EFFECTS OF LIGHTNESS CONTRAST AND IMAGE SIZE ON KANSEI EVALUATION OF PHOTOGRAPHIC IMAGES

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ABSTRACT

The purpose of this study is to clarify the effects of the lightness of main object (L_t), the lightness of background (L_b), and the lightness contrast ($|L_t-L_b|/L_{av}$, L_{av} is the average lightness of image), upon observers' KANSEI impression, and further to investigate their relation to the screen size. Seventeen test images of different lightness contrast were prepared not by using image processing but by manipulating the lighting condition in the photography. Four different image sizes, 7, 14, 29 and 57inches diagonal, were examined. Unipolar scales method using 22 adjectives was utilized for KANSEI evaluation of test images. Results showed that adjectives were divided into three groups. Rating score of the first group changes markedly with the lightness contrast, that of the second group varies with the image size, and that of the third group changes with both the lightness contrast and image size. Three factors were extracted by factor analysis. First factor, called KANSEI factor is described by linear transform of the L_t and image size fairly well, indicating that not only the lightness contrast but also the lightness of main object is important factor for KANSEI evaluation.

Keywords: *KANSEI evaluation, photography, lightness contrast, image size, factor analysis, multiple regression analysis*

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1. INTRODUCTION

In everyday life, we are surrounded by various types of display such as large plasma displays of TV, LCDs of laptop, or small displays of cellular phone, etc. When we see the same content through different types of display, their impression would be different due to the differences of image size, resolution, luminance, and/or color [1-4]. However, this is not a desirable situation for WEB creators who want to send their intent of the digital contents to all kinds of observers whatever the display they see. This is even a serious problem for an advertisement of e-shopping, where the same merchandise should be looked the same in any kind of display ideally.

In our previous study [5], we investigated the effects of lightness contrast and metric chroma upon KANSEI evaluation of color images, and their relation to image size on a display. We used three images of "Fruit", "Flowers", and "Building". For each of them, we prepared 21 kinds of images with different lightness contrast and metric chroma of the CIELAB. Those images were presented on the large LCD (SHARP LCD ML-5M) with one of the three image sizes (2.5， 12， or 22 inches diagonal). Then KANSEI evaluation was done by unipolar scales method using 24 adjectives. Results showed that subjective rating for psychophysical properties of image, such as "Light", or "Dark", increases monotonously with the increase of chromatic contrast and/or the decrease of the lightness contrast, while the rating value for preferential evaluations shows a peak at moderate contrast for both the lightness and chroma. Results also indicated that in the case of small size of image (2.5 inches), image processing to enhance chroma and/or lightness contrast is needed, while for large size of image (22 inches), such a modulation might give poor impression to observers. Therefore, some kind of size-dependent image modulation is necessary to give a same impression to observers. Another implication is that not an average lightness, which was kept constant in the study, but the lightness of main object is an important factor in KANSEI evaluation.

Therefore in this study, we focus on the effect of the lightness contrast, as well as the effect of absolute lightness of main object, upon KANSEI evaluation of color image, and investigate their relation to image size. Considering the applicability of our results to photography of merchandise, different lightness contrast in the test images was produced by manipulating the lighting set in the photography. No image processing was utilized. In the experiment, test images were presented to observers and impression of images were evaluated using the unipolar scales method. Four sizes of image were employed. In the results of some evaluation words, correlated effects of the lightness contrast and image size was observed, while in the results of other words, their effects were independent with each other. In order to clarify the properties of KANSEI evaluation, factor analysis was applied to all the results, and three factors were extracted. First factor, called "KANSEI factor", was explained by a linear regression of lightness of the main object and image size.

2. EXPERIMENT OF KANSEI EVALUATION

2.1. Test image and the lighting set-up for photography

We employed a picture of colorful fruits in a basket as test image (Figure 1). Instead of fresh fruits, highly accurate models were used in order to keep the surface quality constant under a long time light exposure during photography. We defined that the image area of fruit and basket is the "main object" in test image, while the rest of the image is regarded as "background". The background is achromatic while it has a slight gradient of lightness.

