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The multiple characteristics of specific associations from words to colours

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Abstract

This study mainly focused on exploring the multiple characteristics of specific associations from words to colours. Colour association is bidirectional, representing the relationship from colour to concept or concept to colour. The association between word and colour has multiple correspondences in both directions. Colours are associated with ideas, concepts, meanings, emotions and so on. However, it is often discussed as a single relationship from colour to the concept. How the specific ideas or concepts associated with colour, is rarely discussed. So, this work started from a specific concept (words) to colours and then investigated the characteristics of this association. A psychophysical experiment was carried out to collect the specific colour associations from target words. Pearson Correlation Coefficient and K-Means Clustering methods were employed to analyse the associations from words to colours. Therefore, the main contribution of this study is to 1) indicate the stronger association from the word to colour, the larger the colour similarity of the related colours; 2) identify the specific characteristic of the association from a word to colours and the three-aspect characteristic model was summarised.

1 Introduction

A wealth of literature has explored the character of associations from colour to concept or specific words. Cherry[1] has explored links between colour and mood. Cool colours are linked with calm, serene and comfort. Conversely, warm colours are relevant to stressful and exciting moods. Hemphill[2] showed that bright colours are linked with positive emotions like happiness, joy and hope. Likewise, Elliot and Maier[3] consider brighter colours as friendly, cultured, pleasant and beautiful. Conversely, dark colours

are associated with negative concepts such as boredom and sadness[4]. It is clear that colours generate associations and responses with concepts[3]. However, the characteristic of the link from word to colour is an exciting topic waiting to be explored.

As the previous studies presented, colours are associated with ideas, concepts, meanings, emotions, and so on[5]. Moreover, the colour associated is often discussed as a single relationship which is from colours to concepts, such as colour emotion and colour meaning[6,7,8]. However, the colour association is bidirectional, representing the relationship from colour to concept or concept to colour, due to the essential meaning of the term 'association'[9]. It is noticed the associations 'colour to concepts' or 'concept to colour' is different. For example, melancholy is often associated with the colour blue[10]; but the colour blue is generally associated with trust or loyalty.

However, relatively little research has been carried out on colour associations from concepts to colours. Despite this, a wealth of literature has explored the associations from colour to concepts. Significant contributions have been made by Xin et al.[11] and by Ou et al.[6,7,8] in several experiments that typically have used semantic differential scaling or categorical scaling as investigative techniques. With these methods, participants are shown colours (either physical samples or colours on screen). They are asked to indicate the strength of the association of the colour regarding two bi-polar terms (such as maleness and femaleness) in the case of semantic differential scaling or the strength of the association with a single term (such as maleness) using a fixed-number discrete scale in the case of categorical scaling. Whilst these methods provide valuable data and have produced some models that allow the associations of any colour to be determined (concerning the limited number of terms used in the experiments), they are not easy to apply in a design context. A mature intimate association from concepts to colours can significantly optimise the design and creation process.

To address this issue, colour association research from concepts to colour is imperative. The specific characteristics of the association from adjectives to colours are now explored further in this study. An experimental methodology was carried out[12] to study associations from specific words to colours that start with a word and asked participants to select colours associated with this word. A K-means clustering method is employed in this study to analyse the characteristics of the associated colours for each word.

2 Research Objective and Questions

This study mainly focused on exploring the characteristics of the associations from words to colours. One main research question and two sub-research questions are considered (see Table 1). The research objectives are summarised according to the research questions:

- To explore a measurement method of the characteristics of associations;
- To gather the specific characteristic of the association from a word to colours.

Table 1 Research questions for this study

Main research question	***Sub-research questions***
RQ: Are there significant characteristics in the associations from word to colour?	**RQ**1.1: How to measure the characteristic of associations from word to colour?
	RQ1.2: What are the characteristics of the associations between words and colours?

3 Method

A psychophysical experiment was conducted, which started with a word and asked participants to select colours that were associated with this word. This novel approach is an efficient and practicable way to explore word-->colour associations. Several studies have previously been carried out using this methodology to collect data about colour associations from word to colours[12,13].

