The Influence of Single-colour Preference and Area Ratio on Dichromatic Colour Preference

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Colour researchers often suggest that culture, gender, age and other factors strongly affect users' colour preference. There is also some research theory regarding colour harmony based on dichromatic colour combinations. However, previous research on dichromatic colour preference is scant. This article attempts to explore how the preference for dichromatic combinations and the single-colour preference are related. Colour preferences of 37 were evaluated. Results of this study show that a dichromatic colour pair containing a preferred single colour will generally have a higher score of user preference than those of other colour pairs. It is hoped this work can assist designers to achieve a better understanding of colour planning according to different target audiences.

Colour: Design & Creativity

Introduction

Previous research has shown that people's preference for single colours is affected by the hue, chroma and luminance of the colour and also influenced by gender, age, cultural background and many other factors [1–5]. Another important factor in colour preference is the way that two distinct colour combine, and dichromatic colour combinations is the subject of the present work.

Most early researchers on dichromatic colour combinations mention only colour harmony such as the colour harmony theory by Munsell [6], implying that colours in harmony must be preferred. Judd even directly suggests that colour harmony is a 'matter of likes and dislikes' [7]. This indicates that most early researchers took colour harmony and colour preference as being synonymous. However, recent work by Ou *et al.* has looked at the discrepancy between colour harmony and colour preference [8]. In one of the experiments, it was found that some combinations of colours not in harmony are still preferred, which means that there is no positive correlation between colour harmony and colour preference. This present work adds further evidence to support the idea that colours in harmony are not necessarily those that are preferred.

Burchett described how colour harmony could be affected by eight features: area, association, attitude, configuration, interaction, order, similarity and tone [9]. Do these factors also affect colour preference? The goal of this research is to understand how dichromatic colour combinations are affected by single-colour preference and area ratio factors.

Experimental Design

A total of five experiments were conducted in two stages: single-colour preference sorting and dichromatic colour combination sorting. The purpose of the first stage was to determine the participants' single-colour preference order, and that of the second stage was to understand the relationship between preferences (a) for single colours and (b) for dichromatic colour combinations when the two colours are presented at different area ratios. In the first experiment, a single colour was selected from each of the 10 scales in the Munsell colour wheel for a total of 10 colours (Figure 1). To enhance the influence of colours, each colour had the highest chroma value in the selected hue. Colour comparison was made on the samples according to Thurstone's law and paired comparison [10], and a set of sorted order results was obtained. To verify the dependability of the results, the experiment was repeated for a second time on the sorted order set. With Spearman's rank correlation coefficient [11], we calculated the correlation between the results of the two experiments. Experimental results that had a high correlation coefficient between the two values obtained were selected for the next stage of experimental analysis. Experiments in the first stage took approximately 30 minutes.

There were three experiments in the second stage. In order to shorten the time taken by participants to select preferences and to assist in focusing their attention, we reduced the number of colour samples from ten to five by selecting the first, third, fifth, seventh and ninth of each person's single-colour preference order left from the first sorting on the first experiment results. With five single-colour samples, each person had 10 sets of dichromatic colour pairs. To compare the influence of one colour on another in a dichromatic pair in terms of colour preference, different area ratios for the respective colours were selected: 1:1, 2:1 and 4:1. A spiral design was chosen for the test sample, enabling participants to perceive a dichromatic colour pair as a whole (Figure 2). The 1:1 ratio colour pair was used in the first experiment with the comparison made in Thurstone's law and paired comparison on the 10 colour pairs to obtain the order of preference for the colour combination. Colour ratios 2:1 (1:2) and 1:4 (4:1) were conducted consecutively afterwards. Because of the ratio differences in colour ratios 2:1 (1:2) and 1:4 (4:1), there were 20 colour pairs in each of these experiments. The three sets of data collected were used to analyse whether colour preference was affected by changes in area ratios. Between the experiments, participants are asked to close their eyes for a break of 30 seconds to reduce the influence of visual fatigue and to minimise the influence of previous results on those of the next. Each experiment in the second stage took around 30 to 40 minutes.

