Relationship between the two-colour combination feelings evaluation of "kimono" and the visual contexts and observer attributes

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This study aimed to clarify the effects of the presence or absence of visual contexts as "kimono" and observer attributes (knowledge of/interest in/frequency of contact with "kimono" and gender) on the colour combination feelings evaluation by deeming "kimono" as a two-colour combination of *nagagi* (ankle-length garment) and *obi* (sash belt). The observers were presented photographs of a two-coloured "kimono" with *nagagi* and *obi* coloured with different colours, illustrations of a woman wearing "kimono", and rectangular shapes painted in proportion to the area ratio of *nagagi* and *obi*, and the observers evaluated "contrast", "floridness", "warmth", "pleasantness", "refinement", "beauty", and "lucidity" of the presented stimuli. In addition, the relationship between the evaluation results and estimation values obtained by the colour feelings prediction formulas was examined. As a result of the analysis, the following conclusions were obtained: (1) In the two-colour combination evaluation, observer attributes have a larger effect than visual contexts. (2) When two-colour combination stimuli are given visual contexts as "kimono", aesthetic evaluation is significantly improved. (3) The evaluation of conspicuity and warmth of two-colour combinations shows slight differences between observer attributes, whereas aesthetic evaluation varies according to their attributes. (4) In simple figures without a context of "kimono", the effects of the area ratio of colours that constitute a colour combination are limited. (5) The estimation values of "pleasantness" obtained by the colour feelings prediction formulas indicate the highest correlation with evaluation values of "lucidity".

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Introduction

"Kimono" is a traditional Japanese national costume deemed the most formal dress today. Although "kimono" is not worn frequently in everyday life today, many women prefer to wearing "kimono" at coming-of-age ceremonies and college graduation ceremonies. As "kimono" has a standardised shape, its impression is influenced by elements, such as colours, patterns, and textures rather than shapes. Up to the present, we have conducted evaluation experiments of colour combination feelings, deeming "kimono" a two-colour combination of *nagagi* (ankle-length garment) and *obi* (sash belt), and have examined the relationship between the estimation values of feeling factors obtained by the colour combination feelings models and evaluation experiment results [1].

Previous international studies on the emotional effects of colour combinations have shown the evaluation of warmth and coldness, lightness and heaviness, and motion and stillness, and the like are universal, whereas the evaluation of colour combination harmony is affected by observers' cultural backgrounds [2-3]. Thus, as colour combination feelings models, we paid attention to the colour feelings prediction formulas developed by the Colour-Harmony Committee based on a large-scale evaluation experiment conducted in Japan [4-8]. As a result, we confirmed that in two-colour combinations of "kimono", the estimation values of colour combination feelings factors obtained by the colour feelings prediction formulas correlated well with the evaluation experiment results of colour combination feelings [1]. However, it is unclear whether presented stimuli are recognised as colour combinations of "kimono" or, in other words, to what extent the visual contexts of presented stimuli affect the colour combination feelings evaluation. Furthermore, because observers who participated in previous evaluation experiments of colour combination feelings were students and faculty members having contact with "kimono" on a routine basis at a "kimono" vocational school, the possibility cannot be ignored that their attributes, such as knowledge of "kimono", frequency of contact with it, and gender, might affect their evaluation of colour combination feelings toward "kimono". Therefore, this study aimed to clarify the effects of the presence or absence of visual contexts as "kimono" and observer attributes on the colour combination feelings evaluation.

Evaluation experiment of colour combination feelings

As presented stimuli, we prepared illustrations of a woman wearing a two-coloured "kimono" with *nagagi* and *obi* coloured different colours, photographs of "kimono", and rectangular shapes coloured in proportion to the area ratio of the *nagagi* and *obi* (8.7:1) and set three types of visual contexts: illustration, photograph and rectangle (Figure 1).

Figure 1: Three types of visual contexts (from left to right): illustration, photograph and rectangle.

Selections of two-colour combinations were made in the same manner as the previous study as follows [1]. With regard to 102 pairs of two-colour combinations systematically selected by the Colour-

Harmony Committee in the Munsell colour space [5], we calculated the estimation values of each of the basic feeling factors "contrast", "floridness", "warmth", and "pleasantness" using the colour feelings prediction formulas [4] and sorted the colour combinations in descending order of the estimation values for each factor. After that, we extracted two-colour combinations in such a manner that the estimation values were set at equal intervals and selected 27 types of two-colour combinations, excluding overlapping colour combinations. Then, we coloured the areas of *nagagi* and *obi* on "kimono" images consisting only of luminance information with selected colours using Adobe Photoshop™. In so doing, our attention was paid to maintaining the textures and shades of "kimono". The coloured images of "kimono" were presented on an LCD (EV2116W-A, Eizo) used for evaluation experiments of colour combination feelings, and each area of *nagagi* and *obi* was measured using a colour luminance meter (CS-150, Konica Minolta). The correlated colour temperature of the LCD's white point was set to 6500K. Figure 2 shows the conversion results from measured values into the Munsell values. The two combined colours are connected with a dashed line in the figure. In Figure 2, the selected colour combinations consist of various hues, with lightness being distributed in the middle and high lightness range and with chroma in the low and middle chroma range. "Kimono" illustrations and rectangular shapes were coloured in such a manner that colour combinations remained the same as the "kimono" photographs, irrespective of visual contexts. Although we prepared 27 types of two-colour combinations, the total number of stimuli for evaluation was 162, as inverted two-colour combinations of *nagagi* and *obi* were distinguished, and three types of visual contexts (illustrations, photographs, and rectangular shapes) were also set.