3.1 Target Words Selection

In this study, in consideration of the motivation of participants and the experimental length, 30 target words were selected and provided for participants as prompts for choosing colours. In the previous study[13], it has been assumed that words are associated with colours, and adjectives associated with colours are stronger than others. Besides, the function of an adjective is to modify a noun, which is a similar relation between colour and production. The link between the adjective and colour could reflect more preferences or feelings from people. Based on the findings, the 30 target words were all adjectives in the experiment. The 30 adjectives chosen were the most frequent words from the word frequency websites: http://www.wordfrequency.info/ (see Table 2).

Table 2 Sample words list

Number	***Words***	***Number***	***Words***	***Number***	***Words***
1	Active	**11**	Good	**21**	Poor
2	Bad	**12**	Healthy	**22**	Powerful
3	Clean	**13**	Hot	**23**	Religious

4	Cold	**14**	Lucky	**24**	Rich
5	Cultural	**15**	Male	**25**	Safe
6	Dangerous	**16**	Married	**26**	Sweet
7	Dead	**17**	Medical	**27**	Traditional
8	Female	**18**	Modern	**28**	Unlucky
9	Fresh	**19**	Natural	**29**	Urban
10	Future	**20**	Old	**30**	Young

3.2 Participants

Due to the laboratory experiment's actionability, 30 participants were recruited for this study (15 females and 15 males; students or staff at the University of Leeds and of various nationalities), all aged above 18 with normal colour vision. The research purpose was briefly explained to each participant when they were recruited.

3.3 Experimental Procedure

The experiment took place in the Experience Design Laboratory at the School of Design (University of Leeds) with controlled viewing conditions, lighting conditions and display technology. The viewing distance was about 40 inches from the observers' eyes to the display. All observers had a Colour Blindness Test before the experiment started: RR Pseudoisochromatic Test[17]. This method is consisted of plates where patterns located on. Each plate consists of a circle formed by different sizes and colours of circular dots. Figures or numbers are made up of dots of different colour from the background.

Colour palettes were displayed on an LED computer monitor (HP DreamColor LP2480zx—a 24-in. LCD Backlit Monitor) and viewed; a uniform grey (L*=50) was used as the background. The words were presented individually (and in a different random order for each participant) on the computer monitor. There were three buttons below each word; participants could select a colour from a colour picker tool by clicking each. The participants were asked to select the most related colour first, then choose another two colours related to the word (note, however, that participants could select the same colour in all three selections if they preferred).

In total, 2700 colours or RGB combinations (30 participants x 30 words x 3 colours) were selected by the participants; each of these was subsequently measured three times using a Konica Minolta CS-2000 spectroradiometer after the experiment. The spectroradiometer measured spectral radiance at each wavelength, and these data were

converted to CIELAB values (regarding the white display point: CIE x = 0.3116, y = 0.3184) using standard methods[14]. The average of three measurements value will reflect the specific colour participants chosen.

3.4 Data Analysis Method

This study employed two data analysis methods: Pearson Correlation Coefficient (PCC)[15,16] and K-Means Clustering Analysis.

3.4.1 Pearson Correlation Coefficient (PCC)

Pearson Correlation Coefficient (PCC)[15,16] was introduced in the previous study to measure the colour linear relationship within a colour palette. In this experiment, each word was asked to select a most related colour and another two; thus, for each word, there were two colour palettes after the experiment, which are *the most related colour palette* and *the other two colours palette*. The PCC method was employed to measure the self-similarity of the palettes for each word to compare the extent of colour similarity between the most related colour palette and the other two colour palettes. This method is used to measure the direction and the strength of the linear relationship between two variables which is the covariance of variables (x, y) divided by the product of the standard deviations.

3.4.2 K-Means Clustering Analysis

K-Means Clustering Analysis is used to explore the specific characteristic of associations from word to colour. Cluster analysis is a mathematical technique that can find the centres or representative points of clusters in data and is illustrated schematically. This cluster method can be applied to data with more than 2-dimensions; for example, in this study, the data are 3-dimensional because three numbers (CIELAB L*, a* and b*) define each colour patch in each colour palette. K-Means Clustering partition data into k mutually exclusive clusters to present the characteristics of the objects.

