Article:
Chen, Y, Yang, J, Pan, Q et al. (2020) A method for exploring word-colour associations. Color Research and Application, 45 (1). pp. 85-94. ISSN: 0361-2317

https://doi.org/10.1002/col.22434

A Method for Exploring Word-Colour Associations

Yun Chen, Jie Yang, Qianqian Pan, Marjan Vazirian* & Stephen Westland
School of Design, University of Leeds, UK
* AkzoNobel NV, Netherlands.

Abstract

Strong associations exist between colours and concepts or words. Understanding these associations, sometimes referred to as colour emotions, is important for effective use of colour in art and design. Traditionally the relationships have been systematically explored in experiments where participants scale colours according to bi-polar adjectives such as warm-cool. In this paper a method for exploring the relationships between words and colours is suggested and is demonstrated. A psychophysical experiment is described where participants select colours based on words. The data are used to show that many similarities between the word-colour relationships for UK and Chinese participants although some interesting differences are also revealed. The method makes explicit the observation that there is not a one-to-one relationship between words and colours. The method could be used to explore word-colour relationship for specific words and participant groups or could be used to generate ground-truth data for testing methods for automatically generating the word-colour relationships.

1 Introduction

It is established that strong associations exist between colours and concepts[1]. Colour can also elicit an emotional response and the term colour emotion is often used to describe this[2]. Colours or colour combinations may evoke corresponding feelings such as excitement, energy and calmness[2-5]. It is likely that such colours emotions are triggered by learned associations[6] or shaped by nature although the effect of light on the non-imaging-forming pathways of the human visual systems as a contributing cause cannot be ruled out[7]. It has been noted that people associate blue with calming, depressing, peaceful, quiet, serious, and nostalgic[1]; associate yellow with serene, happy and softly exciting[8], or warm and sunny; associate green with envy, red with passion, black with death, yellow with cowardice, blue with loyalty[9]. Cherry has explored the link between colour and mood[5]. In terms of object colour at least, cool colours are linked with the moods as calm, serene and comfort whereas warm colours are relevant to stressful and exciting moods.

Colour is differentiated by hue, brightness and saturation[10]. In terms of hue, colours can be categorized into warm colours (e.g. orange and red) and cool colours (e.g. violet, blue). Brightness and saturation are also significant in colour perception however. Brightness plays an important role in determining lightness or darkness of colour; saturation suggests purity of colour. According to Hemphill, bright colours are linked with positive emotions like happiness, joy and hope[11]. Likewise, Elliot and Maier consider brighter colours as friendly, cultured, pleasant and beautiful[12]. Conversely, dark colours are associated with negative emotions such as boredom and sadness[13]. According to Elliot and Maier, colour may generate associations and responses, and they take meaning of colour as bipartite[12].

In terms of colour preference there is a huge amount of previous literature. The long history of colour preference research has been described as being ‘bewildering, confused and contradictory’[14-15]. Most recent studies have tended to agree that, on average, people have a preference for cool shades such as blue and a dislike for warmer colours such as yellow and orange but there is still huge individual variation and some systematic differences between gender and culture[15-16]. For example, Choungourian studied people from four countries and identified variance in colour preferences representing individual variation[17]. It was found that the US consumers prefer red and blue, but least like blue-green. However, respondents from Iran and Kuwait preferred blue and green. However, whether there are effects of culture and gender on colour preference, and certainly exactly what those effects are, is still somewhat of an open question.

Although colour can elicit emotional responses, the sorts of associations that colours have are not limited to emotions. For example, the colour pink may be associated with femininity, but this does not necessarily mean that looking at pink (or wearing pink) makes one 'feel' more feminine (although it may); it may be that pink is simply associated (cognitively) with the concept of femininity. Such associations are important for the successful application of colour in product design, advertising and marketing[18]. In some case, "meaning" may represent a kind of mental stimulation[19]. Won defined colour meaning in her research thus[20]: "Colour meaning is not about combinations that create pleasing responses (colour harmony), not about the processes with which people understand and react to colour (colour perception), and not about liking a particular colour among alternatives (colour preference). Instead, it is concerned with the meanings that are associated with certain colours." Grieve has argued that colours do not elicit a semiotic response *per se;*[21] however, this can be interpreted as stating that without the cultural framework in which we live, red, for example, would have no specific meaning and would elicit no semiotic response. Nevertheless, we do live in a cultural framework and empirical studies show that colours do elicit response even when presented without any context[22]. These two views can be reconciled if we understand that colours can have a meaning even when presented without a context because of the associations that become formed when individuals previously encounter that colour in context. People associate colours with experience and memories; a colour may remind someone of a specific object, a certain substance, a person, a period time or a region and this has been referred to as colour association[23].