Environment of the Experiments and the Participants

We used a Spider2 Express (Datacolor) for LCD monitor colour deviation calibration [12]. Participants were required to respond to the questions at a distance of 60 cm from the 17

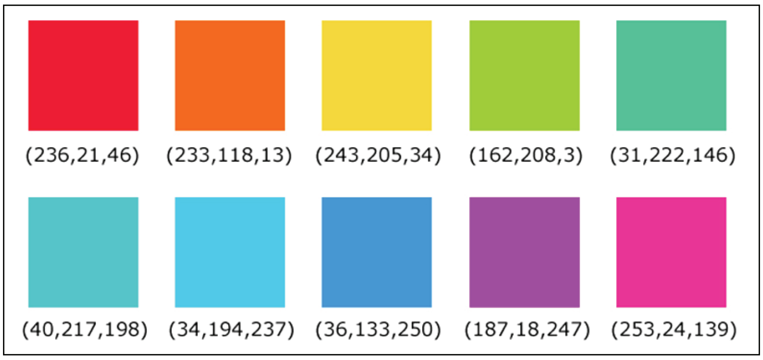

Figure 1 Experimental colour samples and RGB values

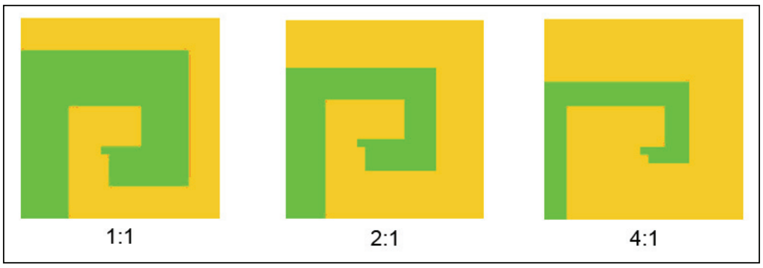

Figure 2 Colour area ratios (1:1, 2:1, and 4:1) and composition

inch LCD monitor. Only the monitor lighting source was available during the experiment. The Taiwanese participants' ages were between 20 and 30, 19 male and 18 female, who exhibited no colour vision defects. None had undertaken any previous professional colour training.

Experiment Preparation

Basic Single-colour Sample Selection

Although comprehensive colour combinations would assist in obtaining a detailed understanding of the differences of participants' colour preference, too many colour combinations would make the experiment overly complicated. Colour preference differs from person to person. Since our goal was not to find out each person's favourite colour, we did not need to include many colour samples to ensure every participant had his/her most favourite colour in our colour samples. The Munsell colour system was used to select experimental samples: this divides the colour wheel into 100 levels, with 10 levels as one hue area, making it straightforward to select 10 hues. The selected hues were the fifth level of each hue area in the system: 5R, 5YR, 5Y, 5GY, 5G, 5BG, 5B, 5PB, 5P and 5RP. To enhance the influence of the colours on the participants, all colours were represented by their highest chroma values. The Munsell values of the 10 colours selected are shown in Table 1, alongside their corresponding CIELAB and RGB values. The latter were needed because we used LCD monitors as display devices (monitor gamma = 1.8).

Table 1 Colours selected for the present study

ID no	Munsell values	CIELAB values*	RGB values
1	5R 5/18	51.57, 74.86, 39.33	236, 21, 46
2	5YR 6.5/13	66.67, 31.17, 70.16	233, 118, 13
3	5Y 8.5/11	86.21, –4.96, 79.04	243, 205, 34
4	5GY 8/12	81.35, –35.08, 80.14	162, 208, 3
5	5G 8/11	81.35, –59.30, 19.69	31, 222, 146
6	5BG 8/9	81.35, –45.45, –4.24	40, 217, 198
7	5B 7.5/9	76.48, –27.51, –28.85	34, 194, 237
8	5PB 6/14	61.70, 5.29, –57.66	36, 133, 250
9	5P 5/26	51.57, 87.27, –72.11	187, 18, 247
10	5RP 5.5/20	56.67, 83.77, –10.79	253, 24, 139

* Obtained by using the Munsell conversion tool, version 8.03 [13]

Colour Selection, Composition and Area Ratio

Colour pairings were generated based on the results of single-colour preference. To select a dichromatic colour pair from 10 colours, covering the different area ratios of the composition used in this work, the number of experimental samples would have been too large. The number of colour samples in the second stage was therefore reduced based on the single-colour preference order established in the first test. The selected colours were the first, third, fifth, seventh and ninth of a participant's single-colour preference order. Two different colours were selected from the five colours for generating a colour pair. Regardless of the colour area ratio distribution of different colours, each participant was assigned his/her own 10 dichromatic colour pairs.