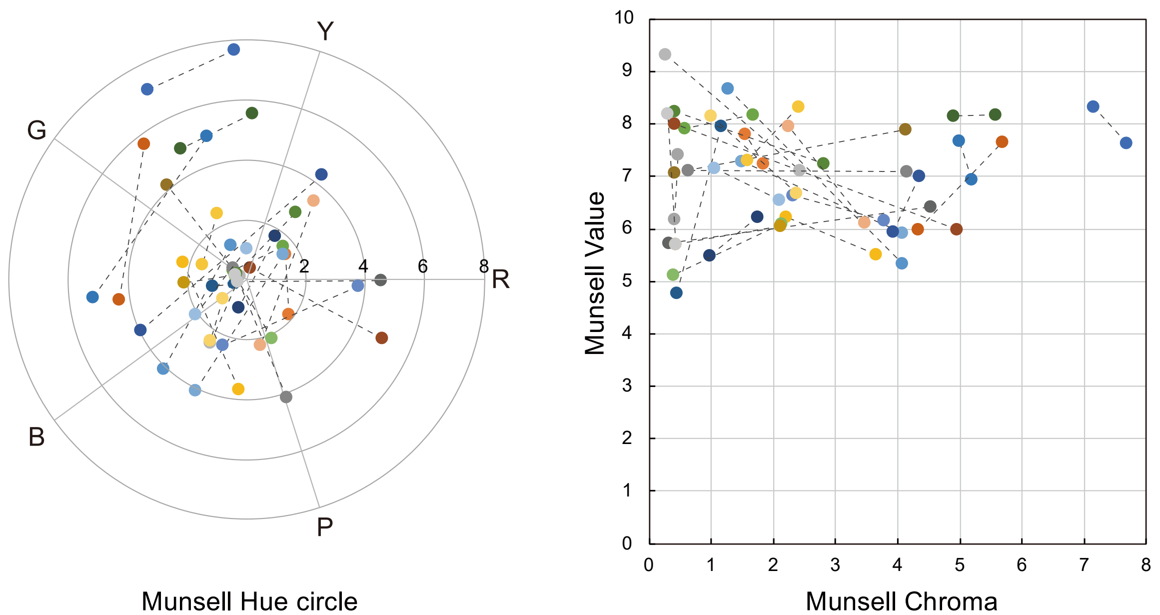

Figure 2: Colour pairs used in the two-colour combinations experiment.

The observers evaluated "contrast", "floridness", "warmth", and "pleasantness" of the displayed stimuli based on a seven-point rating scale. Additionally, among the 38 rating scales selected by the Colour-Harmony Committee, they also evaluated "refinement", "beauty", and "lucidity", which are the rating scales with a high factor loading to the "pleasantness" factor [9], in the same manner. These scales were added in consideration of rating difficulties caused by the ambiguity of the word "pleasantness". These procedures are the same as those used in the previous study [1]. Table 1 shows the seven bipolar scales used in this study.

Colour-feeling scale	Word pair
Contrast	Striking / Vague
Floridness	Florid / Sober and tasteful
Warmth	Warm / Cool
Pleasantness	Pleasant / Unpleasant
Refinement	Refined / Unrefined
Beauty	Beautiful / Ugly
Lucidity	Lucid / Unclear

Table 1: Bipolar scales used in this study.

The distance between the LCD and the observers was ~60 cm. The viewing angle of the presented stimulus was 20° (vertical) × 7° (horizontal) for every visual context. The background of the stimulus was set to an achromatic colour equivalent to N5. During the experiment, lights were turned off, and the laboratory was kept in semi-darkness.

Once the observer completed the evaluation of all rating scales for one stimulus, another stimulus was presented to him or her after a 2 s interval (only the N5 background was displayed). The stimuli were presented in a random order by mixing colour combinations and contexts. The experiment was conducted in two parts, interposed by an ~10-min break. It took ~80 min for the observers to complete all their responses.

The observers were 21 female students studying tailoring, dyeing, and weaving "kimono" at a "kimono" vocational school (average age: 20.1 years old), 15 male and 15 female students from the science and engineering university (average age: male 21.5 years old, female 20.8 years old) having no expertise in "kimono". All observers had normal colour vision and normal visual acuity (including corrected visual acuity). One observer (a student at the "kimono" vocational school) was a British woman residing in Japan, but all others were Japanese.

Results and discussion

Hierarchical cluster analysis was conducted on each evaluation result of "contrast", "floridness", "warmth", "pleasantness", "refinement", "beauty", and "lucidity" (Figure 3). The two-colour combinations arranged in descending order of each rating value are shown in Supplementary Materials Figures A1 to A7. Each dendrogram in Figure 3 compares the degree of similarity between the nine types of evaluation results obtained by combining visual contexts (illustrations, photographs, and simple figures) and observer groups (students at "kimono" vocational school, female and male university students) for each of "contrast", "floridness", "warmth", "pleasantness", "refinement", "beauty", and "lucidity". The vertical axis of the dendrograms shows the degree of dissimilarity (coupling level) of the evaluation results, indicating that the smaller the value is, the higher the degree of similarity. Moreover, the higher the degree of similarity is, the closer a cluster is placed to the horizontal axis of the dendrograms. Overall, in Figure 3, "contrast", "floridness", and "warmth" have a higher degree of similarity between their evaluation results, whereas "pleasantness", "refinement", "beauty", and "lucidity" have a lower degree of similarity between their evaluation results. Furthermore, in the two-colour combination evaluation, observer group attributes (knowledge of/interest in/frequency of contact with "kimono" and gender) have a larger effect than visual contexts because observers belonging to the same group are distributed adjacent to the horizontal axis of the dendrograms even when visual contexts are different. Then, we merged the three types of visual contexts for each observer group and conducted another cluster analysis to clarify the relationship between observer group attributes and evaluation results of two-colour combination feelings (Figure 4). In Figure 4, whereas the evaluations of “contrast”, “floridness”, and “warmth” are common irrespective of observer group attributes, the evaluations of “pleasantness”, “refinement”, “beauty”, and “lucidity” are classified according to observer group attributes. In other words, in the two-colour combination evaluation of conspicuity and warmth, observer attributes have a smaller effect, whereas they have a larger effect in aesthetic evaluation.