Some studies have discussed colour meanings amongst different cultures and some cross-cultural difference in colour meanings and associations have been identified. The colours themselves may differ because of dependence on lighting conditions, observation position and surrounding especially the adjacent colour and all of these factors can shape the ways of perceiving a specific colour[19]. Moreover, even when people are exposed to the same stimulus colour, the way they perceive that colour, and hence the meanings and emotions incurred, may differ as a result of variability in gender, age, educational background and culture, childhood association and others[24]. Nevertheless, broadly speaking, the empirical data suggest more similarities than differences in colour meanings between cultural groups. Osgood and his colleagues carried out colour-meaning research across 20 countries[19]. They chose participants from high schools and asked them to rate seven (red, orange, yellow, green, blue, black and white) colours for each of 12 semantic differential items. The results, analysed using scaling, used "evaluation, potency and activity" as reference, were broadly similar for the 20 countries; blue was the most highly evaluated colour, green and white followed; black and red were the most potent colours; the most active colour was red, whereas grey and black were the most passive colours. In 2000, research indicated some differences and similarities in four cultures (Japan, China, South Korea, and United States)[25]. The students from those four countries were asked to summarize the most closely colour associated with 13 words which are often used in describing objects from eight sample colours. As a result, red was associated with love and blue with high quality for all four cultures. Black was consistently associated with powerful and expensive. In contrast, purple associations showed a sharp contrast between three Asian countries (Japan, China and South Korea) and the United States. In the three Asian countries, purple was associated with expensive products while in the United States purple normally represents inexpensive. Thomas explored cross-cultural similarities and dissimilarities in colour preferences and colour meanings associations in eight cultures (Austria, Brazil, Canada, Colombia, Hong Kong, China, Taiwan and the United State)[25]. In his results, green, white and blue were consistently associated with "calming", "peaceful" and "gentle" in all eight countries. Green, white and blue were also associated with "pleasant" (Austria, Colombia, United States, and to a lesser extent China and Taiwan) and "beautiful" (Brazil, Hong Kong, China, and United States). However, those three colours also represent unique meanings separately in different countries while they share the meanings in the research. Thomas concluded that no universal meanings can be attributed to specific colours and proposed, instead, a "Spectrum of Colour Meaning".

Colour association may be a more accurate term than colour meaning since it implies that the relationship between colour and concept is the result of a learned association rather than being a property of the colours themselves. Colour association can be divided into concrete and abstract colour associations. Schloss and Palmer argued that colour can be associated with specific objects[26]. For instance, blue is associated with sky, red colour is associated with ripe berries and fruits, and brown is associated with faeces and rotten fruit. Moreover, the differences in colour associations between age, areas and environment have been discussed. In Goethe's research[8], it is suggested that colour associations could be different because of some factors (for instance, women and children, or northern

Europeans as opposed to southern Europeans) and hue might not even be the most important element in colour associations[23]. Gage agrees that 'the same colour can be found to have quite antithetical connotations in different periods and cultures and even at the same time and place'[1]. Tofle *et al.* also claimed emotional responses evoked by colour as an outcome of learned associations on basis of culture and individual-related features[6].

In summary, despite Grieve's claim[23] that colours elicit no semiotic response *per se*, empirical data supports the notion that colours are associated with ideas, concepts and emotions. Although there is some variation between individuals and between cultural and gender groups, there is a great deal that is agreed upon. These associations may result from human physiological responses or, more likely, from associations with key objects and experiences but nevertheless are relatively robust. Colours may, however, take on quite different meanings and associations when they occur in context (that is, a red dress may take on quite a different meaning to the colour red without any context). Note that this work is restricted to the associations of colour in an abstract sense rather than with any particular instantiation or context. By context we mean that the colours are not seen as belonging to an object but rather as seen as simple patches (albeit in the context of a background and other colour patches).

The vast majority of experimental work that has been carried out in this field has used a scaling technique called semantic differential scaling[19]. In these studies the participants are presented with a colour and are asked to respond using a slider bar or by otherwise indicating the extent to which the colour is associated with two bi-polar adjectives; for example, male-female, soft-hard, old-new. Some computational models have been produced, fitted to the experimental data, that are able to predict the extent to which any given colour can elicit any of these responses[22]. However, in this work we suggest that there is merit in turning this problem around on its head. That is, rather than starting with a colour and asking to what extent it is, for example, modern, we start with an adjective, such as modern, and ask which colours are associated with this adjective. The reason for this is that in the design process the identification of intended feelings and/or ideas will normally come first, and the designer then seeks colours that can deliver the required message[20]. However, there are obviously a very large number of potential words that could be used as starting points for a colour palette; it is inconceivable that laboratory-based studies such as the one described in this paper could provide the required data for this (especially since this might be required in multiple languages). The purpose of this study therefore is to provide some new psychophysical data on the relationship between word and colour. These data could be used as ground-truth data to validate automatic methods that may be developed to predict colours from words[29,30]. In one previously published study, for example, it was suggested that internet scraping could be used to derive the word-colour relationships automatically based on analyses of millions of images[29]. The second purpose of the work is to illustrate the method used in this study to obtain word-colour relationships from laboratory studies and to encourage other researchers to adopt these methods. Finally, we conduct a study with two distinct cultural groups. The aim of the work is not to undertake a cultural comparison (since that would require many more words and more participants than used in the current study). Nevertheless, the comparison of the results of this method used with two cultural groups will enhance the extent to which the method can be evaluated.

2 Experimental

A total of 30 participants, 15 from the UK (7 males and 8 females) and 15 from China (9 males and 6 females) all of whom had normal colour vision and were more than 18 years old, were recruited to take part in a psychophysical experiment. The number of males and females in the two groups were approximately equal.

There were two purposes to the experiment:

(i) to demonstrate a new method for collecting word-colour associations;

(ii) to produce psychophysical data that could be used to evaluate the performance of algorithms that automatically generate colour palettes.

In the experiment, 30 target English words were selected. Although to some extent the selection of the 30 words was arbitrary, the words chosen were amongst the most frequent words in the English language. A number of websites exist that provide these lists (for example, http://www.wordfrequency.info/).

