A Study of Colour Emotion and Colour Preference. Part III: Colour Preference Modeling

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*Abstract: In this study three colour preference models for single colours were developed. The first model was developed on the basis of the colour emotions, clean–dirty, tense–relaxed, and heavy–light. In this model colour preference was found affected most by the emotional feeling "clean." The second model was developed on the basis of the three colour-emotion factors identified in Part I, colour activity, colour weight, and colour heat. By combining this model with the colour-science-based formulae of these three factors, which have been developed in Part I, one can predict colour preference of a test colour from its colour-appearance attributes. The third colour preference model was directly developed from colour-appearance attributes. In this model colour preference is determined by the colour difference between a test colour and the reference colour (*L*, a*, b**) = (50, −8, 30). The above approaches to modeling single-colour preference were also adopted in modeling colour preference for colour combinations. The results show that it was difficult to predict colour-combination preference by colour emotions only. This study also clarifies the relationship between colour preference and colour harmony. The results show that although colour preference is strongly correlated with colour harmony, there are still colours of which the two scales disagree with each other.* Col Res Appl, 29, 381–389, 2004; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/col.20047

Key words: colour preference; colour harmony; colour combination; cross-cultural study; colour emotion; colour meaning; colour psychology

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INTRODUCTION

Colour preference indicates whether a colour/colour combination is preferred by a group of viewers. It was also referred to as an estimate for the "pleasantness" of a colour.[1–9] Colour preference may be influenced by differences in age, gender, or geographical region. The present study considers the effects of gender and cultural differences on the two kinds of colour preference, the colour preference for single colours, and the colour preference for two-colour combinations.

Early Studies on Colour Preference for Single Colours

Studies on colour preference for single colours have long focused on the hue effect. Eysenck[1] found that blue was the most preferred colour and yellow the least. This finding agreed with those obtained by Granger[2] and Guilford and Smith.[3] Note that in these three studies no gender difference was found with regard to colour preference.

Hogg[4] studied colour preference by using 30 colour samples selected from the entire range of hue, lightness, and chroma. He found a systematic pattern of pleasant–unpleasant in these colours, among which blue and purple had the highest ratings and yellow and green the lowest. He found that colours of medium chroma were rated higher than those of either extremely high or extremely low chroma. Guilford[5] used 40 colours to develop colour-preference equations on the basis of hue, lightness, and chroma. The results indicated that for female observers, hue determined colour preference to the extent of 67% (the multiple correlation, R^2), lightness to the extent of 20%, and chroma 5%; for male observers, hue contributed to the extent of 16%, lightness 5%, and chroma 13%. These results suggested that colour preference was dominated not only by hue but also by other colour-appearance attributes, such as lightness and chroma.

Saito[6] carried out a cross-cultural study on colour preference for single colours. She found that vivid blue, white, and vivid red were the most preferred colours for Japanese observers; white, vivid blue, and black for Korean; and vivid blue, white, and light violet for Taiwanese. These findings indicated that white and vivid blue were both preferred in these three countries, suggesting that cultural difference had little effect on colour preference.

Colour Preference for Colour Combinations

Early studies of colour preference for colour combinations were concerned with how to predict the preference value of a colour pair from individual colours in that pair. For instance, Guilford[7] used various terms in his colour preference formulae to predict a preference value for a colour pair, such as P, U, P^2, U^2, and $P \times U$, where P and U stood for preference values of individual colours in a colour pair. However, the experimental results showed limitations of this method in predicting colour preference values, and the formulae developed were unacceptable. Lo[8] investigated whether the preference value of a colour pair was connected with the sum of preference scores of the colours that generate the pair. The experimental results did not show a clear connection between them. In a study of both single-colour and colour-combination emotions, Hogg[9] found that the preference value of a colour pair could not be predicted by the mean of component colours in that pair.

All these findings suggest that the preference value for a colour combination cannot be predicted by a simple equation that is based on preference scores of individual colours. This is supported by the findings in Part II of the present study, in which the additivity relationship was found to exist in the nine colour-emotion scales, warm–cool, light–heavy, modern–classical, clean–dirty, active–passive, hard–soft, tense–relaxed, fresh–stale, and masculine–feminine. However, this relationship was not found in the scale like–dislike.

Colour Preference and Colour Harmony

Traditional colour harmony theories can be divided into two basic categories, those that decided that colour harmony was based on an orderly relationship of colours and those that decided that colour harmony was connected with colour preference. A brief review on the two categories is given below.

Orderly relationships of colours have long been the main focus on colour harmony studies. For instance, Goethe[10] developed a hue circle that divided hues into two sides, the Positive and the Negative, with which he stated that colour harmony, or *completeness* in his word, was created only if colours were selected from the both sides. Chevreul,[11] in his "Principles of Harmony and Contrast of Colors," identified the two types of colour harmonies: the harmony of *analogous* colours and the harmony of *contrasts*.