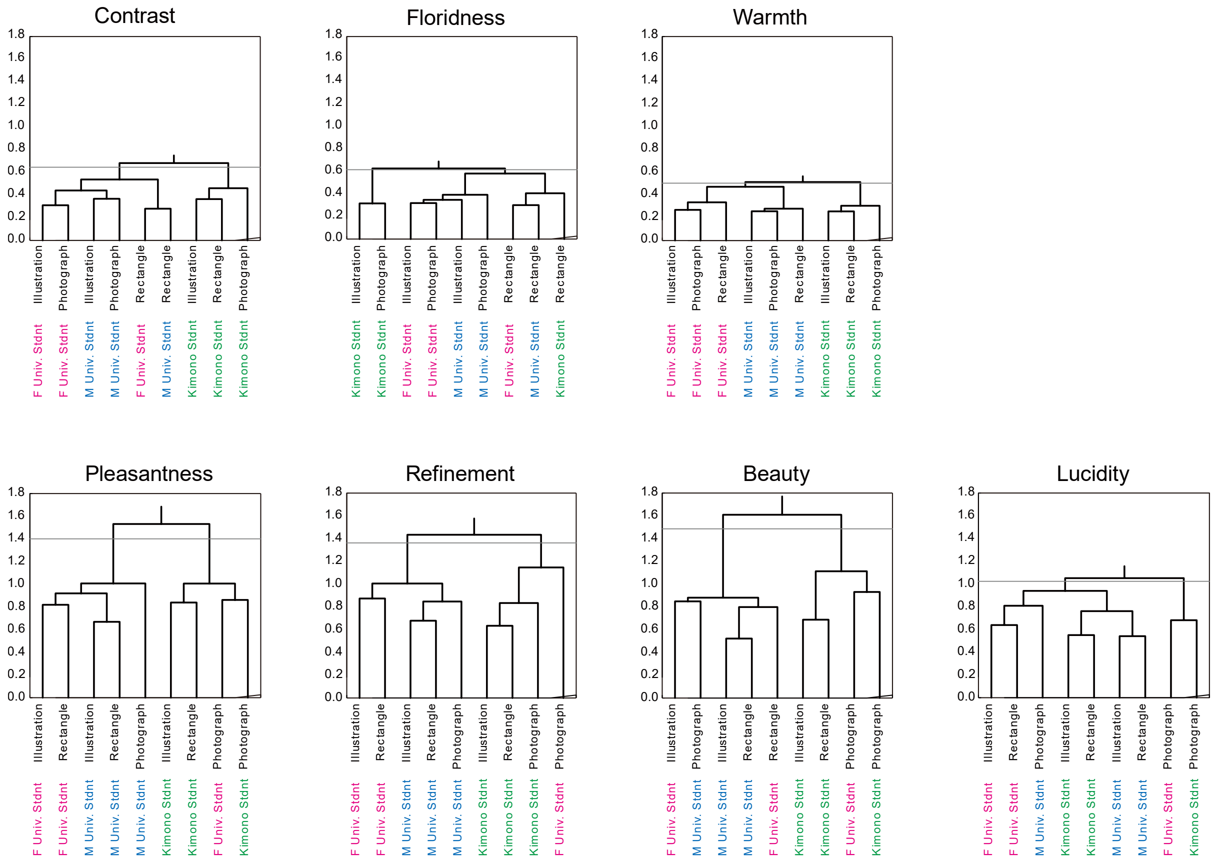

Figure 3: Results of the hierarchical cluster analysis.

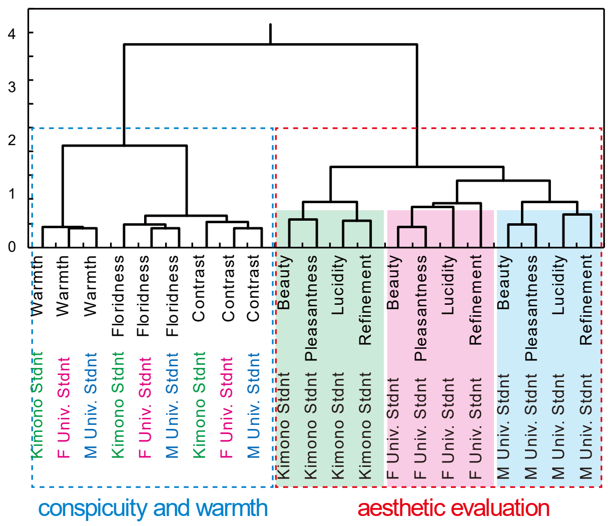

Figure 4: Result of the hierarchical cluster analysis after visual context integration.

Next, we made comparisons of evaluation results between visual contexts. The results of each observer group are shown in Figures 5 to 7, and those of the overall observer group are shown in Figure 8. These figures indicate the mean evaluation results for each presented stimulus using box-andwhisker plots, and they are shown together with the results of multiple comparisons (Steel-Dwass) between each visual context.