Figure 2 shows the lighting set-up for the photography of test images. Seventeen different lightness contrasts between main object and background were achieved. In the photography of ascending series of the lightness of main object (L_t), the distance between the front lighting and the diffuser was varied with 11 stages with 10cm interval, while the setup of the back lighting was kept constant. On the other hand, in the photography of descending series of the background lightness (L_b), transmittance of neutral density filter (ND filter in Figure 2) was varied using six combinations of 25% and 50% filters, while the position of the front lighting was fixed. Lighting set-up shown in Figure 2 was placed in a dark booth. Neutral white fluorescent lamps (correlated color temperature of 5000K) were used for the front and the back-lighting. Pictures were taken by a digital camera (Nikon D50, Focal length 38 mm, ISO sensitivity: 200, Shutter Speed: 2 sec, Resolution: 3008 × 2000 pixel).

Figure 1: Test image

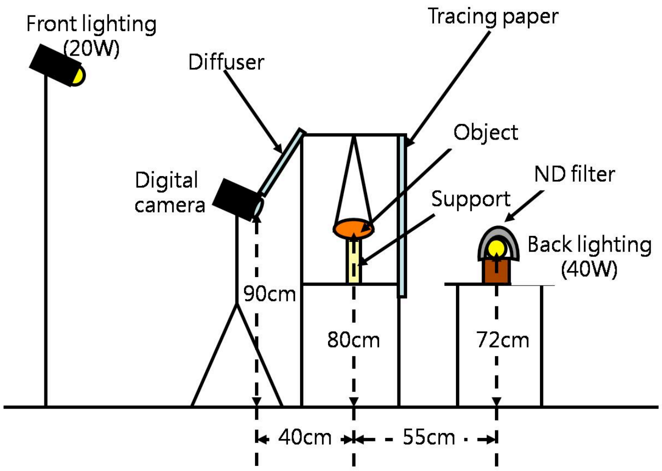

Figure 2: Lighting environment for photography

Lightness of a pixel was derived as follows. Tristimulus values of a pixel ($X, Y, and\ Z$) were calculated from RGB values of the pixel using sRGB [6], and then they were transformed to L^*, a^*, and b^* assuming the perfect diffuser under the D65 illuminant as a standard white. Lightness of main object (L_t) is an average lightness of the 'main object' area in the image, and the lightness of the background (L_b) is an average lightness of the 'background' area. Lightness contrast is defined as the ratio of $|L_t - L_b|$ to the average lightness of the image L_{av}. The lightness of main object, background, and the lightness contrast for 17 images are indicated in Table 1. Increase of the lightness contrast of the images of ① ~ ⑪ is achieved by increasing L_t, while that of the images of ⑧ and ⑫～⑰ is produced by decreasing L_b.

Four kinds of image size (7, 14, 29, and 57 inches diagonal) were prepared. The maximum size was the original image, and the smaller ones were produced using a successive linear transform. Total of 68 test images (17 lightness contrasts X 4 image sizes) were created.

Table 1: Lightness of main object (L_t), lightness of background (L_b), and lightness contrast ($|L_t$-$L_b|/L_{av}$) . L_{av} is an average lightness of image.

Image	L_t	L_b	$\|L_t$-$L_b\|/L_{av}$
□	2.74	93.65	1.81
□	11.69	94.02	1.54
③	14.39	93.78	1.47
④	14.69	94.10	1.42
⑤	22.25	93.00	1.23
⑥	27.40	94.24	1.10
⑦	30.46	94.28	1.03
⑧	35.81	94.41	0.90
⑨	41.43	94.65	0.78
⑩	47.13	94.86	0.67
⑪	51.67	94.94	0.59
⑫	36.46	84.71	0.81
⑬	31.52	71.94	0.77
⑭	33.81	57.45	0.52
⑮	34.65	47.26	0.32
⑯	33.53	37.23	0.11
⑰	32.60	23.26	0.34