Ostwald[12] saw colour harmony as *order*. On the basis of his colour solid, Ostwald suggested that colour harmony was created only if colours were selected from those of equal white content, those of equal black content, those of equal hue content, or those at an equal white and equal black circle.

Munsell[13] suggested that *balance* was the key to creating colour harmony. Based on the Munsell colour solid, a variety of colour harmony principles were developed, in which Munsell N5 was used as a balance point to make harmonious combinations. Munsell suggested an "area balance" principle, in which colour harmony was created only if the area of each component colour in a combination was inversely proportional to the product of Munsell Value and Munsell Chroma.

Itten,[14] in his colour harmony theory, indicated that colours would harmonize if their positions in his hue circle formed a well-defined polygon, such as dyads, triads, tetrads, and hexads. Moon and Spencer[15–17] suggested a colour harmony model in which colours would harmonize if the colour difference between individual colours appeared *unambiguous*. They also suggested the principle of area balance that a balance of colour areas would be obtained if the scalar moments of each component colour about an adaptation point were equal. Chuang and Ou[18] introduced a colour-difference-based model for colour harmony, in which a cubic relationship was revealed between colour harmony and the colour difference between component colours in a colour pair.

By the method of content analysis, Burchett[19] identified, the six colour-harmony attributes: association, order, configuration, area, interaction, and similarity. More recently, Burchett[20] revealed, the eight colour harmony factors: order, tone, configuration, area, interaction, association, similarity, and attitude. He concluded that the predominant understanding of colour harmony was attributed to "order."

The second category of traditional colour harmony theories relies on the connection between colour harmony and colour preference. Judd,[21] in his "Color in Business, Science and Industry," suggested that colour harmony was a "matter of likes and dislikes." He explained, "when two or more colours seen in neighbouring areas produce a pleasing effect, they are said to produce a colour harmony." Judd believed there was a link between colour preference and colour harmony. Granville[22] also saw colour harmony as "the colour usage that pleased people" and indicated that colour preference had "some quality related to harmony." He realized that the reason for applying harmony theories to colour combinations was to enhance the design quality and attraction, so as to give pleasure to viewers.

In the present study, the second category of colour harmony theories was taken into account in modeling colour preference for colour combinations. The relationship between colour preference and colour harmony is clarified in this study by comparing the two scales, like–dislike and harmonious–disharmonious, on the basis of the experimental data obtained from Parts I and II.

Female		Male		British		Chinese		All	
sample	z-score	sample	z-score	sample	z-score	sample	z-score	sample	z-score
13	2.06	5	0.90	9	1.46	3	1.19	5	0.87
3	1.22	17	0.74	5	1.07	12	1.19	3	0.75
10	1.22	20	0.74	4	0.79	5	0.72	13	0.75
12	1.22	3	0.59	11	0.79	10	0.72	4	0.64
4	0.77	4	0.59	13	0.79	13	0.72	10	0.64
5	0.77	13	0.59	16	0.79	4	0.54	11	0.64
9	0.77	9	0.46	20	0.79	11	0.54	20	0.64
11	0.77	10	0.46	2	0.56	20	0.54	9	0.55
20	0.77	11	0.46	10	0.56	2	0.22	12	0.45
1	0.43	2	0.22	17	0.56	17	0.22	2	0.37
2	0.43	12	0.22	19	0.56	1	0.07	17	0.37
16	0.43	19	0.11	3	0.36	9	0.07	16	0.20
14	0.14	1	0.00	6	0.36	16	-0.22	1	0.12
17	-0.14	16	0.00	15	0.36	19	-0.37	19	0.04
19	-0.14	6	-0.22	1	0.18	14	-0.54	6	-0.20
6	-0.43	8	-0.22	8	0.18	6	-0.72	15	-0.28
15	-0.43	15	-0.34	18	0.00	8	-0.93	8	-0.37
18	-0.43	18	-0.59	12	-0.18	15	-0.93	14	-0.37
7	-0.77	14	-0.74	14	-0.18	18	-0.93	18	-0.45
8	-1.22	7	-1.09	7	-0.56	7	-1.56	7	-1.00

FIG. 1. The 20 colour samples on the scale like–dislike rated by the four groups of observers, female, male, British, Chinese.

Aims of the Present Study

This study is aimed at developing colour preference models for single colours and for two-colour combinations. Three types of models were developed for single colours, including the model based on colour emotions, the model based on colour-emotion factors, and the model based on colour-appearance attributes. This study also clarifies the relationship between colour preference and colour harmony.

COLOUR PREFERENCE FOR SINGLE COLOURS

In Part I of the present study, 20 colour samples were assessed on the scale like–dislike by means of the paired comparison. The CIELAB specifications of the 20 colours are summarized in Table II of Part I. Experimental results were transformed into *z* scores according to the Case V of Thurstone"s Law of Comparative Judgement.[23] The results were divided into four groups of observers: female, male, British, and Chinese.