According to Chuang and Ou [14], the layout of the colours in the test specimen has no significant influence on colour preference. We modified the layout of the test specimen used by Ou so that its horizontal and vertical components were roughly similar, to enable the participants to perceive the two-colour mixture as a single entity. The specimen consisted of a square outline, including aspects that could be described as horizontal, vertical, surrounding and semi-surrounding. The colours were present in the sample design in three different area ratios, 1:1, 2:1 and 4:1 as shown in Figure 2.

Experimental Procedures

Stage 1: Sorting and Screening of Single-colour Preferences

We used Thurstone's law and paired comparison analysis to analyse the preference for a single colour by the participants [10]. Two colours were shown each time and participants were required to select their preferred colour. Two colours were randomly selected from the 10 colours. Each coloured sample had a size of 250 × 250 pixels, located on a grey background, (CIELAB 51.57, 0, 0, or RGB 103, 103, 103), with a background size of 1024 × 768 pixels, as shown in Figure 3. If we had compared every possible combination of any two colours in the 10-colour set, there would have been 45 comparisons needed. This was minimised by utilising a merge sort algorithm [15] for sorting the order of the 10 colours. The total comparisons required to decide the order was thereby reduced by around 25 times. This varied from user to user according to their experimental choices.

Figure 3 Experiment 1 (single-colour preference order comparison)

After the first experiment, to test the validity of the participants' results, a second experiment was undertaken 30 seconds after the first experiment. Therefore, each participant had two sets of preferences of 10 colours at the end of first stage. To objectively measure the validity of the data, we used Spearman's rank correlation coefficient [11] to calculate the correlation between the data of the two experiments. A calculated result of 1 indicates that two sets of data are identical, while a value of zero indicates a complete lack of correlation between the two sets. This provided a way of testing the validity and stability of the colour preference order given by each participant.

Stage 2: Preference of Dichromatic Colours in Different Area Ratios

This experiment was similar to the first one. Each participant was asked to indicate a preference between any two colour pairs selected from 10 sets of dichromatic colour pairs with a 1:1 area ratio, following Thurstone's law and a paired comparison model until colour preference order of the 10 sets was established (Figure 4) [10]. Around 25 comparisons were made using a merge sort to complete the order of 10 sets of colours. Experimental environment control and settings were the same as those in the first and second experiments of stage 1. After completing the experiment, participants were required to close their eyes for 30 seconds before continuing with the dichromatic colour preference experiments with area ratios 2:1 and 4:1 respectively. There were 20 colour combinations in the second and third experiments because of the different area ratios. We still used a merge sort algorithm to reduce the total comparisons from 190 to around 65. The total comparison time required to complete the experiment varied from user to user according to the decisions they made during the second and third experiments.

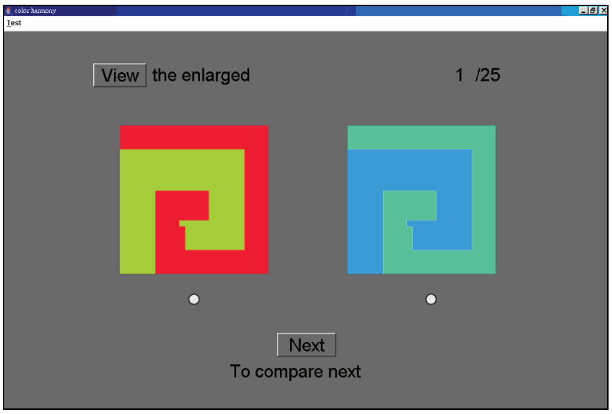

Figure 4 Colour-matching comparison experiment (area ratio 1:1)

Results and Discussion

A total of 37 participants completed the stage 1 of the investigation, and each had two sets of data. Table 2 shows one participant's colour preference order. We used Spearman's rank correlation coefficient equation to calculate the correlation (Eqn 1) [11]:

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2 - 1)} \qquad (1)$$

where d_i is the difference between each rank of corresponding values of x and y, and n is the number of pairs of values. The correlation coefficient, ρ, for each participant is shown in Table 3.