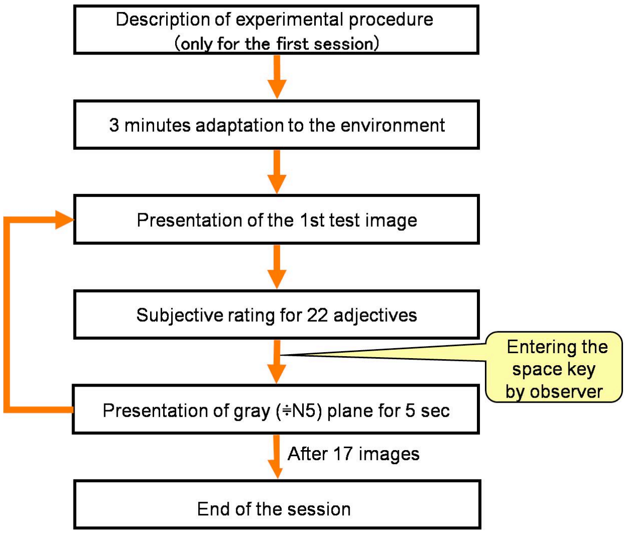

Figure 3: Flow of experiment

Table 2: 22 Adjectives used in unipolar scales method

Weak contrast	Strong contrast	Pale color	Deep color
Dark	Light	Ordinary	Impressive
Fuzzy	Clear	Plain	Showy
Unnatural	Natural	Dirty	Clean
Hate	Like	Unpalatable	Delicious
Plane	Chiseled		

2.2. Subjective evaluation experiment

2.2.1. Experimental environment

In order to reduce the effects of ambient color, walls were covered by gray curtains (nearly equivalent to N5) except the display. Ambient light was a fluorescent light fixed in the ceiling of the room. Horizontal illuminance near the center of the display is about 285 lx, and the vertical illuminance at the same place is approximately 350 lx.

2.2.2. Method of subjective evaluation

Unipolar scales method (US method) using 22 adjectives was employed. These adjectives listed in Table 2 are the same ones as used in our previous study. Rating scale is from 0 to 6 and the description of the scale presented to observers is as follows: “0: not at all”, “2: slightly”, “4: obviously”, and “6: quite”.

2.2.3. Experimental procedure

Figure 3 shows experimental procedure. The observer entered the experimental room and adapted to visual environment there for three minutes. Test images were then presented on a large display (SHRAP AQUOS LC-65RX1W). In a session, 17 images randomly chosen among the 68 images were presented in a random order, and for each of them, observer was instructed to evaluate the test image by choosing his/her position on a scale with 7 steps between 0 to 6 for each of 22 adjectives listed on the answer sheet. The order of the adjectives on the sheet was randomized between observers to avoid the order effect. This was repeated for 17 images. Observer could see the test image as long as he/she satisfied. In order to avoid the comparison between successive images, N5-like plane was presented in each interval for 5 seconds. Two conditions were employed for visual distance, 160cm and 320cm. Four sessions were done for each of visual distance, resulting 8 sessions for each observer.

2.2.4. Observers

Fifteen students, 11 males and 4 females of in their early twenties, participated in the experiment. All of them have normal color vision (C-type).

3. RESULTS AND DISCUSSION

3.1. Effects of lightness contrast and image size

Figure 4(a) shows the average rating scores of 15 observers for 22 adjectives in the image size of 57 inches, with the lightness contrast of 0.67 at the visual distance of 160cm. Results of 17 lightness contrasts in the same image size and visual distance are plotted together in Figure 4(b). As shown in the figure, rating scores of some words such as “Dark” or “Light” disperse widely indicating they are strongly affected by the lightness contrast, while those of other words such as “Chiseled”, “Ordinary” or “Plane” show similar value for all of the lightness contrast implying little influence from the lightness contrast. Standard deviation of the rating score was calculated for each word, and then 22 adjectives are placed in a descending sequence of standard deviation in Figure 4(b). The same order was employed in Figure 4(a) just for convenience. Figure 4(c) shows the results of 4 image sizes in the lightness contrast of 0.67 and visual distance of 160 cm. Similar to Figure 4(b), adjectives are placed in a descending sequence of standard deviation here. Rating scores of adjectives placed in the upper part, such as “Chiseled”, “Impressive” or “Fuzzy” show a larger variance with image size, in other words, the rating scores of these words are influenced by image size.