However, words such as ‘the’ and ‘a’, although frequently occurring, would probably have very weak colour associations. Therefore, 30 words were selected (see Table 1) from a list of the 500 most-frequent words; in selecting the words some attention was paid to whether the words would likely have strong colour associations – in addition, some words were selected because they have been used extensively in other related studies (for example, the word ‘active’). Chinese translations were made for each of the 30 words

(Table 1). Since typeface may affect the mood or emotion created in the reader, Lanting Hei (兰亭黑) was chosen for the Chinese typeface, since it invokes quite similar responses to Calibri in English from different cultures[27].

Table 1: The list of 30 words used in the experiment (note, that before this, each participant was also presented with the words, red, soft and twelve).

English Words	Chinese Words	English Words	Chinese Words
active	积极的	married	婚姻的
bad	坏的	medical	医学的
clean	干净的	modern	现代的
cold	冷的	natural	自然的
cultural	文化的	old	年老的
dangerous	危险的	poor	贫穷的
dead	死亡的	powerful	强大的
female	女性的	religious	宗教的
fresh	新鲜的	rich	富有的
future	未来的	safe	安全的
good	好的	sweet	甜的
healthy	健康的	traditional	传统的
hot	热的	unlucky	不幸的
lucky	幸运的	urban	城市的
male	男性的	young	年轻的

In the experiment the participants viewed the words (presented one at a time in randomised order) on a PC display (HP DreamColor LP2480zx – a 24-inch LCD Backlit Monitor, max luminance 187 cd/m^2) from a distance of about 80 cm in a darkened room. The UK participants were presented with the English words and the Chinese participants were presented with the Chinese (Mandarin) words. A small reward was given to each participant at the end of the experiment to thank them for their participation.

The words were displayed in a black typeface on a uniform grey (CIELAB L*=50) background. For each word that was presented (in random order), each participant was requested to perform the following tasks:

1. To select the colour that most represents the word using a typical colour picker.
2. To indicate the strength of association between that colour and the word using a slider bar (in the range 0-100).
3. To then select two more colours that also are associated with the word.
4. To indicate the strength of the association between the three selected colours and the word using a slider bar.
5. To enter text in a box to describe the reasons that they chose the colours that they did (note, however, that in this paper this text information has not been analysed).

No constraints on or recommendations to the participants were made in terms of which colours they selected. For example, particpants might choose three colours that were quite similar in response to a word prompt or they might choose three very different colours. Participants were not given any time limit to perform the task. However, each participant took about 45-60 minutes to complete the experiment. Before the experiment, participants were presented with three trial words in order to get used to the paradigm and also to provide some anchor points for the extremes of the slider bars (the use of such anchors has been shown to result in more consistent scaling between participants in such experiments). The three trial words were ‘twelve’, ‘soft’ and ‘red’ and these were chosen because they were thought to have little, moderate and substantial colour association respectively. Five Chinese and five UK participants were invited back (one or two days after the experiment) in order to repeat the experiment to provide information about intra-observer variability. The interface for displaying the words, for allowing the participants to select colours, and for automatically randomizing the words and collected the data was written using MATLAB.

The colours selected were automatically recorded as RGB values. After the experiment the colours selected (40 participants × 3 colour selections × 33 words = 3960 colours) by each participant for each word were displayed on the computer screen and measured using a Minolta 2000 Spectroradiometer (the spectral data were subsequently converted to CIELAB values using the screen’s white point, CIE x = 0.3116, y = 0.3184).

For each word (and for each nationality, UK and Chinese) this generated palettes containing 45 colours (3 selections × 15 participants) and 15 colours (1 selection × 15 participants) depending upon whether all three selections from each participant are included or whether only the first selected colour by each participant is used.

The colour measurements of each patch will be used to quantify colour differences within a palette or selection of colours and between palettes. For within a palette, each colour will be compared with each other and the CIELAB colour difference calculated; the mean of these colour differences will be used an indicator of similarity *within* the palette.

For comparing similarity between palettes, a method for quantifying the visual difference ΔE_P between two palettes has been developed by Pan and Westland[28]. The algorithm to calculate the ΔE_P is according to the following 5 steps given *N* colours in the palette:

1. For each colour in one palette, the CIELAB colour difference between this colour and each of the colours in the second palette are calculated. The minimum colour difference is recorded.
2. Step 1 is repeated for all the colours in the first palette, for each finding their closest corresponding colours in the second palette, resulting in *N* colour differences.
3. The *N* minimum color difference values are averaged and the mean value symbolized as m_1.
4. Steps 1-3 are repeated, but this time for each of the colours in the second palette. In other words, for each of these colors the closest corresponding colour in the first palette is found. The mean value of these *N* color differences is symbolized as m_2.
5. The values of m_1 and m_2 are averaged to obtain the visual colour difference ΔE_P between the two palettes

Smaller values of ΔE_P are associated with greater similarity between two palettes.

3 Results

The first colour selected by the UK and Chinese participants for the three trial words are illustrated in Figure 1. The mean strength of association for these words were 98.3 (red), 75.5 (soft) and 33.2 (twelve) for the 15 UK participants and 99.2 (red), 82.0 (soft) and 59.6 (twelve) for the 15 Chinese participants. This confirms the assumption made at the beginning that the words red, soft and twelve would have strong, moderate and weak colour associations respectively. The mean colour difference within each palette was 13.6 (red), 44.4 (soft) and 99.6 (twelve) for the UK participants and 18.0 (red), 46.7 (soft) and 96.6 (twelve) for the Chinese participants. Based on these three words alone it seems that palettes that are strongly associated with the words contain more self-similar colours than palettes that are weakly associated with the words. This will be tested later for all 30 of the test words.