Table 2 Participant colour preference order for the two experiments in stage 1

Munsell colour	First order	Second order
5R	4	2
5YR	8	10
5Y	6	5
5GY	10	8
5G	9	9
5BG	3	1
5B	2	4
5PB	7	7
5P	5	6
5RP	1	3

Table 3 All 37 participants' ρ values

Participant no	ρ value	Participant no	ρ value
1	0.93	20	0.60
2	0.64	21	0.39
3	0.52	22	0.94
4	0.65	23	0.87
5	0.78	24	0.49
6	0.45	25	0.84
7	0.38	26	0.36
8	0.62	27	0.84
9	0.94	28	0.76
10	0.77	29	0.99
11	0.56	30	–0.43
12	0.90	31	0.98
13	0.25	32	0.61
14	0.70	33	0.61
15	0.79	34	0.92
16	0.73	35	0.71
17	0.26	36	0.20
18	0.58	37	0.35
19	0.88		

The correlation coefficient for this data was 0.84, showing a high positive correlation between the two results. Among the 37 participants, 17 participants scored over the pre-defined value, 0.7, which we had determined to be necessary before they could move on the stage 2.

To understand the influence of single-colour preference and area ratios in dichromatic colour combinations, we assigned scores ranging from 1 to 10 for the 10 selected single colours according to their preference order, and we then multiplied these by the area ratios occupied by the single colours in the colour pairs to obtain the estimated scores of the dichromatic colour average scores, as shown in Eqn 2:

$$\text{Estimated score} = C_1 A_1 + C_2 A_2 \quad (2)$$

where C is the colour score and A is the area ratio score for colours 1 and 2 as shown.

To analyse the relationship between the estimated scores and colour preference order for the dichromatic colours, we allocated estimated scores to the y-axis and colour preference of participants to the x-axis, as shown in Figure 5. We then conducted linear regression analysis to explain a single participant's experimental result. Although the R^2 values indicated in Figure 5 (b and c) are not high, the regression lines in Figure 5 (a–c) all have fixed tendency. With reduced estimated scores, the rank of colour preference decreases, showing that the single-colour preference and area ratios can somehow affect dichromatic colour preference order. The reason that the R^2 values of Figure 5 (b and c) were low in the regression graph might be because the preferred colour pairs were affected by other factors, and it is also difficult to describe the relationship just using one equation without taking other influential factors into consideration. It might still be appropriate to infer that participants' preferences for a single colour could affect their preferences for paired colours.

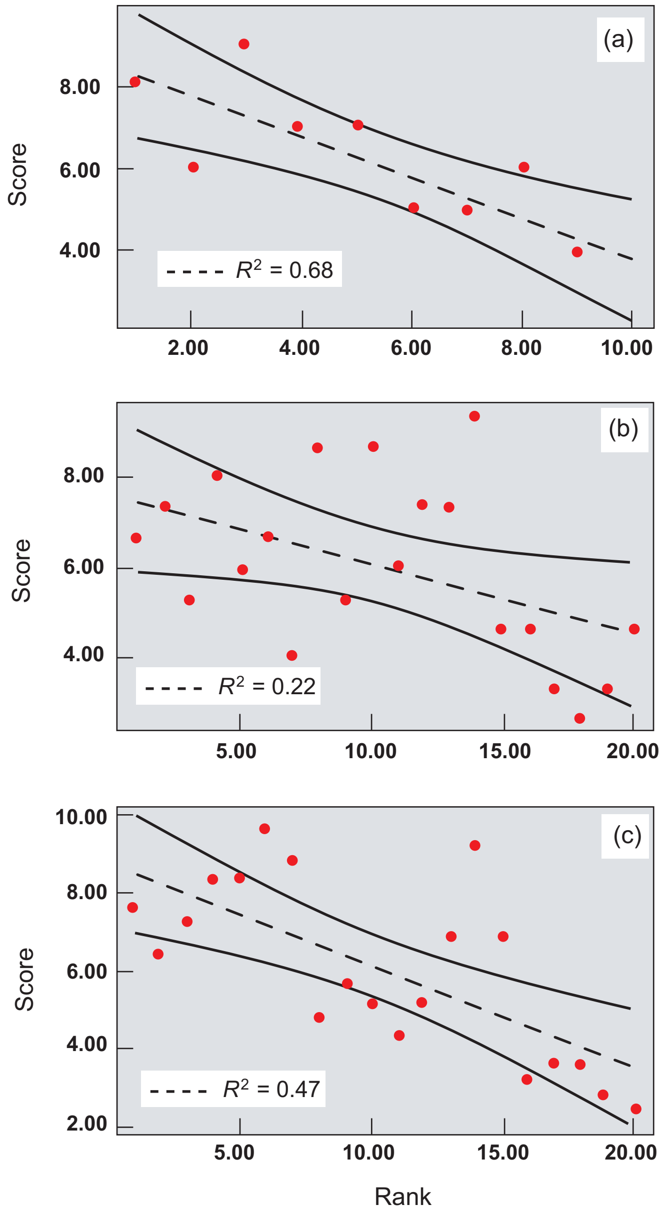

Figure 5 Regression curves of single participant's preference of dichromatic colour and estimated scores at the (a) 1:1, (b) 2:1 and (c) 4:1 area ratios