For each word, a colour palette of 90 colour patches (30 participants x 3 colours) was collected (in the case where all three selected colours were considered). K-Means Clustering was carried out to partition all the colour patches into several exclusive clusters and identify the centroids representing this palette's characteristic. The analysis follows three steps:

1) All the colour data are organised into different colour palettes by each word. 30 colour palettes of 90 patches were collected, each corresponding to one of the 30 target words. For each palette, the colour patches were defined in CIELAB space.

2) Determining the correct number of clusters for each palette.

Every colour palette was divided into a different number of clusters. A silhouette value was used to analyse the results of different k-means clustering solutions. The silhouette represents how close each point in one cluster is to points in the neighbouring clusters. To compare the performance of the different number of clusters, the mean silhouette values of each cluster were collected. The larger the value, the better performance of this number of clusters. For example, the plot (Figure 2) shows that the highest silhouette value occurs at 2 clusters, suggesting that the optimal number of clusters is 2.

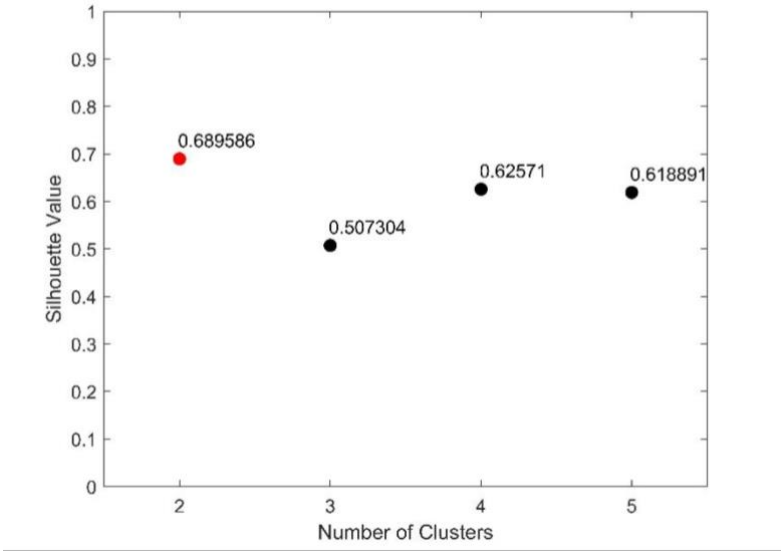
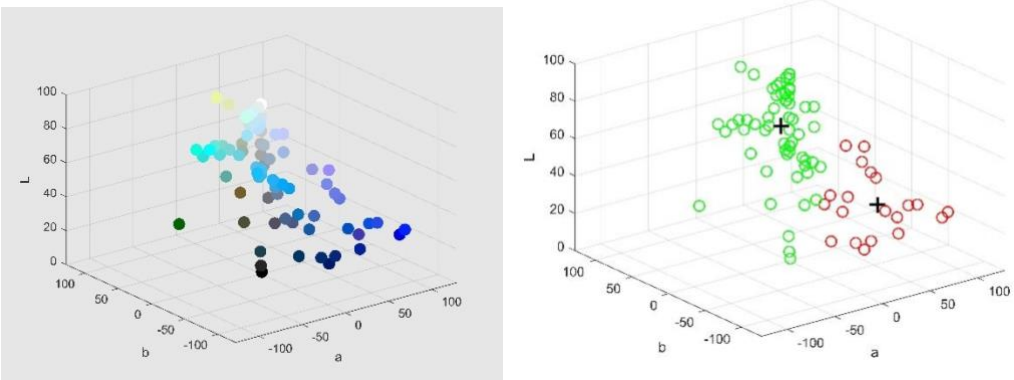


Figure 2 It shows the highest silhouette value occurs at 2 clusters, suggesting that the optimal number of clusters is 2

3) Analysis of the characteristic of each palette by K-Means Clustering.