Figure 5(a) indicates the standard deviations of the rating scores of 22 adjectives shown in Figure 4(b). As noted above, the image size in this result is 57 inch and the visual distance is 160cm. In the experiment, four image sizes, 7, 14, 29, and 57 inches diagonal, were employed at the same visual distance. Therefore we drew figures similar to Figure 5(a) for four image sizes. Then, standard deviation of the rating score for the adjective “Dark”, for example, is obtained for each of the four image sizes, as well as those for other adjectives. Results of 7, 14, and 29 inches are basically similar to Figure 5(a), although they are not shown here to save space. Figure 5(b) indicates the average of standard deviations of the rating scores among four image sizes. Error bars denote the standard deviation of them. In Figure 5(b), adjectives are placed in descending sequence, which is not drastically changed from that in Figure 5(a). “Dark” and “Light” are still in the top, while “Plane” and “Ordinary” are still in the lowest positions, indicating that similar tendency is found in all image size conditions about the variance with lightness contrast.

Figure 4(c) implies that rating score of some adjectives shows image size dependency. Figure 6(a) indicates the standard deviations of the rating scores of 22 adjectives shown in Figure 4(c). However, it is only at the lightness contrast of 0.67. To explore this property for all the lightness contrast, we drew figures similar to Figure 6(a) for 17 lightness contrasts, not shown here to save space. It is interesting that adjectives showing a large variance with image size mostly overlap among all the lightness contrast conditions, although the absolute value of rating score varies with lightness contrast. Figure 6(b) indicates the average of standard deviations of the rating scores among 17 lightness contrasts. Error bars denote the standard deviation of them. In Figure 6(b), adjectives are placed in descending sequence there. As noted above, adjectives in the upper part are similar to those found in Figure 6(a), for example, "Chiseled" and "Impressive" are still in the top here. However, the order of adjectives in the middle to lower part changes from that in Figure 6(a), indicating the image size dependency is vague for the rating scores of these adjectives.

Standard deviation of the rating score for a certain adjective among different lightness contrast conditions (SD_{light}) reflects the effect of lightness contrast, while that among different image size conditions (SD_{size}) exhibits the influence of image size, upon the assessment using the adjective. It is shown that some adjectives are in the top part in Figure 5, and some other adjectives are in the top part in Figure 6. So, to understand the mutual relation between the effects of the lightness contrast and image size, SD_{light} and SD_{size} are plotted in the horizontal and vertical axis, respectively, for each adjective in Figure 7. Result of the viewing distance of 160cm is shown here. Broken vertical and horizontal lines are drawn at the average values of SD_{light} and SD_{size}, respectively. It is clear that adjectives "Light" and "Dark" show large value of SD_{light}, while their SD_{size} are relatively small, representing that assessment with these words is strongly affected by the change of lightness contrast while hardly influenced by difference of image size. Similar to that, adjectives "Impressive", "Chiseled", and "Plane" show large value of SD_{size} while their SD_{light} are relatively small, implying that assessment with these words is intensely affected by the change of image size while scarcely influenced by variance of the lightness contrast. The third group of adjectives, "Clear", "Clean" , "Showy", "Delicious" and "Like", show both SD_{light} and SD_{size} values larger than the average, indicating that the assessment with these words is affected by both the lightness contrast and image size.

In the results of viewing distance of 320cm, similar results are obtained except that the superiority of the performance in the image size of 57 inches diagonal is more eminent than that in 160cm condition.