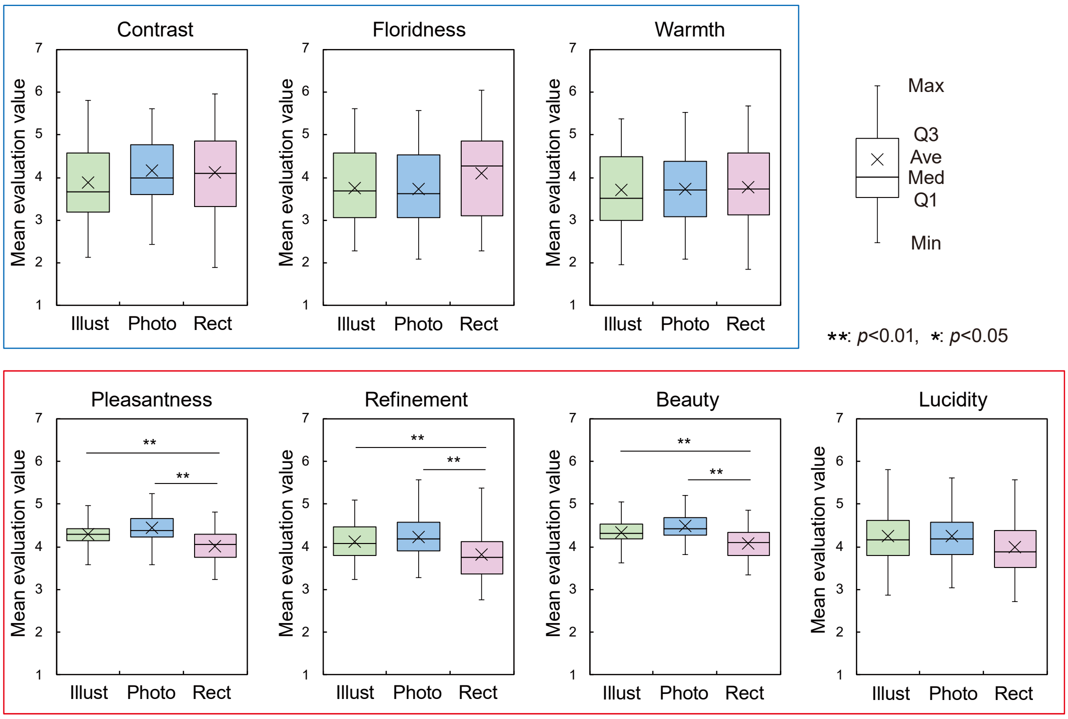

Figure 5: Comparisons of evaluation results between visual contexts (Kimono vocational school students).

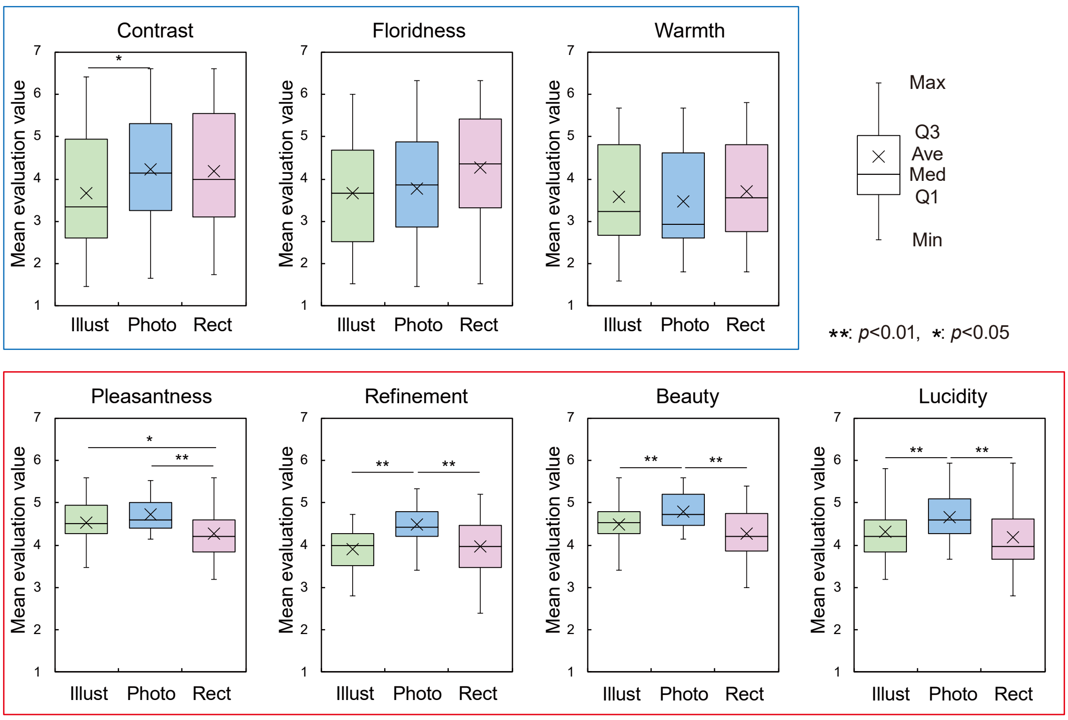

Figure 6: Comparisons of evaluation results between visual contexts (Female university students).