As shown in Fig. 1, the 20 colours were ranked in order of their *z* scores on like–dislike. It appears that for each observer group, vivid colours tended to be ranked higher than were grayish colours. In general, vivid purplish blue (Sample 5) was ranked highest and muddy yellow (Sample 7) was ranked lowest. The five most saturated colours, Samples 1 to 5, were ranked in the following order: purplish blue (PB, at the hue angle of 288°), green (G, 160°), blue (B, 255°), yellow (Y, 86°), and red (R, 25°). These colours had slightly different rank orders in the four groups of observers: female, G, B, PB, R, Y; male, PB, G, B, Y, R; British, PB, B, Y, G, R; Chinese, G, PB, B, Y, R. These results agreed well with those found in early studies,[1–3] in which blue was always found preferred most and yellow least.

Colour preference scores of the 20 colours were compared between genders and between cultures. As shown in Fig. 2 (a), male and female results appear somewhat similar, with a correlation coefficient of 0.68. Black (Sample 17) was found to be the most deviate colour, having a *z* score of −0.14 for female observers and 0.74 for male, as circled in the diagram. Figure 2(b) shows the comparison results between British and Chinese observers, in which vivid green (Samples 3) and bright cyan (Sample 12) were the most deviate colours, as circled in the diagram. It appears that the two data sets were little correlated with each other, as indicated by the correlation coefficient 0.46. However, if the two most deviate colours are discarded, the correlation coefficient will be 0.74 and the two data sets will appear more closely correlated with each other. This indicates that some bad data can affect the final conclusion significantly. More colour samples are required in future experiments.

Modeling Colour Preference for Single Colours

This section presents the three approaches to colour preference modeling for single colours the model based on colour emotions, the model based on the three colour-emotion factors developed in Part I, and the model based on colour-appearance attributes. These models were developed using the experimental data obtained in Part I, in which the data of all 31 observers were included.

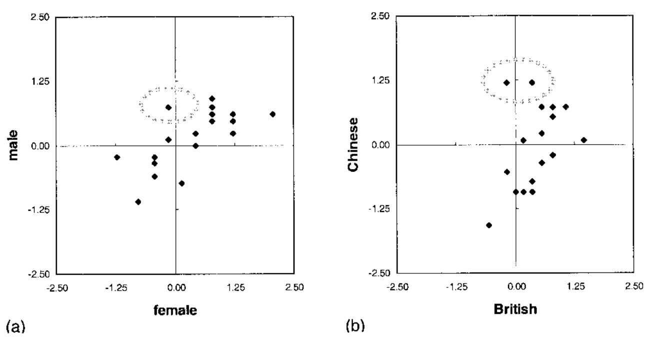

FIG. 2. The correlation of single-colour preference (a) between genders ($r = 0.68$) and (b) between cultures ($r = 0.46$).

TABLE I. The correlation (Pearson r) between 'like-dislike' and the nine colour-emotion scales used in Part I.

	Warm–cool	Heavy–light	Modern–classical	Clean–dirty	Active–passive	Hard–soft	Tense–relaxed	Fresh–stale	Masculine–feminine
Female	−0.04	−0.63	0.51	0.70	0.21	−0.54	−0.67	0.72	−0.54
Male	−0.21	−0.45	0.32	0.72	0.45	0.03	−0.26	0.71	−0.25
British	−0.15	−0.11	0.03	0.34	0.06	−0.04	−0.39	0.25	−0.13
Chinese	0.05	−0.66	0.76	0.80	0.53	−0.44	−0.42	0.82	−0.45
Total	−0.14	−0.54	0.58	0.74	0.36	−0.23	−0.37	0.75	−0.40

Colour Preference Model Based on Colour Emotions

The first approach to colour preference modeling was based on colour emotions. As shown in Table I, like–dislike was compared with the nine colour-emotion scales used in Part I, warm–cool, light–heavy, modern–classical, clean–dirty, active–passive, hard–soft, tense–relaxed, fresh–stale, and masculine–feminine. The experimental data in Part I were adopted here in the comparisons. The results show that fresh–stale and clean–dirty were most closely correlated with like–dislike. Some of the other scales also showed high correlation coefficients with like–dislike, such as modern–classical, heavy–light, and tense–relaxed. On the basis of these colour emotions, a predictive model of like–dislike was determined by means of multiple regression, as shown below:

Colour preference for single colours

$$= -0.13 + 1.33\ \text{Clean}' - 0.37\ \text{Tense} + 0.19\ \text{Heavy}, \quad R^2 = 0.66 \quad (1)$$

where $\text{Clean}' = -0.06 + 0.71 \tanh(0.95\ \text{Clean} + 0.45)$; the three variables Clean, Tense, and Heavy represent the z scores on clean–dirty, tense–relaxed, and heavy–light, respectively.