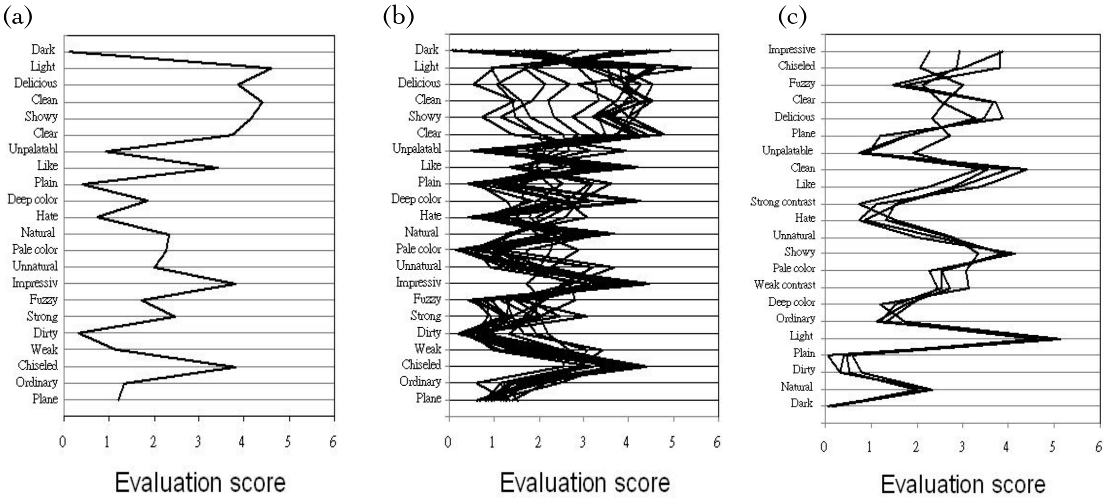

Figure 4: Results of the unipolar scales method at the viewing distance of 160cm. (a): results in the lightness contrast of 0.67 and image size of 57 inches, (b): results of all the lightness contrast (17types) with image size of 57 inches, and (c): results of all the image size (4types) with the lightness contrast of 0.67.

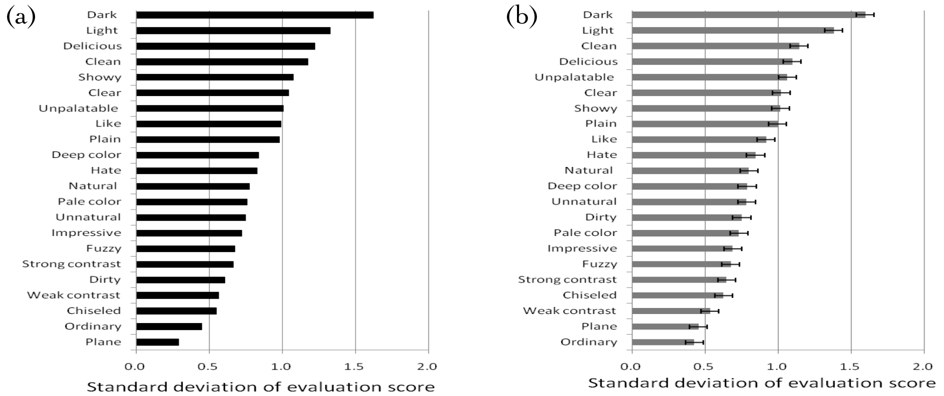

Figure 5: Variability with the lightness contrast. (a): standard deviation among the 17 lightness contrast in the image size of 57 inches, (b): average of standard deviation among the results of all image sizes, denoted as SD_{light} for each adjective.

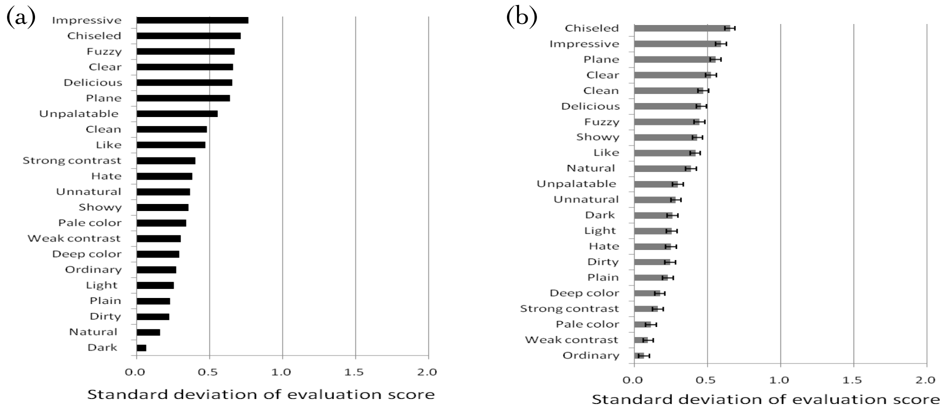

Figure 6: Variability with the image size. (a): standard deviation among 4 image sizes in the lightness contrast of 0.67, (b):average of standard deviation among the results of all lightness contrast, denoted as SD_{size} for each adjectives.