In step 1, all the colour patches of a palette were defined in CIELAB space (Figure 3 a), and the optimal number of clusters was calculated in step 2. In this step, all the colour patches were partitioned into several excursive clusters and centroids were identified for each cluster (Figure 3 b).



(a) (b)

Figure 3 (a) All the colour patches of a palette were pointed in CIELAB space; (b) They were partitioned into 2 excursive clusters and the centroids of each cluster were presented by '+'.

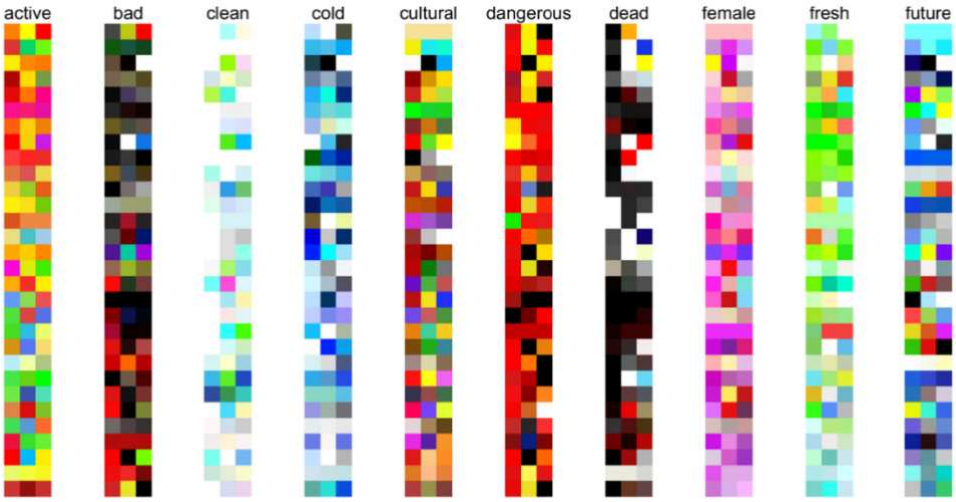
To analyse the characteristics of a specific palette, the number of clusters and the weight of each cluster were collected:

- **The number of clusters** represents the colour distribution of a palette, and it indicates how many main colour clusters are within this palette. For instance (Figure 6-5), this palette has two main colour clusters, which means that this word is associated with two main colour categories.
- **The weight of each cluster** represents the colour tendency of a palette. A considerable weight for a colour cluster means apparent colour tendency within a palette, indicating a specific colour tendency associated with the word.

Therefore, for each colour palette, the related colour distribution and related colour tendency were obtained to obtain the specific characteristic of the association.

4 Results and Analysis

All the data from thirty participants were organised into 30 colour palettes for every 30 words (Figure 4). Note, in each palette, the first column corresponds to the most related colours; the other two columns correspond to the other two related colours.