Equation (1) shows that colour preference values can be predicted directly from the three colour emotions clean–dirty, tense–relaxed, and heavy–light. All the coefficients in this equation have been optimized to fit the experimental data. Note that fresh–stale and modern–classical were not included in Eq. (1) as predictive variables, although they were both found closely correlated with like–dislike. This was because clean–dirty was strongly correlated with fresh–stale ($r = 0.95$) and modern–classical ($r = 0.85$).

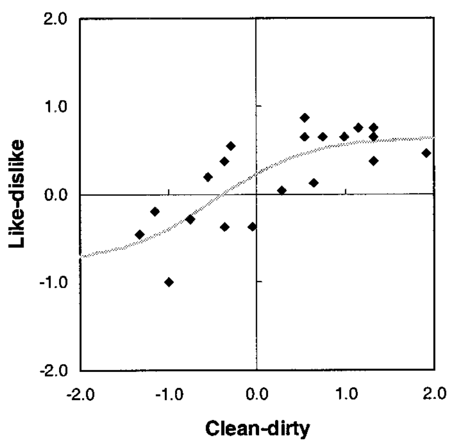

FIG. 3. The correlation between clean–dirty and like–dislike for single colours, in which the S-shaped curve shows the hyperbolic tangent of z score on clean–dirty.

As indicated by the coefficients in Eq. (1), clean–dirty is the most predominant variable and heavy–light the least. The negative coefficient of the term *Tense* indicates that colour preference is negatively correlated with "tense–relaxed," provided that the other two variables are held constant. Note that in this equation colour preference is not correlated linearly with clean–dirty but in correlation with the hyperbolic tangent of z score on clean–dirty, as illustrated by the S-shaped curve in Fig. 3.

Colour Preference Model Based on Colour-Emotion Factors

The second approach to colour preference modeling was based on the three colour-emotion factors developed in Part I, colour activity, colour weight, and colour heat. Table II shows the relationship between like–dislike and these three factors in the form of correlation coefficient. In this table, colour activity is strongly correlated with like–dislike for all observers except British. Colour weight had a high correlation coefficient with like–dislike for female observers but not for male. In general, like–dislike was correlated positively with colour activity and negatively with both colour weight and colour heat. Accordingly, the second model of like–dislike is determined by the following:

Colour preference for single colours

$$= -0.01 + 0.84\ \text{Activity}' - 0.18\ \text{Weight} - 0.14\ \text{Heat}, \quad R^2 = 0.67 \quad (2)$$

where $\text{Activity}' = -0.05 + 0.60 \tanh(1.55\ \text{Activity} + 0.73)$; Activity, Weight, and Heat represent the predicted values of colour activity, colour weight, and colour heat,

TABLE II. The correlation (Pearson r) between like–dislike and the three colour-emotion factors, colour activity, colour weight, and colour heat.

	Colour activity	Colour weight	Colour heat
Female	0.49	−0.62	−0.11
Male	0.59	−0.17	−0.19
British	0.16	−0.14	−0.12
Chinese	0.71	−0.41	−0.14
Total	0.60	−0.37	−0.14

TABLE III. The correlation (Pearson r) between like–dislike and three colour-appearance attributes, hue (h), lightness (L^*), and chroma (C^*).

	h	L^*	C^*
Female	0.29	0.48	0.15
Male	0.45	0.14	0.02
British	0.49	−0.01	−0.06
Chinese	0.29	0.38	0.18
Total	0.40	0.29	0.12

respectively. These three variables can be determined by Eqs. (3)–(5), which were developed in Part I of this series of studies.

$$\text{Activity} = -2.1 + 0.06 \times \left[(L^* - 50)^2 + (a^* - 3)^2 + \left(\frac{b^* - 17}{1.4}\right)^2\right]^{1/2} \quad (3)$$

$$\text{Weight} = -1.8 + 0.04(100 - L^*) + 0.45\cos(h - 100°) \quad (4)$$

$$\text{Heat} = -0.5 + 0.02(C^*)^{1.07}\cos(h - 50°)\,, \quad (5)$$

where L^*, a^*, b^*, C^*, and h are CIELAB lightness, redness-greenness, yellowness-blueness, chroma, and hue angle, respectively.

Note that colour preference was not linearly correlated with colour activity but in correlation with the hyperbolic tangent of colour activity. This hyperbolic tangent illustrates the relationship between like–dislike and colour activity as an S-shaped curve.

Colour Preference Model Based on Colour-Appearance Attributes

The first colour preference model [Eq. (1)] is impractical in use because the three terms *Clean*, *Tense*, and *Heavy* are useful only for the data set in this study. The second model, which includes Eqs. (2) to (5), is more practical because all the terms in the model can be determined by CIELAB values. However, it is a cumbersome model in which users need to calculate five equations to predict a preference value for one single colour. To solve these problems, a third approach to modeling colour preference was carried out, which focused on direct links between like–dislike and colour-appearance attributes.