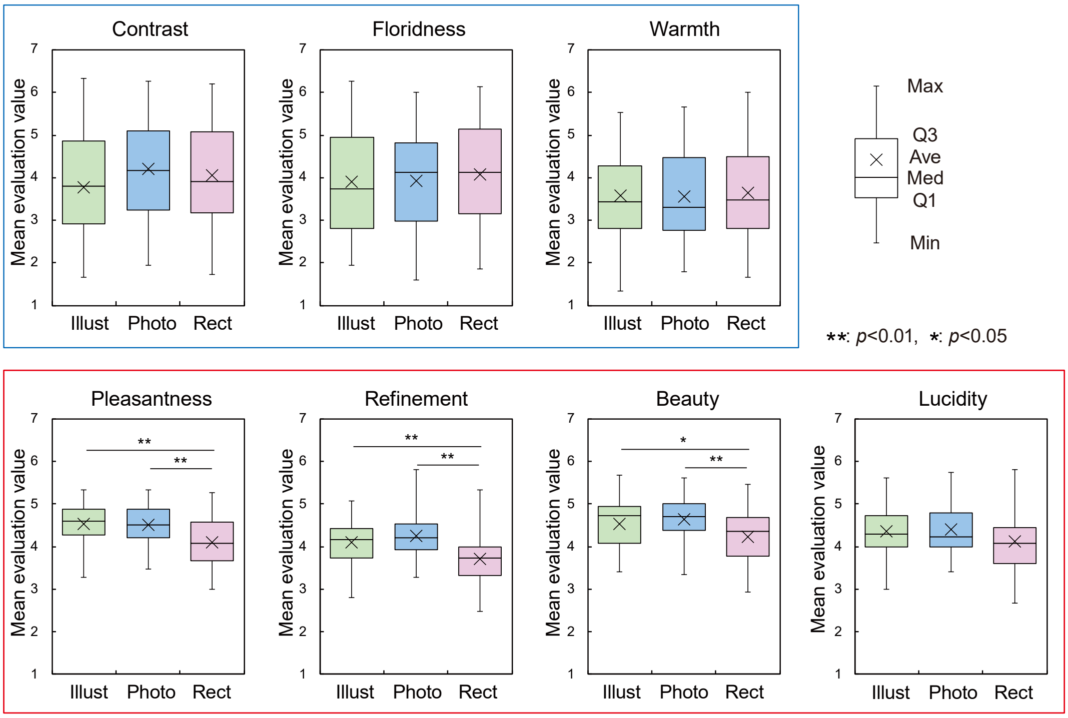

Figure 7: Comparisons of evaluation results between visual contexts (Male university students).

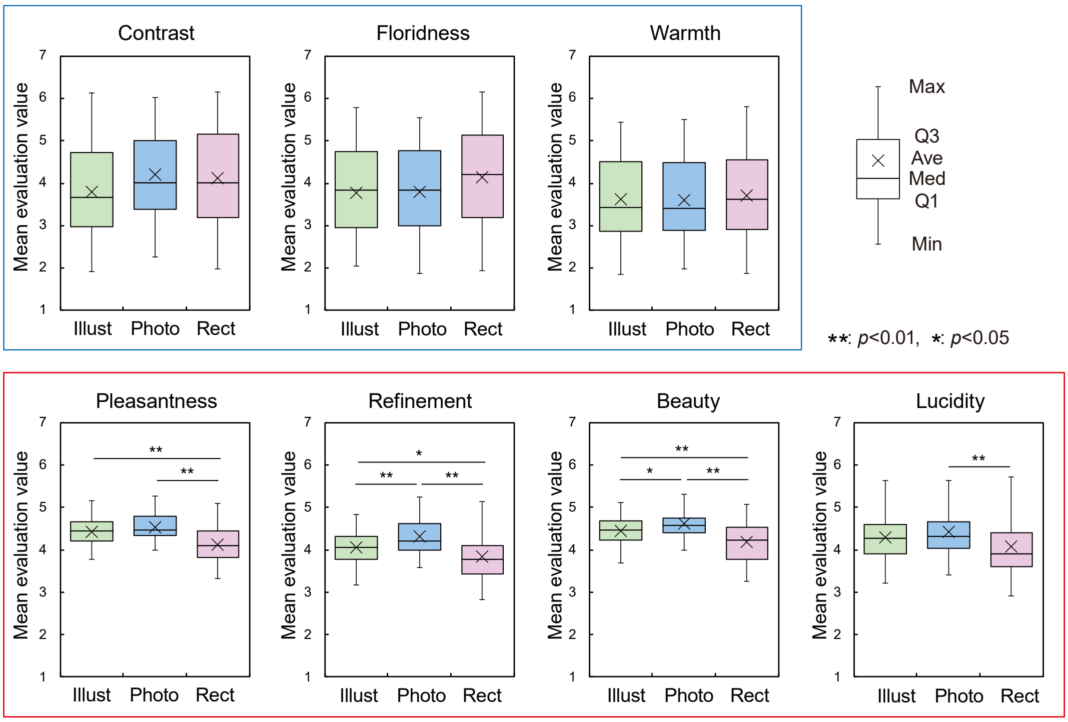

Figure 8: Comparisons of evaluation results between visual contexts (All observers).

Overall, in Figures 5 to 7, in any observer groups, the evaluations of "contrast", "floridness", and "warmth" have a wider range, whereas the evaluations of "pleasantness", "refinement", "beauty", and "lucidity" have a narrower range. Additionally, the results of multiple comparisons between each visual context are similar between the "kimono" vocational school students and the male university students, and when the context of "kimono" was given in the form of illustrations or photographs, the evaluations of "pleasantness", "refinement", and "beauty", which are aesthetic evaluations, significantly improved compared to the simple figures (rectangular shape). As for the female university students, when the context of “kimono” was given in the form of photographs, the aesthetic evaluation showed a significant improvement compared to the illustrations and the simple figures. Moreover, “contrast”, “floridness”, and “warmth” showed no significant difference in evaluation results between visual contexts for any observer group (excluding the evaluation of “contrast” by the female university students). From the overall results of the observers (Figure 8), visual contexts have no effect on the evaluation of conspicuity and warmth, and the aesthetic evaluation improves significantly when the context as “kimono” is given.

Next, we examined how evaluation results would change when the colour combinations of *nagagi* and *obi* in the illustrations and photographs and those of the large and small areas of the simple figures were inverted. Figure 9 shows the results of comparisons of evaluation values between the stimuli with inverted colours. The results of a test of no correlation confirm a significant correlation at a 1% level in all cases; especially in “contrast” and “pleasantness”, the effects of inversion of colours are small. Besides, in the simple figures, the simple correlation coefficient is higher than in other visual contexts in the evaluation of conspicuity and warmth and the aesthetic evaluation, suggesting that the effects of inversion of colours on colour combination feelings are small. This indicates that the effects of the area ratio of colour combinations in the simple figures are limited and consistent with the results of previous studies [10-11].

