that our defined saliency value was capable to predict favorability due to color of the tray, namely, peripheral colors of the target. It could also be interpreted like that the effect by peripheral colors behind the observation targets for their favorability could be weaker than the effect by saliency of the targets. However, verifying it when the tray colors were cool colors is needed to prove that possibility.

6-3. Other Factors and Saliency

In the case that number on display has been increased, the favorability has shown higher score. This phenomenon must have been happened naturally because the saliency value that we defined was the value proportional to the size of the target in the image. The correlation coefficient in Table 4 showed strong correlation between the number on display and saliency. The p-value was not low enough, but almost the same as 0.05, so the correlation would be allowed to interpret as a reliable result.

In Fig. 6, even the variables that had only under 3 levels and described using dummy value were included in the analysis. The variables with significantly high or low favorability scores have shown greater or approximately the same VIP than the variables regarding color. The reason why mesh angle has shown higher VIP was estimated as follows. When the angle was larger, since the observed area of each hot snack became larger, the cue to aware the feature of each hot snack appearance must have become more intelligible. To consider this idea with the favorability results, it would indicate the possibility that the more intelligible appearance provided the more processing fluency, and the fluency might have helped to determine the favorability. The same idea might be applied from the opposite aspect relating to "Hiding rear" condition.

The aforementioned idea can also be interpreted as suggesting that favorability may depend on the size of the observation target in images. On the other hand, our defined saliency value depends on the size, and has shown the highest VIP (Fig. 6). The VIP indicates the possibility the saliency value can be a variable to predict favorability score. These results and discussion support the possibility that the saliency can be used to predict favorability except in the case that only lighting condition is change.

7. General Discussion

It was shown that our defined saliency value probably predicts effects on favorability by major variables except lighting conditions. Fig. 7 is the result including all possible conditions on our product and indicates that there is correlation between the saliency value and favorability score of the hot snacks. Therefore, we concluded that the saliency value and saliency map, which is the origin to extract the saliency value, is useful at least to roughly determine whether some unknown variables affect to food appearance such as hot snacks. Our defined saliency value couldn't predict the effect by color of lighting. On the other hand, although lighting color temperature or Ra are important factors effecting on favorability, it is obvious that these variables alone never be able to predict favorability change that is occurred by the number of observation targets when the lighting conditions are fixed. Therefore, the saliency value is expected to be used more effectively by used with the variables relating to lighting.

There are some limitations on the results of this study. The conditions of each display that the participants used, and the environment light and sound conditions of the experiment were not under controlled. Since the experiment was relative evaluation with the method of paired comparison, it was expected that errors due to uncontrolled conditions would be reduced, but it cannot be denied the possibility that there were noise affecting the results. Next, in experiment No. 2, 4, and 12, the presented images were created by editing images that were taken under illumination with color temperatures different from the set conditions. Hence, appearances of the images presented in No. 2, 4, and 12 may differ from the appearance that would be observed if each condition could be set in the real world.

Finally, the assumption that saliency is correlated with processing fluency has been supported by the result showing correlation between saliency and favorability. However, direct observing processing fluency against saliency change is needed to proof the assumption in the future. Moreover, it is desirable in the future to discuss regarding the favorability of appearance under more complicated conditions.

Conclusion

The usability of saliency map as a tool to predict favorability of food appearance was verified using the hot snack samples. Saliency value we defined becomes higher when L* contrast between the food and its peripheral colors becomes higher, or when the target size in images becomes larger within this study. The saliency map, which is the origin to extract the saliency value, is useful at least to roughly determine whether some unknown variables affect to food appearance such as hot snacks.

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