Table III shows the relationship between like–dislike and the three colour-appearance attributes, hue, lightness, and chroma. For female observers, lightness was found the most strongly correlated attribute with like–dislike, whereas for male observers hue was the most strongly correlated. This result disagreed with that obtained by Guilford,[5] in which hue was found the most predominant attribute for both male and female observers. In the comparison between British and Chinese results, hue was found the most predominant attribute for British, whereas lightness was the most predominant for Chinese. For all observers, as shown in the "Total" row in Table III, the predominant attribute was hue ($r = 0.40$), followed by lightness (0.29) and chroma (0.12).

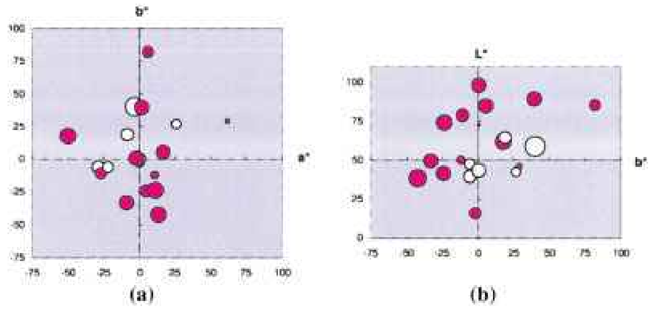

FIG. 4. A geometric pattern of like–dislike in CIELAB colour space: (a) a^*-b^* diagram and (b) b^*-L^* diagram, in which red bubbles represent the colours that were liked and white bubbles disliked.

It is insufficient, however, to develop a colour preference model understanding only the relationship between like–dislike and the three colour-appearance attributes. Therefore, a further investigation was carried out on the distribution pattern of like–dislike in the CIELAB colour space. The "bubble" method used in Part I was also adopted here, and the results are shown in Figs. 4(a) and 4(b). The size of each bubble in the diagrams indicates the z score on like–dislike for a colour. Red bubbles represent liked colours and white bubbles represent disliked colours. The larger the size of a red bubble, the more the colour was liked; the larger the size of a white bubble, the more the colour was disliked. As shown in these diagrams, the colours located near the midlightness yellow area are more disliked and those located far away from this area are more liked; the farther the colour located away from this yellow area, the more liked the colour appears to be. This suggests a connection between a colour preference value and the colour difference between a test colour and the midlightness yellow area, as described below:

$$\text{Colour preference for single colours} = -0.65 + 0.03\left[(L^* - 50)^2 + \left(\frac{a^* + 8}{2}\right)^2 + \left(\frac{b^* - 30}{1.7}\right)^2\right]^{1/2}, \quad R^2 = 0.70 \quad (6)$$

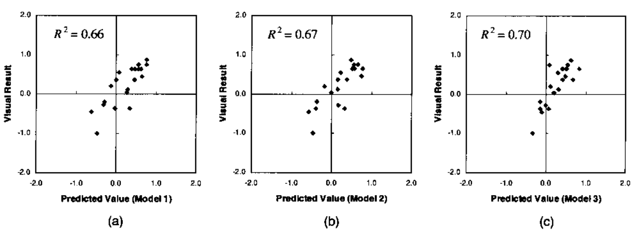

FIG. 5. Performance of the three colour-preference models for single colours (a) Model 1 [Eq. (1)] based on colour emotions, (b) Model 2 [Eq. (2)] based on colour-emotion factors, and (c) Model 3 [Eq. (6)] based on colour-appearance attributes.