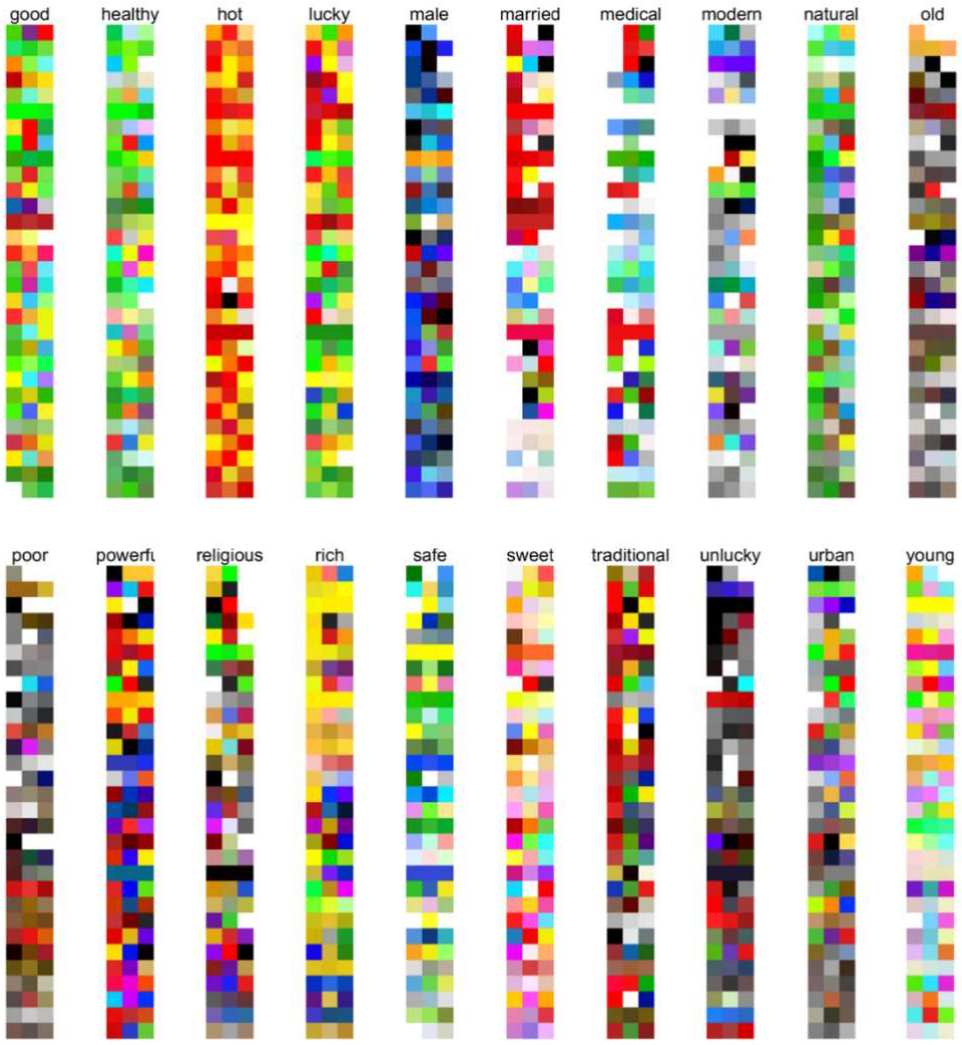


Figure 4 The presenting visual data of each word. In each palette. The first column corresponds to the most related colours; the left two columns correspond to the other two related colours.

4.1 Colour similarity comparison

In the experiment, each word was asked to select a most related colour and another two; thus, for each word, there were two colour palettes after the experiment which is *the most related colour palette* (Palette 1) and *the other two related colours palette* (Palette 2). The self-colour similarity of both palettes for each word was measured by PCC values (Table 3) for the most-related colour (Palette 1) and for the other two related colours (Palette 2).

Table 3 The self-colour similarity of each palette by PCC values.

Word	Palette 1*	Palette 2*	Word	Palette 1	Palette 2

Active	0.74	0.73	***Married***	0.74	0.73
Bad	0.74	0.64	***Medical***	0.81	0.74
Clean	0.93	0.85	***Modern***	0.74	0.72
Cold	0.76	0.75	***Natural***	0.89	0.70
Cultural	0.67	0.63	***Old***	0.73	0.70
Dangerous	0.90	0.66	***Poor***	0.74	0.65
Dead	0.88	0.73	***Powerful***	0.68	0.63
Female	0.76	0.67	***Religious***	0.64	0.66
Fresh	0.82	0.77	***Rich***	0.86	0.68
Future	0.63	0.68	***Safe***	0.68	0.64
Good	0.84	0.77	***Sweet***	0.65	0.64
Healthy	0.87	0.71	***Traditional***	0.79	0.68
Hot	0.72	0.72	***Unlucky***	0.70	0.69
Lucky	0.83	0.80	***Urban***	0.73	0.64
Male	0.73	0.64	***Young***	0.62	0.67

Only 3 words have less the PCC value of Palette 1 compared with the value of Palette 2.