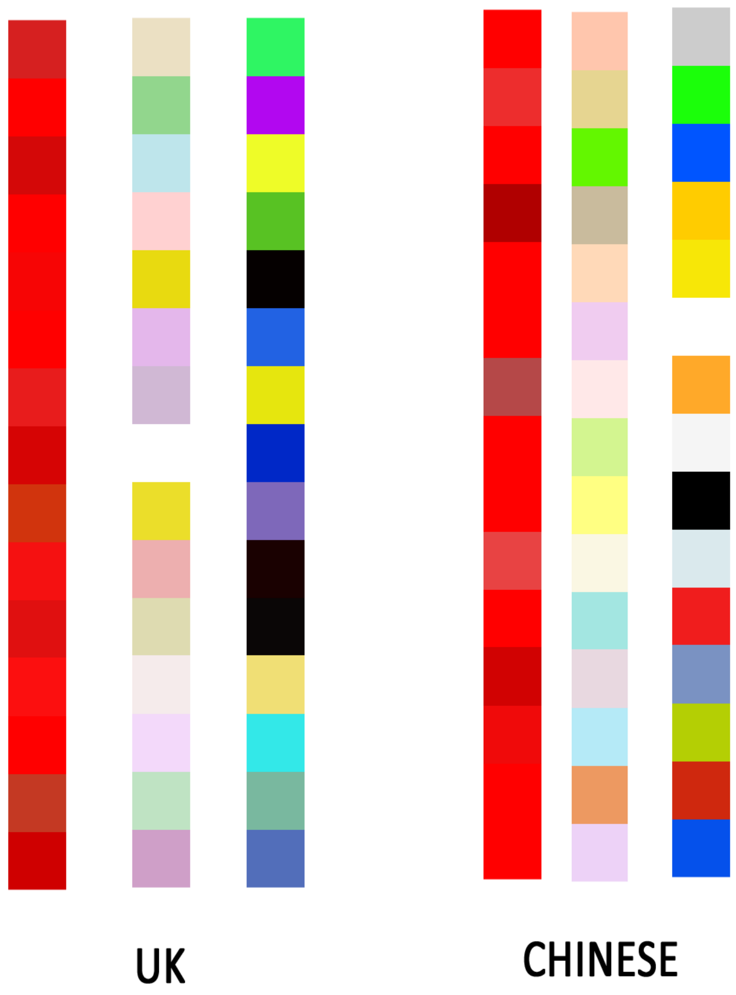

Figure 1: The trial results for the UK (left) and Chinese (right) participants. Each row represents the first colours chosen by one of the participants for the words red, soft and twelve (shown from left to right).

Figures 2 and 3 respectively show the first colours selected by the UK and Chinese participants for the 30 test words. For example, for the word ‘hot’ the vast majority of participants selected a red colour whereas for the word ‘natural’ the vast majority of participants selected a green colour. In some cases the colours selected are intuitively what one would expect (that is, for example, there is a large amount of published studies that would equate blue with cold, for example). Note the predominance of pink for female, and the predominance of blue for cold (and compare these to the reds that are generally associated with hot). Visually there are many similarities between the colours chosen by the UK participants and those chosen by the Chinese participants. Even when the colours that were collected were less obviously intuitive (such as the reds and blacks that are associated with bad and the colours associated with active) there is evidence of some common relationship between word and colour. However, some interesting differences can be observed between the UK and Chinese colours. For example, red is used much more by Chinese participants in association with traditional and with married. Note also the dominance of red for the word lucky in the Chinese data whereas there is a dominance of green for the same word in the UK data.

However, the similarity between palettes can be quantified using the palette comparison metric ΔE_P. Table 2 lists the ΔE_P values for each of the 30 words where the UK palette is compared with the Chinese palette. From Table 2 it can be observed that the three words that produced the most similar palettes between the UK and Chinese participants were dead ($\Delta E_P = 5.9$), clean ($\Delta E_P = 8.9$) and hot ($\Delta E_P = 9.8$). The three words that produced the least similar palettes between the UK and Chinese participants were religious ($\Delta E_P = 39.6$), bad ($\Delta E_P = 36.1$) and rich ($\Delta E_P = 31.9$). More work may be needed with the ΔE_P metric to ascertain a threshold value above which palettes may be considered to be visually dissimilar. Words that produce similar colour palettes for UK and Chinese participants tend to have strong associations. However, words that produce less similar palettes may have weak associations for one or both of the participant groups (e.g. the strength of association for the word safe was only 55.5 for UK participants but is 82.8 for Chinese participants). However, the colour associations for the word bad are quite different for the two groups but both groups report strong associations (76.3 and 82.1 for UK and Chinese participants respectively) for the colours that they select. The strength of the associations are detailed in Table 3. Note that in nearly every case the strength of the association of three selected colours is a little less than for the first selected colour.