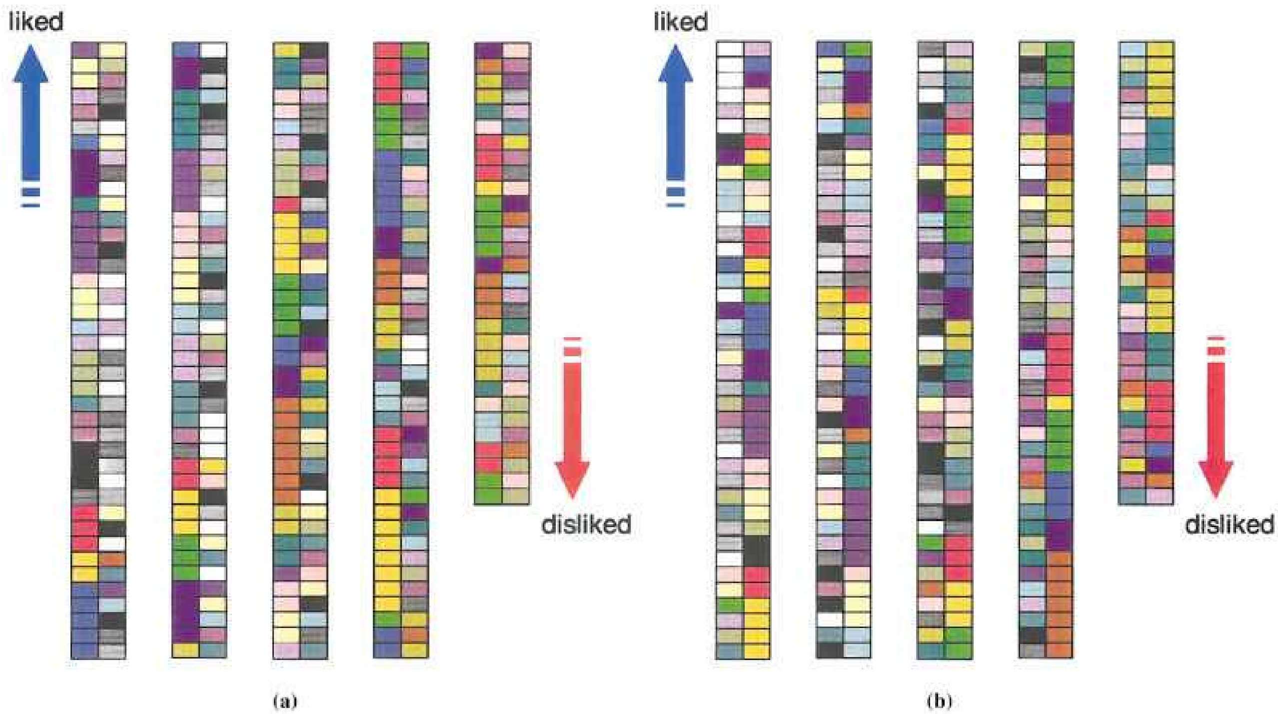

FIG. 6. The 190 colour pairs studied in Part II are ranked in order of like–dislike by (a) British observers and (b) Chinese observers.

where L^*, a^*, and b^* are CIELAB coordinates L^*, a^*, and b^*.

Equation (6) indicates that the most disliked colour is approximately at (L^*, a^*, b^*) = (50, −8, 30). As indicated by the coefficients under a^* and b^* terms in the equation, the prediction of a colour preference value is affected most by lightness difference and affected least by a^* coordinate difference. Note that the reference colour (50, −8, 30) is at the hue angle of 105° with the chroma of 31. This indicates that colour preference is also influenced by hue, in which blue is liked most and yellow least. This is because a blue colour has the largest colour difference from the reference colour and a yellow the smallest, provided that the blue and the yellow are both at the same levels of lightness and chroma.

In Figs. 5(a)–5(c) are shown the performance of predictions of the three colour preference models, with the multiple correlation (R^2) of 0.66 for Eq. (1), 0.67 for Eq. (2), and 0.70 for Eq. (6).

COLOUR PREFERENCE FOR COLOUR COMBINATIONS

Colour preference for single colours can be modeled on the basis of colour emotions, as shown in the previous section. The same modeling methods were adopted in the present section to quantify colour-combination preference. The colour-emotion data obtained in Part II were used for the model development.

Difficulties in Modeling Colour-Combination Preference

Looking at the colour pairs presented simultaneously in order of preference, as shown in Figs. 6(a) and 6(b), one may have an impression that somehow the colour pairs on the liked side evoke particular feelings such as clean, lightness, and relaxation, and those on the disliked side evoke the opposite feelings such as dirtiness, heaviness, and tenseness. This impression can be found in both British and Chinese rank orders. It suggests a connection between colour emotions and colour preference for colour pairs.

To clarify how colour emotions are connected with colour-combination preference, the scale like–dislike was compared with the 10 colour-emotion scales studied in Part II, as shown in Table IV. The comparisons were made in four groups of observers: female, male, British, and Chi-

TABLE IV. The correlation (Pearson r) between the scale like–dislike and other 10 colour-combination emotions.

	Warm–cool	Heavy–light	Modern–classical	Clean–dirty	Active–passive	Hard–soft	Harmonious–disharmonious	Tense–relaxed	Fresh–stale	Masculine–feminine
Female	−0.04	−0.47	0.07	0.38	−0.21	−0.39	0.76	−0.68	0.34	−0.44
Male	−0.33	−0.24	0.13	0.35	−0.06	0.06	0.81	−0.30	0.22	−0.00
British	−0.18	−0.18	−0.18	0.15	−0.31	−0.08	0.80	−0.61	0.02	−0.01
Chinese	−0.13	−0.40	0.40	0.51	0.11	−0.19	0.71	−0.35	0.48	−0.21
Total	−0.32	−0.35	0.14	0.39	−0.12	−0.09	0.85	−0.47	0.27	−0.14

TABLE V. The correlation (Pearson *r*) between like–dislike and the three colour-emotion dimensions for two-colour combinations.