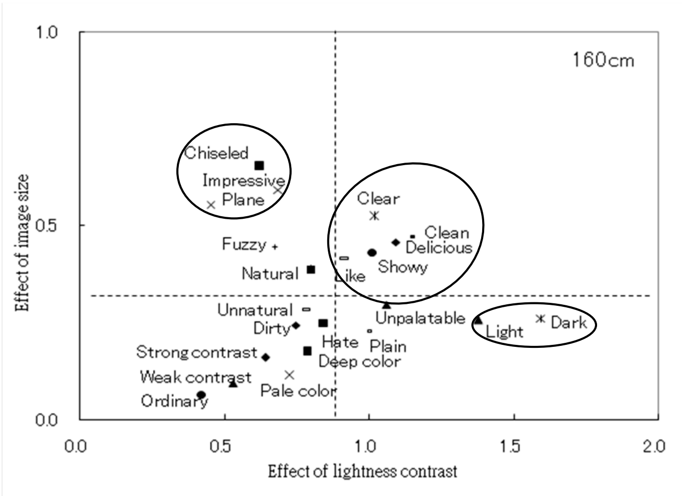

Figure 7: SD_{light} and SD_{size} for 22 adjectives in the viewing distance of 160cm.

3.2. Factor analysis and discussion

In order to extract the factors to contribute the KANSEI evaluation, we applied a factor analysis using 136 results (17 contrasts X 4 sizes X 2 distances, in each of them the average scores of 15 observers were used). After the factor extraction, VARIMAX rotation was used by the main factor method. As a result, three factors having an eigenvalue larger than 1, were extracted and their cumulative contribution rates larger than 80%. The results of factor analysis are shown in Table 3.

Most of the adjectives show the largest absolute value of factor loading in the first factor. We named the first factor as "KANSEI factor", because adjectives of "Showy", "Like", and "Impressive" indicate large values of the factor loading. Note that negative value indicates positive evaluation here. In the second factor, adjectives such as "Pale color" and "Weak contrast" show large values of the factor loading, and then we named the factor as "Contrast factor". Finally, we named the third factor "Ordinary factor" because adjectives of "Ordinary" and "Unnatural" show large values of the factor loading.

Because most of adjectives have the largest values in the factor loading of "KANSEI factor" among three factors, we investigated its property in detail. Figure 8 shows the change of factor score of "KANSEI factor" with the lightness contrast. Note that the vertical axis is plotted upside down because in this factor, negative value means positive assessment. Figure 8(a) shows the results of images in which L_b is almost constant and the lightness contrast increases as L_t decreases (from ⑪ to ① in Table 1). In this figure, the factor score significantly varies as a function of the lightness contrast. It increases, i.e. assessment becomes worth, with the increase of lightness contrast, in other words, the decrease of L_t. On the other hand, Figure 8(b) indicates the results of images in which L_t is almost constant and the lightness contrast increases as L_b increases (from ⑯ to ⑫, and ⑧ in Table 1). In this figure, the factor score shows nearly the same value in spite of the variation of the lightness contrast. It indicates that similar degree of assessment is obtained so far as the L_t is constant.