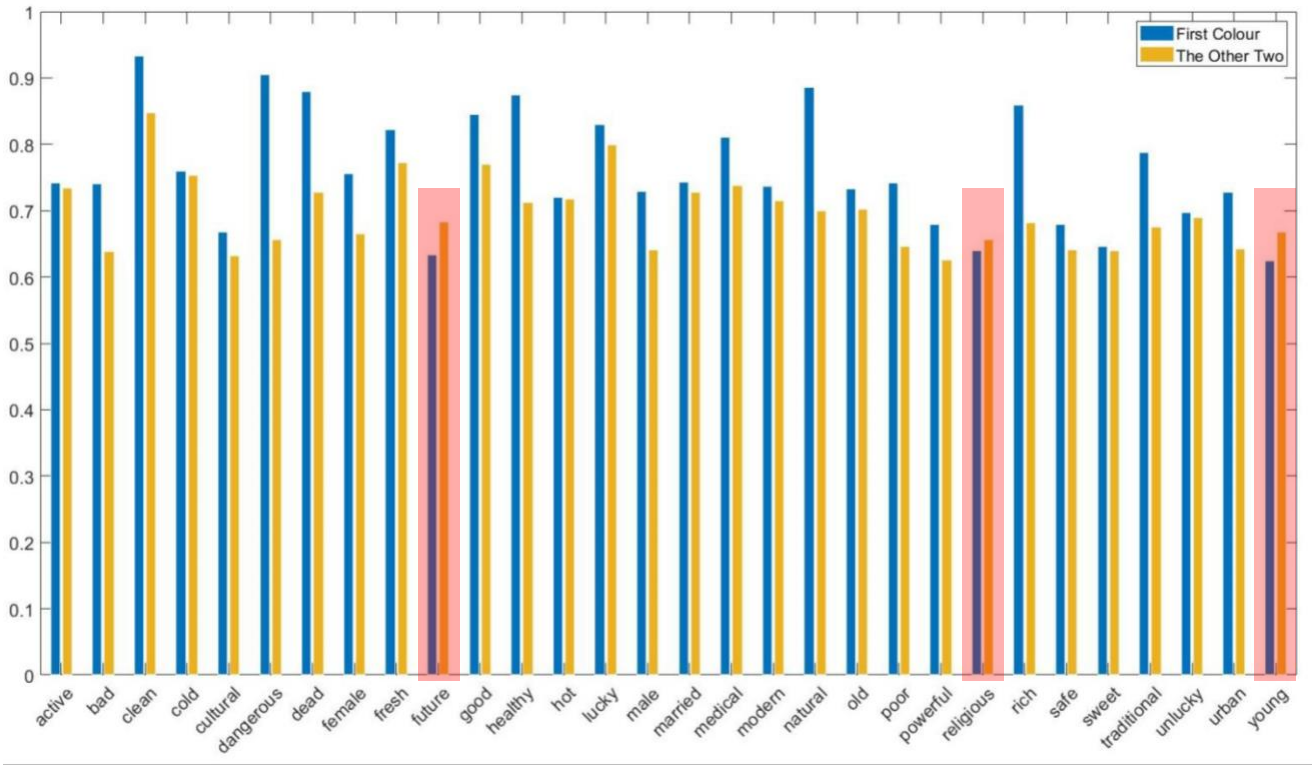
**Palette 1: the most related colour palette;*

Palette 2: the other two related colour palettes.

The PCC value is larger, the higher correlation and the larger similarity of the palette. For most of the words (90%), the similarity value of Palette 1 is larger than Palette 2; in only three cases, the similarity value of Palette 1 is less than Palette 2, marked in the table. A histogram (Figure 5) was carried out to present a clear visual comparison between each set of Palette 1 and Palette 2. It is obvious that, for many cases, the colour similarity value of Palette 1 is much larger than Palette 2 (such as 'clean', 'dangerous', 'dead', 'natural' and 'rich'). On the contrary, in the three exceptional cases (marked by

red colour in the figure), the colour similarity value of Palette 1 is slightly less than Palette 2. Therefore, this result indicated that the colour of the most related colour palette is more similar to the other two related colours palette for most of the words (90%).

Figure 5 The comparison between each set of Palette 1 and Palette 2.



For each word, the right column corresponds to the colour similarity value of Palette 1; the left column corresponds to the colour similarity value of Palette 2.