	Colour activity	Colour weight	Colour heat
Female	0.20	−0.43	−0.21
Male	0.20	−0.27	−0.32
British	−0.06	−0.33	−0.31
Chinese	0.43	−0.30	−0.23
Total	0.22	−0.36	−0.32

nese. As a result, harmonious–disharmonious was found most strongly correlated with like–dislike for each observer group. Tense–relaxed, clean–dirty, heavy–light, and warm–cool were also found in close correlation with like–dislike, although their correlation coefficients were not as high as that between harmonious–disharmonious and like–dislike. In general, like–dislike was positively correlated with harmonious–disharmonious and clean–dirty and negatively correlated with tense–relaxed, heavy–light, and warm–cool.

In modeling like–dislike, the scale harmonious–disharmonious should be excluded from the equation as a predictive variable, because the correlation coefficient between these two scales was far higher than those between like–dislike and the other scales. If harmonious–disharmonious is among the predictive variables in the equation, all the other colour emotions will have insignificant contribution to model prediction, and it will be difficult to tell how well these colour emotions determine colour preference values. In addition, modeling colour harmony is perhaps as difficult to do as modeling colour-combination preference; none of the existing colour harmony model has acceptable performance of prediction about colour harmony values. It is thus pointless to use colour harmony to model colour preference. Therefore, only the four scales tense–relaxed, clean–dirty, heavy–light, and warm–cool were among the predictive variables in the equation. The advantage of using these four scales is that they can be predicted by single-colour emotion scores, according to the additivity relationship described in Part II.

A like–dislike equation for colour combinations was developed in the same modeling method used in Eq. (1). This equation was supposed to predict colour preference values by calculating the sum of the four colour-emotion scores. However, it was found to determine like–dislike to the extent of only 45% ($R^2 = 0.45$), which was unacceptable. The result indicates that the emotional impression about the rank order of colour preference, as shown in Figs. 6(a) and 6(b), can determine colour preference to the extent of only 45%.

Another attempt was made in modeling like–dislike for colour combinations, on the basis of the three colour-emotion factors: colour activity, colour weight, and colour heat. Table V summarizes the relationship between like–dislike and the three factors, in which all the three factors show little correlation with like–dislike. Nevertheless, these factors were still adopted as predictive variables in the equation, using the same method in Eq. (2). As a result, the new equation was found to determine like–dislike to the extent of only 28% ($R^2 = 0.28$), which was even more unacceptable.

One of the reasons the two approaches above both had disappointing results is that none of the colour-emotion scales had strong enough correlation with like–dislike, except harmonious–disharmonious. It has been found that the additivity relationship for colour emotions was inapplicable to like–dislike, as indicated in Part II of this study. This means that for colour combinations, a colour emotion can be determined by specific qualities of individual colours. Colour preference, however, may need to take into account the interrelationship between individual colours, such as lightness difference and chromatic difference. In the two approaches described above, no matter how the colour emotions are combined as predictive variables in the equation, they can determine only the qualities of individual colours, but never determine the interrelationship between them. This suggests that the interrelationship between colours is a predominant part in colour-combination preference modeling. Accordingly, it is by no means possible to predict fully colour-combination preference by colour emotions only.

Comparisons between Colour Preference and Colour Harmony

As indicated in the previous section, like–dislike were found in strong correlation with harmonious–disharmonious. The present section focuses on how well the two scales are correlated with each other.

First, the scale harmonious–disharmonious was compared with the other 10 colour emotions used in this study in terms of the correlation coefficient, as shown in Table VI. As a result, like–dislike was found the most closely corre-

TABLE VI. The correlation (Pearson *r*) between harmonious–disharmonious and the other ten colour-combination emotions

	Warm–cool	Heavy–light	Modern–classical	Clean–dirty	Active–passive	Hard–soft	Tense–relaxed	Fresh–stale	Masculine–feminine	Like–dislike
Female	−0.16	−0.37	−0.08	0.17	−0.32	−0.36	−0.66	0.12	−0.38	0.76
Male	−0.23	−0.21	0.03	0.22	−0.12	−0.04	−0.38	0.13	0.03	0.81
British	−0.16	−0.25	−0.18	0.10	−0.35	−0.13	−0.61	−0.01	0.02	0.80
Chinese	−0.17	−0.25	0.12	0.26	−0.07	−0.16	−0.35	0.22	−0.15	0.71
Total	−0.27	−0.28	−0.03	0.21	−0.22	−0.15	−0.51	0.12	−0.08	0.85

lated with harmonious–disharmonious. The scale tense–relaxed was also found in close correlation with it, whereas all the other scales had low correlation coefficients.

These results were compared with those in Table IV, which shows the relationship between colour preference and the other colour-combination emotions. The two tables show more or less the same pattern in the form of correlation coefficient, indicating a great similarity between like–dislike and harmonious–disharmonious in terms of the relationship with the other colour emotions.