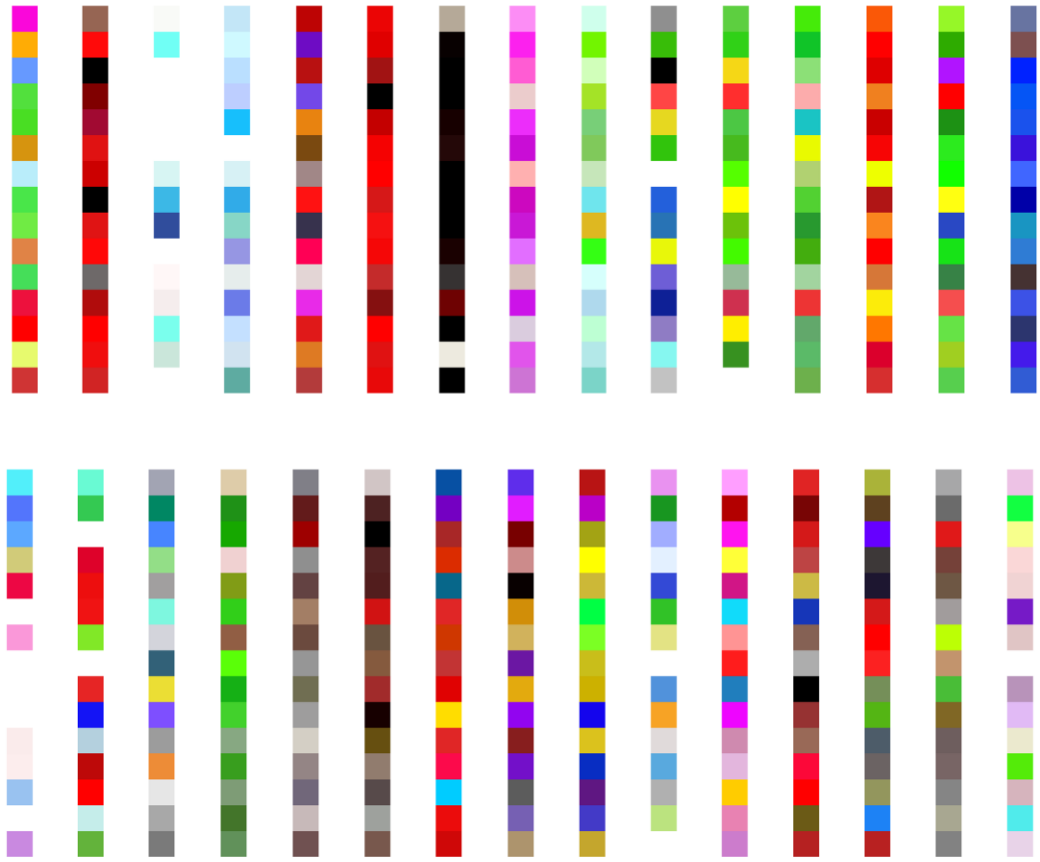

Figure 2: The experimental results for the UK participants the first colour selected. The words are, from left to right in the top row (active, bad, clean, cold, cultural, dangerous, dead, female, fresh, future, good, healthy, hot, lucky, male) and in the second row (married, medical, modern, natural, old, poor, powerful, religious, rich, safe, sweet, traditional, unlucky, urban, young).

Table 2: Visual colour differences DEP between the UK and Chinese colour palettes (smaller values of DEP indicate more similarity between the two palettes). Based on the first colour selected by each participant for each word.

word	difference	word	difference	word	difference
dead	5.88	old	16.73	male	23.54
clean	8.89	dangerous	17.25	unlucky	23.67
hot	9.80	good	17.57	sweet	25.28
fresh	12.95	urban	19.02	young	26.13
medical	13.41	cold	19.02	future	26.32
poor	14.38	female	19.39	married	27.06
traditional	14.72	lucky	19.43	active	27.64
natural	15.34	powerful	20.70	rich	31.93
modern	16.10	cultural	22.35	bad	36.10
healthy	16.13	safe	23.03	religious	39.64

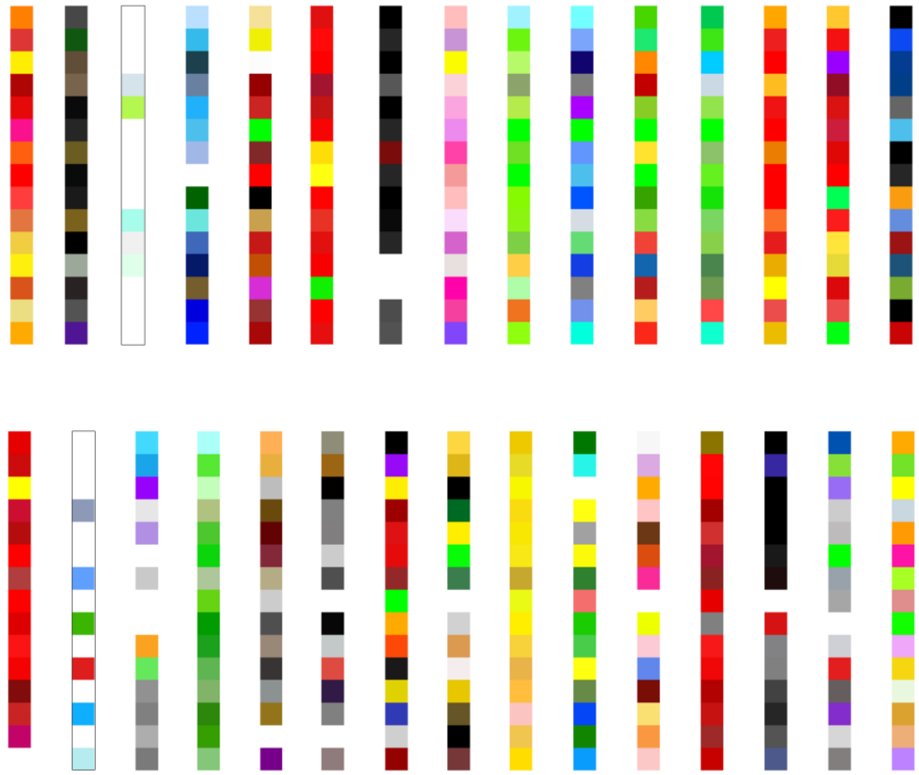

Figure 3: The experimental results for the Chinese participants the first colour selected. The words are, from left to right in the top row (active, bad, clean, cold, cultural, dangerous, dead, female, fresh, future, good, healthy, hot, lucky, male) and in the second row (married, medical, modern, natural, old, poor, powerful, religious, rich, safe, sweet, traditional, unlucky, urban, young).