4.2 The characteristic of associations

In this part, K-Means Clustering Analysis was employed to explore the specific characteristic of the associations from word to colour. The most related colour and the other two related colours were organised into a single palette for each word. Thus, 90 related colour patches were collected from each palette for each word. Each palette was analysed by K-Means Clustering to partition each of 90 colour patches and collect the characteristic. For instance, the analysis of the first word - 'active'- is presented (Figure 6).

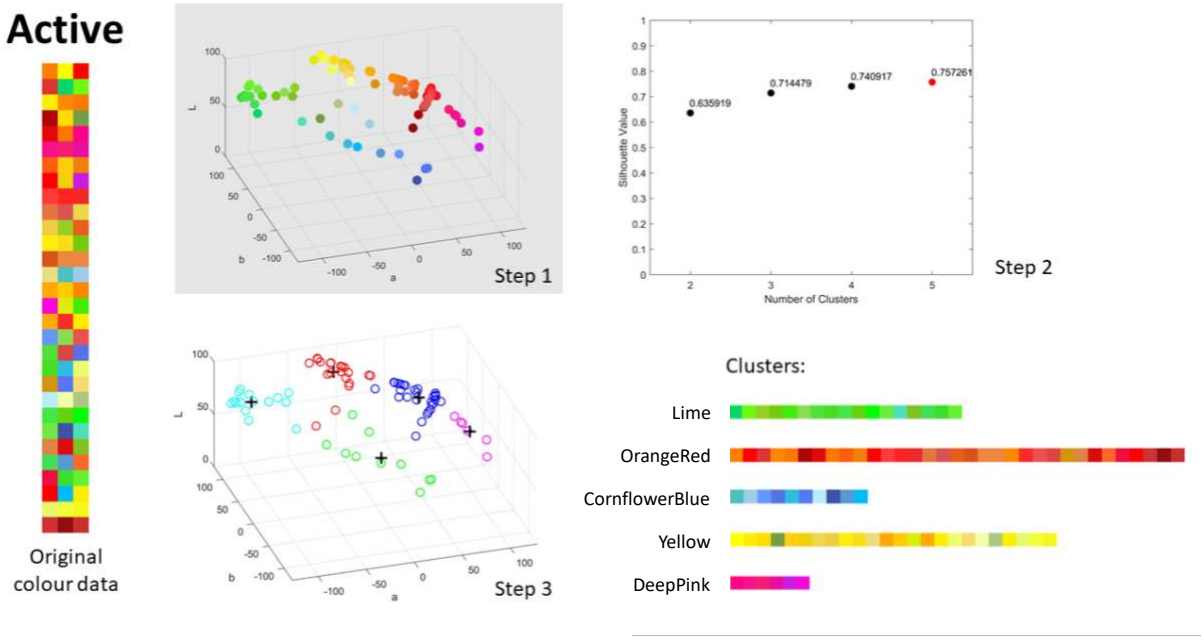


Figure 6 The analysis process of 'active'.
***Step 1**: 90 related colour patches of 'active' were pointed in CIELAB space;*
***Step 2**: highest silhouette value occurs at 5 clusters, suggesting that the optimal number of clusters is 5;*
***Step 3**: 90 colours were partitioned into 5 clusters. The weight of each cluster was collected (Table 4).*

Table 4 The description of all clusters for 'active'

Active					
	Lime Cluster	***OrangeRed Cluster***	***CornflowerBlue Cluster***	***Yellow Cluster***	***DeepPink Cluster***
Colours:	17	33	10	24	6
Weight:	0.189	0.367	0.111	0.267	0.067

To summarise the characteristic of the association for 'active', the number of clusters and the weight of each cluster were collected (Table 4):

- **Related Colour distribution:**

In this palette, there are 5 colour clusters. Thus, 'active' is associated with 5 main colour categories in this study.

- **Related colour tendency:**

The weights of each cluster were collected. The largest weight of the clusters is Cluster 2 (33 colours and a weight of 0.367), which means the obvious colour tendency of this palette is red and orange colours. It indicates that 'active' is closely associated with red and orange colours.