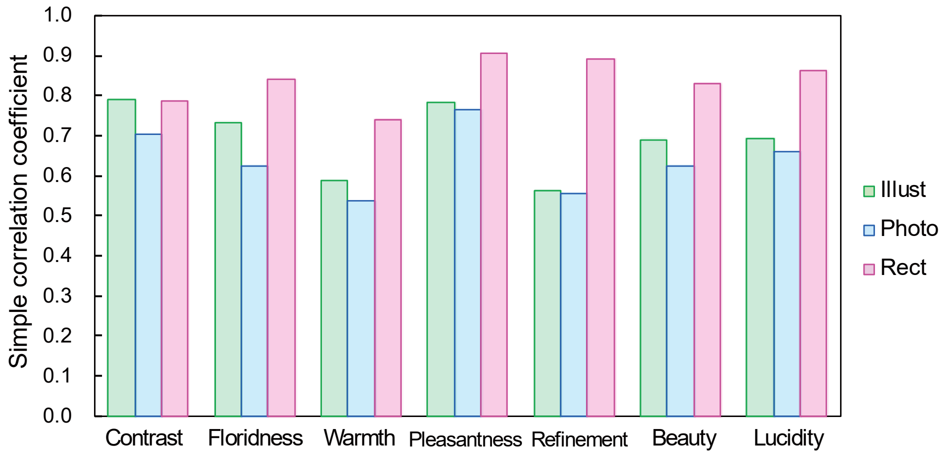

Figure 9: Comparisons of evaluation values between the stimuli with inverted colours.

As in our previous study [1], we examined the relationship between the estimation values of two-colour combination feelings obtained by the colour feelings prediction formulas [4] and the evaluation results. Figure 10 shows simple correlation coefficients between the estimation values and the evaluation results of “contrast”, “floridness”, and “warmth”. The dashed lines in the figure represent the p-value. All simple correlation coefficients are significant at a 1% level. From the above, the colour feelings prediction formulas have a good estimation accuracy with respect to the evaluation of conspicuity and warmth irrespective of visual contexts and observer attributes. Figure 11 shows simple correlation coefficients between the estimation values of “pleasantness” obtained by the colour feelings prediction formulas and each evaluation result of “pleasantness”, “refinement”, “beauty”, and “lucidity”. The dashed lines in the figure indicate the p-value; in all cases, a significant correlation was confirmed at the 1% level. However, the estimation accuracy of the colour feelings prediction formulas varied according to visual contexts. As for “pleasantness”, “refinement”, and “beauty”, when the stimuli were simple figures, the estimation accuracy was high. The evaluation results of “lucidity” had the highest correlation with the estimation value of “pleasantness” obtained by the colour feelings prediction formulas, irrespective of observer attributes and visual contexts. This coincides with the analysis results of our previous study [1].

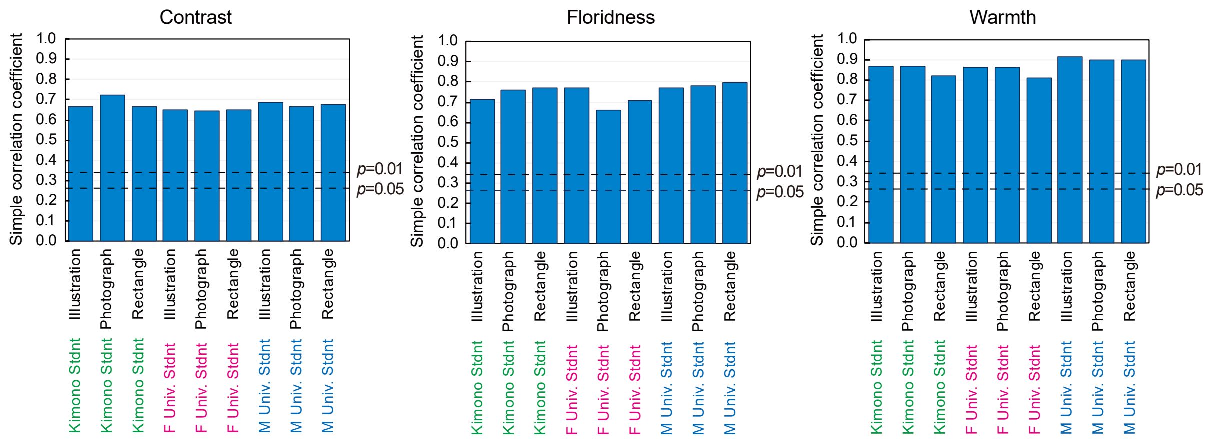

Figure 10: Simple correlation coefficients between the estimation values of "contrast", "floridness", and "warmth" obtained by the colour feelings prediction formulas and the evaluation results.

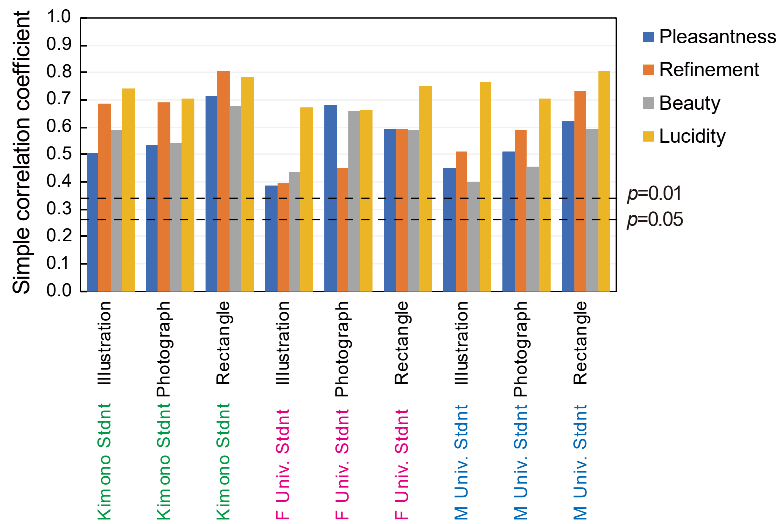

Figure 11: Simple correlation coefficients between the estimation values of "pleasantness" obtained by the colour feelings prediction formulas and each evaluation result of "pleasantness", "refinement", "beauty", and "lucidity".