The analysis so far has considered the first colour chosen by each participant for each word. Figures 4 and 5 show the colour palettes (3 colours × 15 observers) that result by considering all three colours chosen by each participant. In this figures, each row shows the colours selected by a participant with the left-most colour in each case being the first colour that was selected.

Figure 6 shows the relationship between the self-similarity of the colours in a palette and the strength of the association between word and colour. The left-hand figure shows the average ΔE between the 15-colour palettes that result from considering the first colour selected only and the average strength of the association between the word and colour ($r^2 = 0.20$). The right-hand figure shows the average ΔE between the 45-colour palettes that result from considering all colours selected and the average strength of the association between the word and colour ($r^2 = 0.29$). Correlations are relatively weak but indicate some evidence that palettes that are strongly associated with the words contain more self-similar colours than palettes that are weakly associated with the words. Other metrics that quantify self-similarity of the palettes may show stronger correlations with the visual strength data. For example, the ΔE could be calculated using other colour difference equations such as CIEDE2000.

Table 3: Mean strength of association reported by participants. Data are shown for UK and Chinese participants and based on the first selected colour and on all three colour selections.

	UK (1)	UK (3)	China (1)	China (3)
red	98.3	95.2	99.2	91.4
twelve	33.2	23.9	59.6	44.8
soft	75.5	64.3	82.0	67.2
active	62.1	58.3	84.9	81.7
bad	76.3	68.2	82.1	77.4
clean	85.8	73.9	97.3	88.8
cold	87.3	83.8	88.1	83.7
cultural	34.9	35.3	75.8	71.2
dangerous	87.6	77.9	93.0	86.4
dead	77.4	71.2	91.5	82.2
female	75.8	70.6	86.0	80.0
fresh	79.0	72.9	89.8	86.4
future	48.4	40.9	83.5	74.0
good	78.5	63.6	79.7	72.6
healthy	69.8	65.8	87.2	80.3
hot	90.7	84.6	89.8	85.1
lucky	79.0	67.2	90.1	81.2
male	78.4	63.9	78.7	74.6
married	68.8	57.5	90.1	79.1
medical	75.2	72.3	91.6	87.1
modern	52.6	45.5	79.9	70.7
natural	82.7	81.8	91.1	83.1
old	59.2	46.3	86.2	79.8
poor	58.3	52.2	81.6	71.8
powerful	70.7	63.8	84.9	73.4
religious	47.3	45.5	81.4	77.3
rich	74.6	62.8	89.8	80.3
safe	55.5	50.9	82.8	73.6
sweet	63.8	55.1	86.2	80.8
traditional	49.1	55.7	86.7	79.2
unlucky	54.4	48.5	81.2	73.6
urban	68.7	61.3	79.1	75.4
young	65.0	60.4	82.0	76.5

Recall that 5 UK and 5 Chinese participants undertook the experiment twice within a few days in order to investigate intra-observer variability. Intra-observer variability varied greatly between words as would expected if some words elicit strong associations and other words elicit much weaker associations (or no associations at all). The words dead for example elicited strong associations from UK participants (see Figure 2 – where the colours for dead are displayed in the upper row and the 7th column for a visual representation and note that in Table 3 the mean strength association was 77.4).

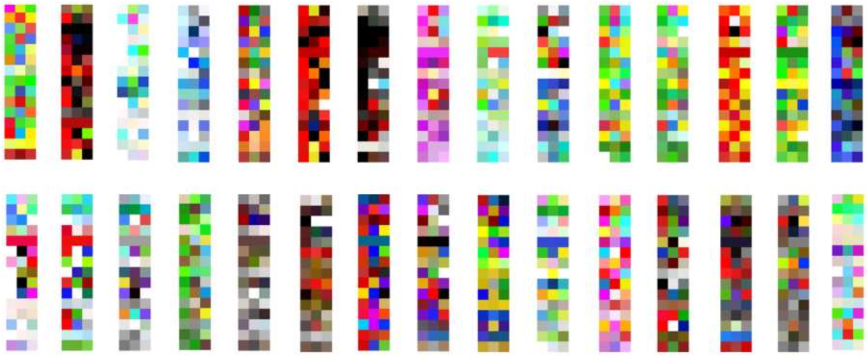

Figure 4: The experimental results for the UK participants for all three selected colours. The words are, from left to right in the top row (active, bad, clean, cold, cultural, dangerous, dead, female, fresh, future, good, healthy, hot, lucky, male) and in the second row (married, medical, modern, natural, old, poor, powerful, religious, rich, safe, sweet, traditional, unlucky, urban, young).

