An Investigation of Colour Emotions using Two-Colour Combinations

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ABSTRACT

A psychophysical experiment was carried out to investigate colour emotions for two-colour emotions. Thirty-four Thai observers assessed a set of 253 colour pairs using 14 colour-emotion scales: Dark-Light, Hard-Soft, Cool-Warm, Turbid-Transparent, Pale-Deep, Vague-Distinct, Light-Heavy, Sombre-Vivid, Weak-Strong, Passive-Dynamic, Plain-Gaudy, Subdued-Striking, Disharmony-Harmony and Dislike-like, whereby the magnitude of each sensation scale was divided into 7 categories. The experimental raw data were analysed statistically to obtain visual scores for all of colour-emotion scales investigated. No simple correlation was found between colour sensations of two-colour combinations and differences in lightness, chroma and hue between the two colours in a given colour pair. However, an additivity relationship between single-colour and two-colour emotions was found and could be used to predict colour emotions for a colour pair.

1. INTRODUCTION

Colour emotion is the term used to describe the feeling induced in an observer when viewing a particular colour. For example, colours such as blue are often described as cool whereas other colours such as red are described as warm. Similarly colours are often judged to be Hard or Soft, Weak-Strong, etc. In addition to an understanding of the emotions induced by a single colour it is often useful (in for example, clothes design) to be able to predict the emotions induced by colour combinations. In this work, we present a study aimed at better understanding the colour emotions induced by two-colour combinations. The current work is similar to that of Ou et al.[1] who investigated colour emotion for two-colour combinations using a forced-choice pair comparison technique. However, our work differs in an important way since it is based on a categorical judgement experiment. Using this technique we obtained colour-emotion data of a range of colour pairs as judged by 34 Thai observers using 14 different scales. We used the data gathered in this experiment to determine whether or not it was possible to predict the emotion induced by a colour pair based on simple measures of their colorimetric difference and in addition as to whether the colour emotions induced by a colour pair could be predicted from the emotions induced when each of the colours was viewed in isolation.

2. EXPERIMENTAL METHOD

Colour emotions for two-colour combinations were investigated using 14 opponent-word pairs: Dark-Light, Hard-Soft, Cool-Warm, Turbid-Transparent, Pale-Deep, Vague-Distinct, Light-Heavy, Sombre-Vivid, Weak-Strong, Passive-Dynamic, Plain-Gaudy, Subdued-Striking, Disharmony-Harmony and Dislike-Like. Observers identified the magnitude of each of the colour-emotion scales using 7 numbers ranging from –3 to +3, where –3 represents one extreme of the scale, e.g. Dark, Hard, Cool, and +3 represents the other extreme of the scale, e.g. Light, Soft, Warm. The visual experiment was conducted in a darkened room where a series of colour pairs were presented in a viewing cabinet illuminated with D65 simulators. A set of 23 single colour samples was selected from the PCCS (Practical Color Co-ordinate System) colour notation, which included five colour hues (red, yellow, green, blue and purple) varying in four different tones (vivid, dull, light and dark) and three achromatic samples (white, medium grey and black). Each colour patch was 3”x3” in size and was combined in turn to generate a set of 253 colour pairs used in the visual experiment. Colorimetric values of the colour samples were measured in terms of lightness (L*), chroma (C^*_{ab}) and hue (h_{ab})

using a Gretag Macbeth Color Eye 7000 spectrophotmeter. Colour difference (ΔE^*_{ab}), lightness difference (ΔL^*), chroma difference (ΔC^*_{ab}) and hue difference (ΔH^*_{ab}) were calculated for each colour pair.

Thirty-four Thai observers, including 17 males and 17 females, ranging in age from 20-27, participated in the visual experiment. The experimental raw data accumulated from 34 observers were calculated to obtain visual scores for each of the colour-emotion scales. The visual scores represented colour emotions in terms of a percentage ranging from +100% to –100%, as given in Equation 1:

$$VS\% = \frac{a(-3)+b(-2)+c(-1)+d(0)+e(+1)+f(+2)+g(+3)}{3(a+b+c+d+e+f+g)} \times 100 \quad (1)$$

where a, b, c, d, e, f and g are the number of observers choosing the score of –3, -2, -1, 0, 1, 2 and 3, respectively. The negative visual scores represent the intensity of one of the opponent colour emotions on the scales, e.g. Dark, Hard, Cool, and the positive values represent the intensity of the other one on the scales, e.g. Light, Soft, Warm.