In 2011, the TC1-86 of Division 1, the Technical Committee of CIE was established to develop universal colour harmony models [3]. We examined the relationship between the aesthetic evaluation results of this study and the colour harmony estimation values (CHu) derived from the Colour Harmony Model [3], a research achievement of the TC1-86 (Figure 12). As in Figure 11, it shows simple correlation coefficients between the colour harmony estimation values (CHu) obtained by the TC1-86 Colour Harmony Model and each evaluation result of "pleasantness", "refinement", "beauty", and "lucidity". Comparing Figures 11 and 12, in any observer groups and any visual contexts, the estimation accuracy of the TC1-86 Colour Harmony Model is lower than that of the colour feelings prediction formulas. This is because the data set used for the development of the TC1-86 Colour Harmony Model does not include data from Japanese observers. Moreover, in Figure 12, the colour harmony estimation values (CHu) obtained by the TC1-86 Colour Harmony Model were better correlated with the evaluation results of "lucidity" than those of "pleasantness", and there was a significant correlation at the 1% level irrespective of observer group attributes and visual contexts. In Figures 11 and 12, it can be considered that the observers who participated in the experiment of this study evaluated the harmony of two-colour combinations as the degree of "lucidity".

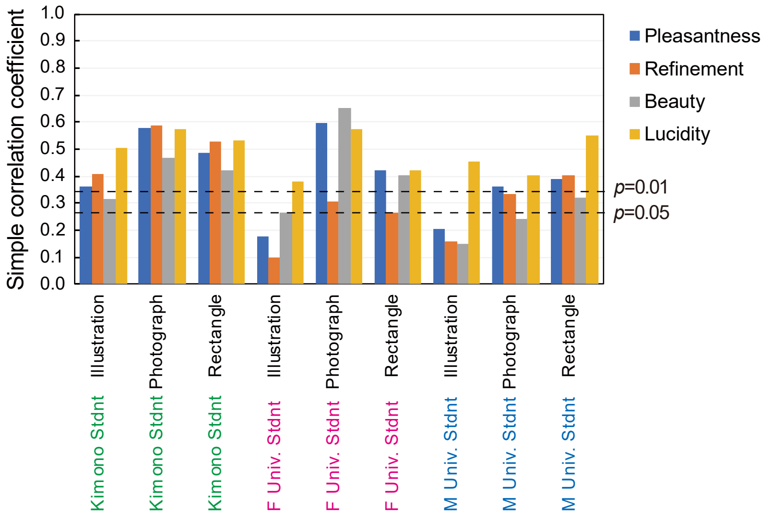

Figure 12: Simple correlation coefficients between colour harmony estimation values (CHu) obtained by the TC1-86 Colour Harmony Model and each evaluation result of "pleasantness", "refinement", "beauty", and "lucidity".

Conclusions

The following conclusions were obtained by examining the effects of the presence or absence of visual contexts as "kimono" and observer attributes on the colour combination feelings evaluation.

(1) In the two-colour combination feelings evaluation, observer attributes (knowledge of/interest in/frequency of contact with "kimono" and gender) have a larger effect than visual contexts.

(2) When two-colour combination stimuli are given visual contexts as "kimono", aesthetic evaluation is significantly improved.

(3) The evaluation of conspicuity and warmth of two-colour combinations shows slight differences between observer attributes, whereas aesthetic evaluation varies according to their attributes.

(4) In simple figures without a context of "kimono", the effects of the area ratio of colours that constitute a colour combination are limited.

(5) Although the estimation values of "pleasantness" obtained by the colour feelings prediction formulas show a significant correlation with any of "pleasantness", "refinement", "beauty", and "lucidity" that are the results of aesthetic evaluations, they indicate the highest correlation with evaluation values of "lucidity".

Acknowledgements

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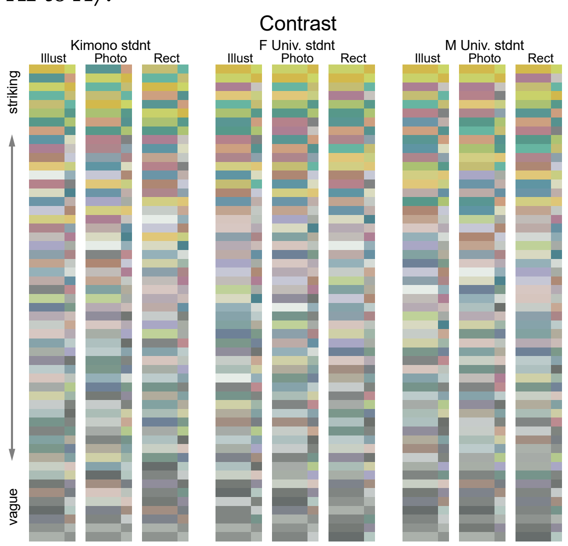
Supplementary materials

The two-colour combinations arranged in descending order of each rating value are shown in Figures A1 to A7.