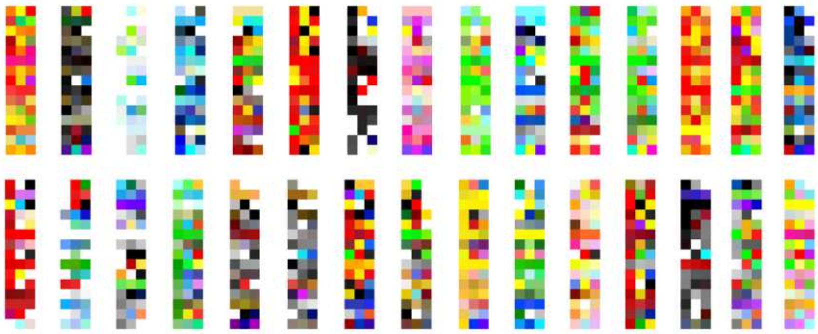

Figure 5:The experimental results for the Chinese participants for all three selected colours. The words are, from left to right in the top row (active, bad, clean, cold, cultural, dangerous, dead, female, fresh, future, good, healthy, hot, lucky, male) and in the second row (married, medical, modern, natural, old, poor, powerful, religious, rich, safe, sweet, traditional, unlucky, urban, young).

For this word, the mean CIELAB colour difference between the first colour selected by the UK participants during their 1st and 2nd visit was 2.0. By contrast, the word future has much weaker associations for UK participants (see Figure 2 – where the colours for future are displayed in the upper row and the 10th column for a visual representation and note that in Table 3 the mean strength association was 48.4). For this word, the mean CIELAB colour difference between the first colour selected by the UK participants during their 1st and 2nd visit was 34.6. Participants were more consistent in their choices when the associations between the words and the colours were strongest.

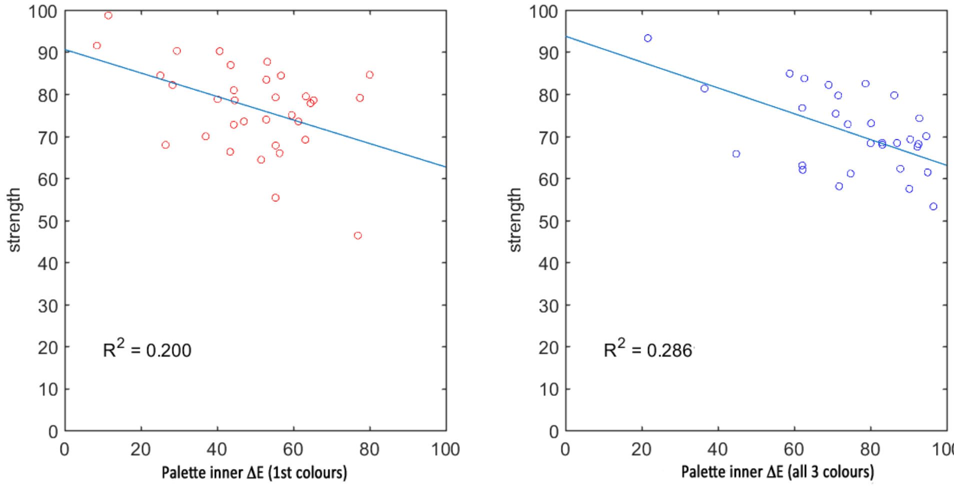

Figure 6: Correlation between within-palette ΔEs and mean strength of word-colour association for all 33 words used in the study. Note that in general the stronger the association of word and colour, the greater the similarity of the colours within a palette. The left figure shows the correlation for when only the first colour selected is considered (15 colours per word); the right figure shows the correlation for when all three selected colours are considered (45 colours per word).

Discussion

In this paper a new method for exploring the relationships between words and colours has been suggested. The data derived have been used to show, for example, that there are a great many similarities between the word-colour relationships for UK and Chinese participants although some interesting differences were also revealed.

The majority of the published literature explore word-colour relationships by starting from a colour and finding the strength of the relationship between that colour and various terms, often expressed as bi-polar adjectives such as weak-strong or warm-cool. It is suggested that there is merit in reversing the experimental paradigm and in this study participants were asked to identify colours that relate to various adjectives. One of the advantages of this method is that it makes explicit the observation that there is not a one-to-one relationship between words and colours. Numerous infographics can be found on the internet that grossly simplify the relationship between colour and meaning, suggesting for example that red means this or green means that. For example, in our data the colours red and blue are found in many of the relationships (see Figures 2 - 5). The method described in this study could be used by those who wish to explore specific relationships. Nevertheless, for practical use the method is somewhat time consuming and more efficient methods to obtain the relationships should be sought. In one previous study, it was suggested that internet scraping could be used to derive the word-colour relationships automatically based on analyses of millions of images[29]. Further work may be required to ascertain whether the colour palettes derived using automatic methods are consistent with those derived from psychophysical experiments. In this regard the data generated in this paper can be regarded as test data that could be used to evaluate the performance of internet-based automatic word-colour extraction (the RGB values obtained are available on request from the authors to any researchers who wish to use them). The possibility of automatic extraction of word-colour relationships offers the potential for design tools that allows users to input a word and to be presented with a colour palette – a range of colours that represent that word from which the user can select. Such a system would present obvious and commercially valuable opportunities in design, marketing and branding. It would also allow a large-scale investigation of differences in word-colour relationships that may exist between cultures, sub-cultures, or even over time in a way that small-scale laboratory-based studies will always struggle to deliver.