3. RESULTS AND DISCUSSIONS

Kobayashi[2] suggested that the distance of colour pairs on the colour scale could predict colour emotions of the colour pairs. For instance, combinations of colours distant from each other induced sporty emotion. This study thus examined whether distances in a colorimetric space, i.e. colorimetric differences, between two colours in a given pair could be used to predict colour emotions induced by two-colour combinations. Relationships between colorimetric differences (ΔL^*, ΔC^*_{ab}, ΔH^*_{ab} and ΔE^*_{ab}) of colours in a given pair and colour emotions were investigated by means of Pearson product-moment correlation coefficient (Table 1). The results showed that there was very little correlation between colour-emotion scales and lightness (Pearson *r* values in a range of 0.02-0.48 for positive correlation and 0.02-0.09 for negative correlation), chroma (0.02-0.55 for positive and 0.05-0.20 for negative correlation), and hue differences (0.08-0.55 for positive and 0.21-0.56 for negative correlation). Some correlations were found between total colour differences (ΔE^*_{ab}) and colour-emotion scales of Vague-Distinct (0.70), Passive-Dynamic (0.71) and Plain-Gaudy (0.72). However, the correlations found between colour differences and colour-emotion scales were not high, suggesting that colour emotions for two-colour combinations cannot be predicted using simple colorimetric differences between colours in a given pair.

Table 1. Correlation (Pearson *r*) between mean visual scores of colour-emotion scales for two-colour combinations and colorimetric differences.

	Dark - Light	Hard - Soft	Cool - Warm	Turbid - Transparent	Pale - Deep	Vague - Distinct	Light - Heavy
ΔL^*	0.36	0.05	0.03	0.28	0.02	0.48	-0.09
ΔC^*_{ab}	0.36	-0.16	0.41	0.31	0.18	0.53	0.02
ΔH^*_{ab}	0.23	-0.21	0.29	0.17	0.16	0.30	0.08
ΔE^*_{ab}	0.52	-0.21	0.42	0.40	0.20	0.70	0.02

	Sombre - Vivid	Weak - Strong	Passive - Dynamic	Plain - Gaudy	Subdued - Striking	Disharmony - Harmony	Dislike - Like
ΔL^*	0.31	0.06	0.15	0.11	0.23	-0.02	0.32
ΔC^*_{ab}	0.54	0.20	0.52	0.55	0.51	-0.20	-0.05
ΔH^*_{ab}	0.37	0.08	0.53	0.55	0.37	-0.56	-0.35
ΔE^*_{ab}	0.68	0.18	0.71	0.72	0.63	-0.52	-0.14

An earlier study by Hogg[3] showed that colour emotions for two-colour combinations had high correlation with an average of single-colour emotions of a given pair, i.e. additivity relationships. A relationship between single-colour and two-colour emotions was described as CE = (CE1+CE2)/2,

where CE is the magnitude of colour emotions for a colour pair that is made of colours 1 and 2 having colour emotions for single colours of CE1 and CE2, respectively. Ou et al.[1] employed this equation to predict colour emotions for two-colour combination and found good agreement between predicted and visual colour-emotion scores. This study thus investigated the correlation between single-colour and two-colour emotions using such concept and the results are shown in Table 2. Note that colour emotions for single colours were calculated based on colour-emotion formulae for single colours derived in the previous study by Bangchokdee[4] whereby formulae for Disharmony-Harmony and Dislike-Like scales were not available. In addition, studies by Ou et al.[1], Hogg[2], Lo[5], and Guilford[6], showed that colour preference for colour pairs was unable to be predicted by simple calculations on single-colour emotions. Hence, the investigation in this study was done on 12 colour-emotion scales, omitting the Disharmony-Harmony and Dislike-Like scales. As can be seen from Table 2, colour emotions for two-colour combinations were found to be high correlated with the mean values of colour emotions of single colours in a given pair. The Pearson *r* values ranged from 0.65 to 0.91, which were much higher than those representing the correlation between colorimetric differences and colour emotions. This suggests that colour emotions for colour pairs can be predicted by additivity relationships. These results agreed well with the findings by Ou et al.[1], where two-colour emotions were investigated by British and Chinese observers.

Table 2. Correlation (Pearson *r*) between mean visual scores of single-colour emotions and visual scores of colour emotions for two-colour combinations.