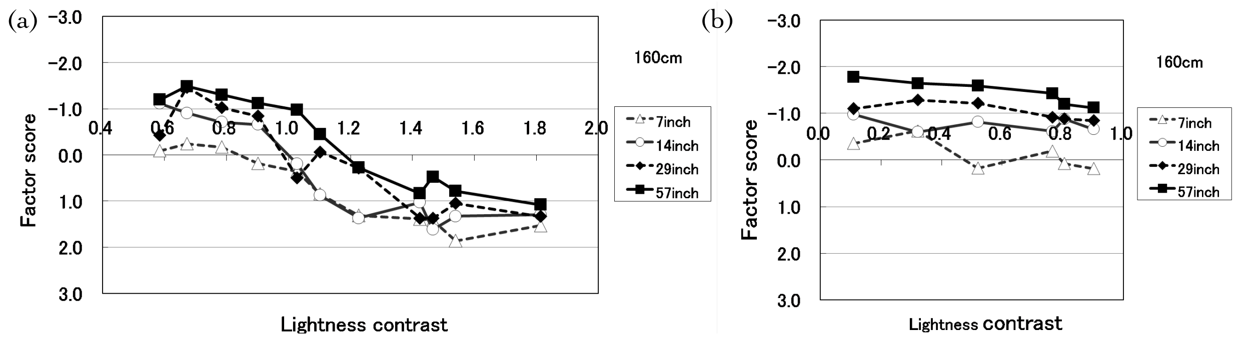

Figure 8: Factor score of "KANSEI factor" plotted against the lightness contrast. (a): results of the images where L_t changes with almost constant L_b (from□ down to □ in Table 1), (b) : results of the images where L_b changes with almost constant L_t □down to□, and⑧ in Table 1).

Table 3: Results of factor analysis

Adjectives	First factor	Second factor	Third factor
Showy	-0.95	0.21	-0.04
Clean	-0.94	0.12	0.25
Like	-0.91	-0.04	0.33
Delicious	-0.90	0.04	0.38
Clear	-0.90	-0.26	0.27
Plain	0.88	-0.37	-0.06
Impressive	-0.87	-0.21	-0.18
Hate	0.86	-0.03	-0.40
Unpalatable	0.86	-0.12	-0.41
Dirty	0.82	-0.30	-0.38
Dark	0.80	-0.52	-0.25
Light	-0.78	0.59	0.06
Fuzzy	0.77	0.46	-0.27
Chiseled	-0.76	-0.29	0.40
Natural	-0.74	-0.04	0.61
Plane	0.58	0.35	-0.43
Strong contrast	0.57	-0.54	-0.31
Pale color	-0.12	0.92	-0.15
Deep color	-0.14	-0.82	-0.21
Weak contrast	0.02	0.79	-0.11
Ordinary	-0.09	0.05	0.78
Unnatural	0.65	0.07	-0.72

In order to investigate physical factors to contribute "KANSEI factor", multi-regression analysis was applied. Objective variable is the factor score, and based on the results shown in Figure 8, we chose not the lightness contrast but the lightness of main object L_t as an explanatory variable. Image size was chosen as another explanatory variable. Result of all conditions (17 contrasts X 4 sizes X 2 distances = 136 points) is indicated in Figure 9. Multi-regression equation is as follows,

$$EV = -0.78 \cdot Lt - 0.33 \cdot Size$$

where EV is an estimated value of KANSEI factor. In Figure 9, factor scores are plotted on the horizontal axis while the values estimated by the multi-regression analysis are plotted on the vertical axis. As shown in Figure 9, fairly good correlation is obtained. Weighting coefficients of the L_t and image size are -0.78 and -0.33, respectively. This suggests that the L_t and image size are the two major contributing factors to observers' assessment of color images along the "KANSEI factor" axis.

Using the result of multi-regression analysis, the factor score of "KANSEI factor" can be estimated by the L_t and image size. This is shown in Figure 10 horizontal axis is the L_t, the vertical axis is an image size, and then the contour map of factor score is drawn based on the results obtained by the factor analysis. Furthermore, dotted straight lines indicate the estimations derived by the multi-regression analysis. They are not perfect but satisfactorily fitted to the results.