To further clarify the relationship between the two scales, we classified the disagreement in judgment between colour preference and colour harmony into two cases: (1) when a colour pair was judged as liked but disharmonious, and (2) when a colour pair was judged as harmonious but disliked. According to the two cases, the 190 colour pairs studied in Part II were divided, as shown in Table VII. For all observers, there were about 4% of colour pairs in Case 1 and about 18% in Case 2. This indicates that the colour pairs that were preferred were not always regarded as harmonious and that those regarded as harmonious were not always preferred. Note that the number of colour pairs in Case 2 was much larger than that in Case 1, which means that Case 2 occurred more often than Case 1. This pattern can be found in all the four observer groups.

Figure 7 illustrates the relationship between colour preference and colour harmony according to the experimental data of the 190 colour pairs. It shows that the number of colour pairs that were liked and harmonious was almost the same as that of colour pairs that were disliked and disharmonious. The former made up 40% of the total number of colour pairs, and the latter made up 38%. Harmonious colour pairs comprised 40 + 18 = 58% of the entire range of colour pairs, and that was much higher than the number of liked colour pairs, 44%. This implies that if an observer likes a colour pair, there will be a 9% chance (4/44 = 9%) that the observer finds the same colour pair disharmonious (Case 1). Conversely, if an observer decides that a colour pair is harmonious, then there will be a 31% chance (18/58 = 31%) that the observer dislikes the same colour pair (Case 2).

The reason Case 2 occurred more often than Case 1 may be that colour preference is one of the factors that influence observers' judgments on colour harmony (i.e., observers tend to judge a colour pair to be harmonious when they like it). However, judgements on colour preference may be

TABLE VII. Disagreement between like–dislike and harmonious–disharmonious as a percentage of the 190 colour paris

	Case 1 (%) (liked but disharmonious)	Case 2 (%) (harmonious but disliked)
Female	4	13
Male	4	19
British	7	14
Chinese	2	21
Total	4	18

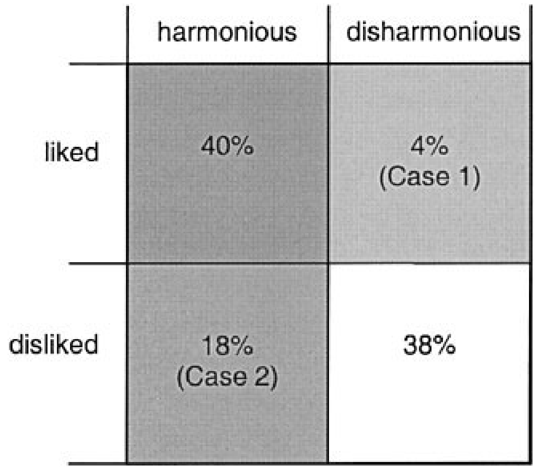

FIG. 7. The relationship between colour preference and colour harmony.

dominated by observers' subjective criteria such as personal taste and the effect of cultural difference, and thus observers more often dislike a colour pair when they find it harmonious.

The above results indicate that although colour preference is strongly correlated with colour harmony, there are still colours on which the two scales disagree with each other. Further investigations on colour harmony will be carried out in future work.

CONCLUSIONS

Three colour preference models were developed for single colours. In the first model colour preference is determined by the colour emotions clean–dirty, tense–relaxed, and heavy–light. The scale clean–dirty was found the most predominant parameter to predict colour preference among all the colour emotions studied.

The second model was developed on the basis of the three colour-emotion factors identified in Part I, colour activity, colour weight, and colour heat. By combining this model with the colour-science-based formulae of these three factors, as developed in Part I, one can predict colour preference by colour-appearance attributes of a test colour. However, the combined model is cumbersome in use. One needs to calculate five equations in this model to predict a colour preference value for one single colour.

The third model was developed directly from colour-appearance attributes. In this model a colour preference value is determined by the colour difference between a test colour and the reference colour (L^*, a^*, b^*) = (50, −8, 30). This reference colour is at the hue angle of 105° with chroma of 31, indicating that hue also contributes to the prediction of colour preference.

The above methods were also adopted in developing colour preference models for colour combinations. However, the results show that it is difficult to determine colour-combination preference by colour emotions only. One of the reasons is that for colour combinations, a colour emotion can be determined by specific qualities of individual colours, but colour preference may need to take into account the interrelationship between them.

This study also investigates the relationship between colour preference and colour harmony. The results show that the number of colour pairs that were judged as harmonious but disliked were much greater than that of the colour pairs judged as liked but disharmonious. The reason may be that colour preference is one of the factors that influence observers' judgments on colour harmony, whereas the judgements on colour preference are dominated by subjective criteria such as personal taste and the effect of cultural difference.

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