Dark - Light	Hard - Soft	Cool - Warm	Turbid- Transparent	Pale - Deep	Vague - Distinct
0.90	0.71	0.88	0.91	0.76	0.71

Light - Heavy	Sombre - Vivid	Weak - Strong	Passive - Dynamic	Plain - Gaudy	Subdued - Striking
0.82	0.85	0.68	0.83	0.84	0.65

The prediction of the intensity of a colour emotion for a colour pair by averaging colour-emotion scores of individual colours in the given pair assumes the equal weight in the combined effect of colour components. Guilford[6] stated that the values of the two-colour combination would be proportional to the arithmetic mean or some simple functions of the values of its two components, rather than the algebraic sums of the values of the components. This indicated the unequal weight of each component in the colour pair. Further investigation in the present study was therefore made to find the relative weight of each component based on the additivity relationship, so as to verify the performance of the prediction by arithmetic mean. Firstly, the relationship between the two-colour emotions was assumed to be in a form of a linear function of colour components in the pair in such way: CE = aCE1+bCE2+c. CE is the magnitude of colour emotions for a colour pair that is made of colours 1 and 2 having colour emotions for single colours of CE1 and CE2, respectively, whereby CE1 is lower than CE2. The relative weights a and b, and the constant c were determined by means of linear regression. The results are shown in Table 3.

Table 3. Relative weights and constants used in linear functions for predicting two-colour combinations.

	Dark - Light	Hard - Soft	Cool - Warm	Turbid- Transparent	Pale - Deep	Vague - Distinct
a	0.2845	0.5913	0.6178	0.4633	0.2825	0.4611
b	0.6619	0.4130	0.6657	0.5066	0.7589	0.6449
c	-6.2361	7.1855	10.8453	2.1578	-26.6386	-16.9997

	Light - Heavy	Sombre - Vivid	Weak - Strong	Passive - Dynamic	Plain - Gaudy	Subdued - Striking
a	0.4055	0.3261	0.2921	0.2634	0.2291	-0.0589
b	0.5862	0.6082	0.6757	0.6177	0.6885	1.0245
c	-15.9653	-7.6343	-26.6809	-3.5845	-3.7109	30.3319

The performance of predictions of colour emotions for two-colour combinations by the linear model was investigated by means of Pearson product-moment correlation coefficient (Table 4). The Pearson *r* values indicated the correlation between the predicted values and the actual visual scores of colour emotions for two-colour combinations. It was found that the assumed additivity relationship had good prediction with the Pearson *r* values ranging from 0.69 to 0.93. In addition, the prediction was slightly improved for overall results. The significantly better prediction was found for the Subdued-Striking scale, where the *r* value was 0.79, as opposed to the value of 0.65 when predicted using the arithmetic mean.

Table 4. Correlation (Pearson *r*) between predicted values based on simple linear functions of visual scores of single-colour emotions and visual scores of two-colour emotions.

Dark - Light	Hard - Soft	Cool - Warm	Turbid- Transparent	Pale - Deep	Vague - Distinct
0.93	0.71	0.88	0.91	0.79	0.71
Light - Heavy	**Sombre - Vivid**	**Weak - Strong**	**Passive - Dynamic**	**Plain - Gaudy**	**Subdued - Striking**
0.82	0.86	0.69	0.85	0.87	0.79

The additivity relationship provides a convenient way of predicting two-colour emotions by single-colour emotions. Since the single-colour emotions are predicted by colour-appearance attributes of the particular colours[4], the colour emotions for two-colour combinations can be predicted using colorimetric values by combining the additivity relationship with a single-colour emotion formula. With this combined model, one can easily predict colour emotions for a colour pair when colorimetric values of individual colours are known.

4. CONCLUSIONS

A set of 253 colour pairs was assessed on fourteen colour-emotion scales by Thai observers. It was found that two-colour emotions could not be accurately predicted using colorimetric differences between individual colours in the given colour pairs. Further investigation into a relationship between single colours and two-colour combinations in this study confirms an additivity relationship between single-colour and two-colour emotions. According to this relationship, a colour emotion for a colour pair can be predicted by the arithmetic mean or linear function of single-colour emotions in the given pair. With this relationship and a colour-appearance-based formula for single colours, colour emotions for two-colour combinations can be predicted based on colorimetric values of component colours in the given pairs.

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