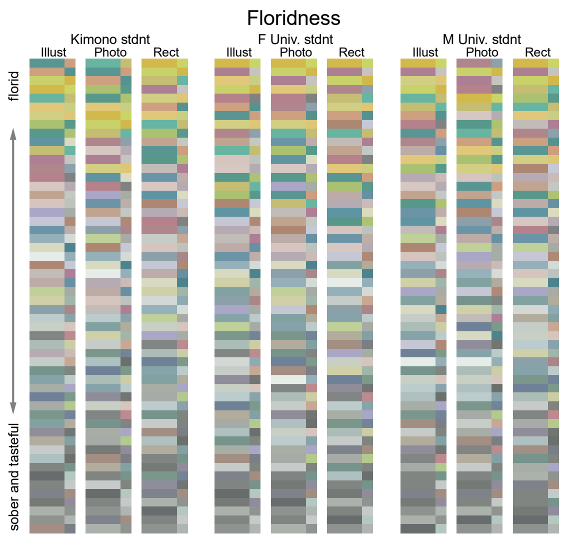
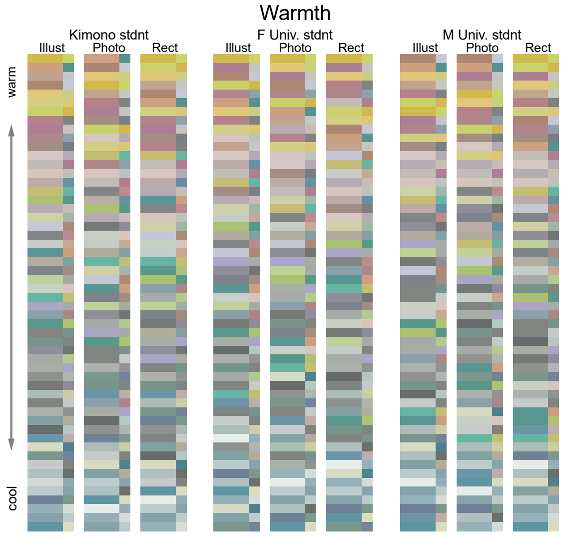


Figure A1 (left): Two-colour combinations arranged in order of "contrast".
Figure A2 (right): Two-colour combinations arranged in order of "floridness".



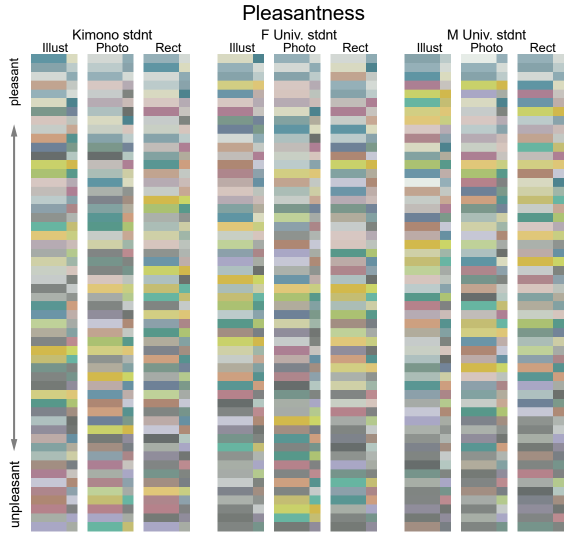
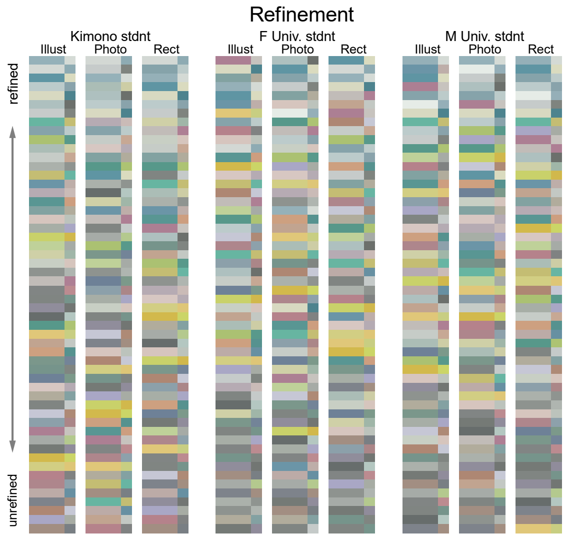


Figure A3 (left): Two-colour combinations arranged in order of "warmth".
Figure A4 (right): Two-colour combinations arranged in order of "pleasantness".



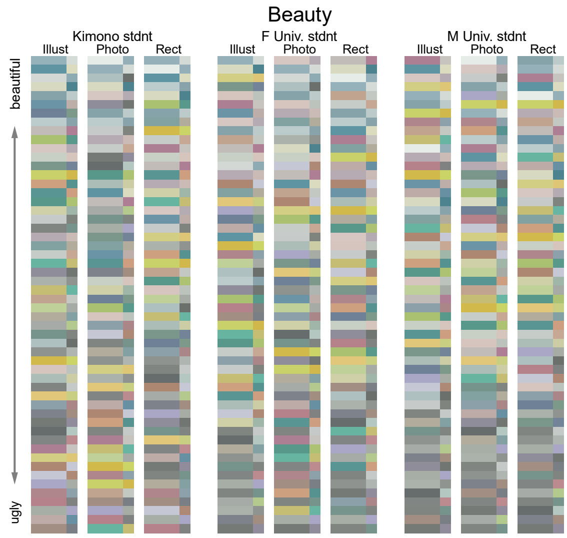


Figure A5 (left): Two-colour combinations arranged in order of "refinement".
Figure A6 (right): Two-colour combinations arranged in order of "beauty".

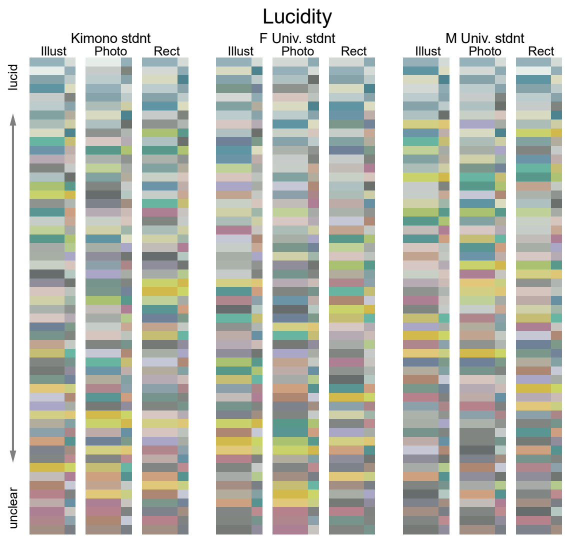


Figure A7: Two-colour combinations arranged in order of "lucidity".