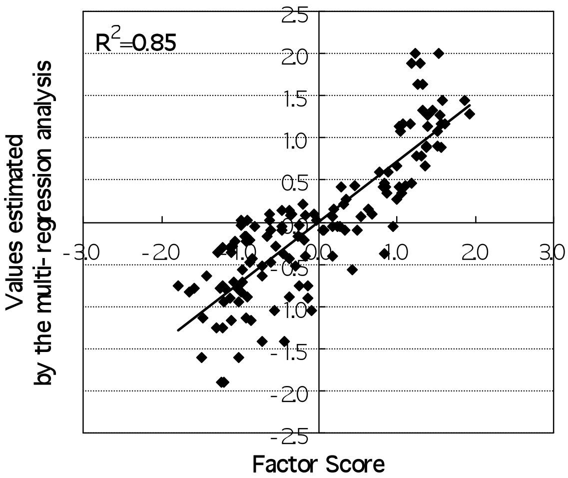

Figure 9: Correlation between factor score obtained in the factor analysis and the estimated value derived from the linear transform of L_t and image size based on multi-regression analysis.

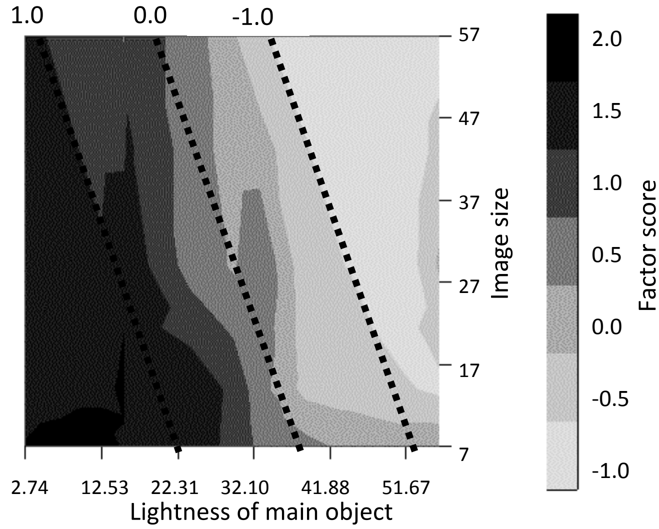

Figure10: Contour map for the factor score of "KANSEI factor" as a function of L_t (horizontal axis) and image size (vertical axis). Dotted lines indicate the estimations using the linear transform of L_t and image size based on the multi-regression analysis.

4. CONCLUSION

In this study, to clarify the effects of lightness of main object, lightness of background, and lightness contrast upon observers' KANSEI impression to color image, and further to investigate their relation to the screen size, subjective evaluation experiment was carried out. Seventeen test images of different lightness contrast between main object and background were prepared not by using image processing but by manipulating the lighting condition in the photography. In the experiment, a test image was presented to observer with one of the four different sizes, 7, 14, 29 and 57inches diagonal. Unipolar scales method using 22 adjectives was utilized for KANSEI evaluation of test images.

Results showed that evaluations using 22 adjectives were divided into three groups. First group, evaluation assessed using adjectives such as "Light" or "Dark", was strongly affected by lightness contrast. Second group, evaluation assessed using adjectives such as "Chiseled" or "Plane", was strongly affected by image size. Third group, evaluation assessed using adjectives related with KANSEI impression such as "Delicious" or "Unpalatable", was affected by both lightness contrast and image size.

Three factors were extracted by factor analysis. We name the first factor, “KANSEI factor”, because factor loadings of “Like” and “Beautiful” are high, the second factor, "Contrast factor", because factor loadings of "Pale color" and "Weak contrast" are high, and the third factor, " Ordinary factor", because factor loadings of "Ordinary" and “Unnatural” are high, respectively. Results showed that the first factor is most important for KANSEI evaluation. Results of the multi-regression analysis indicate that the factor score of “KANSEI factor” is described by a linear transform of the lightness of main object and image size. It is interesting that the lightness of main object rather than the lightness contrast has more significant role to KANSEI evaluation.

As shown in Figure 8, factor score of KANSEI factor becomes around zero as the best case for the image size of 7 inch, while it becomes -1.5 for the image size of 57 inch. These results indicate that to make a highly good KANSEI impression for observers, images should be presented on a large display. On the other hand, advertisement or information distribution through mobile phone is quite important especially for young people. Based on our results, photo images distributed through mobile phone network should be taken in the way that lightness of main object should satisfactorily high to make a certain quality of KANSEI impression. Our results provide useful data not only for e-shopping creators but also for designers handling artistic images.

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