The data from the 17 participants was gathered for another analysis and the results shown in Figure 6. The results shown in Figures 5 and 6 tend to indicate that Eqn 2 is not suitable for predicting paired colour preference scores. The experimental results confirm Lo's conclusion that it is dangerous to predict a person's reaction towards a given colour combination solely on the basis of his or her preference for its individual

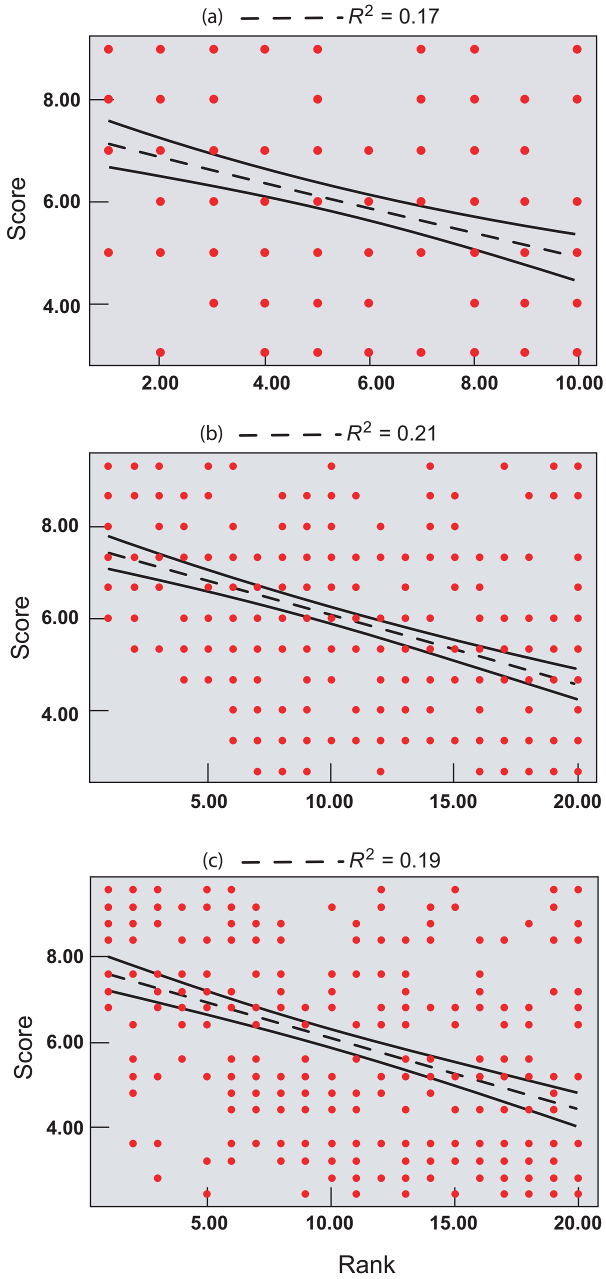

Figure 6 Regression curves of 17 participants' dichromatic colour preference order and estimated scores at the (a) 1:1, (b) 2:1 and (c) 4:1 area ratios

constituents [16]. However, from the constant negative correlation between the estimated paired colour preference and the rank number, we inferred that the higher the estimated score, the better the chance that the paired colour could win a participant's preference. The results of this analysis can be interpreted to mean that single-colour preference is indeed just one of several factors affecting dichromatic colour combination preferences.

Also, varying the ratios of the individual colours present in a specimen did not give any noticeable difference in the results obtained.

Conclusion

It is inferred that single-colour preferences affect the preference of dichromatic colours. However, this influence does not ensure that single-colour preferences can predict dichromatic colour preferences. Nevertheless, designers still need to consider the colour preferences of the target groups. Colour combinations are more likely to be successful when cultural backgrounds are taken into consideration.

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