References

1. Gage, J., 1999. *Colour and Meaning: Art, Science and Symbolism*. London: Thames and Hudson.
2. Ou, L., Luo. M.R., Woodcock, A. and Wright, A., 2004a. A study of colour emotion and colour preference. I. Colour emotions for single colours, *Color Research and Application*, **29**, 232–240.
3. Ou, L., Luo, M.R., Woodcock, A. and Wright, A., 2004b. A study of colour emotion and colour preference. II. Colour emotions for two-colour combinations, *Color Research and Application*, **29**, 292–298.
4. O'Connor, Z., 2011. Colour psychology and colour therapy: Caveat emptor, *Color Research and Application*, **36** (3), 229-234.
5. Cherry, K., 2015. Colour psychology: How colours impact moods, feelings, and behaviours, https://www.verywellmind.com/color-psychology-2795824 [last accessed 29th Jan 2019].
6. Tofle, R.B., Schwartz, B., Yoon, S., and Max-Royale, A., 2004. Color in healthcare environments: A critical review of the research literature. California: The Coalition for Health Environments Research (CHER).
7. Westland, S., Pan, Q. and Lee, S., 2017. A review of the effect of colour and light on non-image function in humans, *Coloration Technology*, **133** (5), 349-361.
8. Goethe J.W., 2006. *Theory of Colours*. Mineola, N.Y.: Dover Publications.
9. Caivano JL, 1998. Color and Semiotics: A Two-Way Street, *Colour Research and Application*, **23** (6), 390-401.
10. Wyszecki, G., and Stiles, W.S., Color Science: concepts and methods, quantitative data and formulae. John Wiley and Sons, 2nd Edition, 1982.
11. Hemphill, M., 1996. A note on adults' colour–emotion associations, *The Journal of Genetic Psychology*, **157** (3), 275-280.
12. Elliot, A.J., and Maier, M.A., 2007. Colour and psychological functioning, *Current Directions in Psychological Science*, **16** (5), 250-254.
13. Camgöz, N., Yener, C. and Güvenç, D., 2002. Effects of hue, saturation, and brightness on preference, *Color Research and Application*, **27** (3), 199-207.
14. McManus, I.C., Jones, A.L. and Cottrell, J., 1981, The aesthetics of colour, *Perception*, **10**, 651-666.
15. Hurlbert, A. and Ling, Y., 2007. Biological components of sex differences in color preference, *Current Biology*, **17** (16), R623-R625.

16. Tao, L., Westland, S. and Cheung, V., 2011. Blackness: preference and perception, *Proceedings of the IS&T/SID's Nineteenth Color and Imaging Conference*, 270-275, San Jose, USA.
17. Choungourian, A., 1969. Color preferences: A cross-cultural and cross-sectional study. *Perceptual and Motor Skills*, **28** (3), 801-802.
18. Ares, G. and Deliza, R., 2010. Studying the influence of package shape and colour on consumer expectations of milk desserts using word association and conjoint analysis, *Food Quality and Preference*, **21** (8), 930-937.
19. Osgood, C.E., Suci, G.J. and Tannenbaum, P.H., 1957. The Measurement of Meaning. Urbana: University of Illinois Press.
20. Won, S., 2016. PhD Thesis, *University of Leeds*.
21. Grieve, K.W., 1991. Traditional beliefs and colour perception, *Perceptual and Motor Skills*, **72**, 1319-1323.
22. Ou L, Luo MR, Woodcock A, Wright A., 2004c. A study of colour emotion and colour preference. III. Colour preference modelling, *Color Research and Application*, **29**, 381–389.
23. Kress, G. and Van Leeuwen, T., 2002. Colour as a semiotic mode: notes for a grammar of colour, *Visual communication*, **1** (3), 343-368.
24. Scott-Kemmis, J., 2013. Target Markets – Using color psychology to attract your target markets. http://www.empower-yourself-with-color-psychology.com/target-markets.html
25. Madden, T. J., Hewett, K., & Roth, M. S. (2000). Managing images in different cultures: A cross-national study of color meanings and preferences, *Journal of international marketing*, **8** (4), 90-107.
26. Schloss, K.B. and Palmer, S.E., 2011. Aesthetic response to color combinations: Preference, harmony, and similarity, *Attention, Perception, & Psychophysics*, **73**, 551–571.
27. Li, D. 2017, Private Communication.
28. Pan. QQ and Westland, S., 2018. Comparative evaluation of color differences between color palettes, in *Proceedings of the IS&T/SID's Twenty-Sixth Color and Imaging Conference*, 110-115, Vancouver, Canada, Society for Imaging Science and Technology.
29. Lindner, A. and Süsstrunk, S., 2013. Automatic color palette creation from words, in Proceedings of the Twenty-Third Color and Imaging Conference, pp. 69-74, Society for Imaging Science and Technology.
30. Murray, N., Skaff, S., Marchesotti. L., Perronnin. F., 2012. Toward automatic and flexible concept transfer, *Computers & Graphics*, **36** (6), 622-634.

Author Bios

Yun Chen is a second-year PhD student of colour design at the University of Leeds (UK). Her research topic is about colour meanings.

Jie Yang is a second-year PhD student of School of Design at the University of Leeds (UK). Her research is about generating colour palettes from landscape images.

Qianqian Pan is Senior Research Fellow in the School of Design at the University of Leeds. Her research interests are colour appearance, colour measurement, psychophysical methods and computational aspects of colour.

Marjan Vazirian received her PhD in display colour characterisation from the University of Leeds. Since then she has worked as a Research Fellow in the colour and imaging group in the University of Leeds in colour science.

Stephen Westland is Professor of Colour Science and Technology at the University of Leeds (UK). His research interests include colour measurement, colour imaging, colour design and data-driven design.