Each colour palette of each word was analysed following this process one by one. The related colour distribution and related colour tendency were collected as the specific

characteristics of each association from word to colour in this study. All the results of 30 words were presented in Table 5.

Table 5 The description of clusters for each word.

Word		Clusters				
Active	N=5	***OrangeRed Cluster***	***Lime Cluster***	***CornflowerBlue Cluster***	***Yellow Cluster***	***DeepPink Cluster***
	Weight:	0.189	0.367	0.111	0.267	0.067
Bad	N=4	***Black Cluster***	***MediumBlue Cluster***	***Red Cluster***	***OliveDrab Cluster***	
	Weight:	0.222	0.189	0.533	0.056	
Clean	N=2	***LightCyan Cluster***	***Lime Cluster***			
	Weight:	0.911	0.089			
Cold	N=2	***BlueViolet Cluster***	***SkyBlue Cluster***			
	Weight:	0.767	0.233			
Cultural	N=5	***Gold Cluster***	***Gray Cluster***	***Red Cluster***	***DarkOrchid Cluster***	***LimeGreen Cluster***
	Weight:	0.167	0.322	0.267	0.122	0.122
Dangerous	N=4	***Black Cluster***	***Yellow Cluster***	***Red Cluster***	***DarkSlateGray Cluster***	
	Weight:	0.644	0.144	0.200	0.011	
Dead	N=5	***AliceBlue Cluster***	***Black Cluster***	***Red Cluster***	***MediumBlue Cluster***	***Gold Cluster***
	Weight:	0.278	0.600	0.022	0.022	0.078
Female	N=3	***Magenta Cluster***	***PeachPuff Cluster***	***Tomato Cluster***		
	Weight:	0.411	0.467	0.122		
Fresh	N=3	***PaleTurquoise Cluster***	***Cyan Cluster***	***Orange Cluster***		
	Weight:	0.122	0.489	0.389		
Future	N=4	***DarkTurquoise Cluster***	***Lime Cluster***	***OrangeRed Cluster***	***BlueViolet Cluster***	
	Weight:	0.544	0.067	0.256	0.133	
Good	N=5	***OrangeRed Cluster***	***Cyan Cluster***	***LimeGreen Cluster***	***DarkOrchid Cluster***	***Gold Cluster***
	Weight:	0.356	0.189	0.233	0.067	0.156
Healthy	N=3	***LimeGreen Cluster***	***LightSteelBlue Cluster***	***Orange Cluster***		
	Weight:	0.300	0.178	0.522		
Hot	N=3	**OrangeRed Cluster**	**Gold Cluster**	**Tan Cluster**		
	Weight:	0.056	0.633	0.311		
Lucky	N=4	***Orchid Cluster***	***LimeGreen Cluster***	***Yellow Cluster***	***OrangeRed Cluster***	
	Weight:	0.267	0.100	0.233	0.400	
Male	N=5	***LimeGreen Cluster***	***CornflowerBlue Cluster***	***Blue Cluster***	***DarkOrange Cluster***	***Maroon Cluster***
	Weight:	0.322	0.067	0.289	0.233	0.089
Married	N=5	***Black Cluster***	***Violet Cluster***	***Azure Cluster***	***Red Cluster***	***GreenYellow Cluster***
	Weight:	0.311	0.389	0.144	0.100	0.056

Medical	N=4	***LightBlue Cluster***	***Blue Cluster***	***LimeGreen Cluster***	***Red Cluster***	
	Weight:	0.556	0.056	0.211	0.178	
Modern	N=5	***BlueViolet Cluster***	***LimeGreen Cluster***	***LightBlue Cluste***	***MidnightBlue Cluster***	***Orange Cluster***
	Weight:	0.578	0.100	0.111	0.111	0.100
Natural	N=2	***LimeGreen Cluster***	***DarkGray Cluster***			
	Weight:	0.567	0.433			
Old	N=5	***FireBrick Cluster***	***Silver Cluster***	***Indigo Cluster***	***DarkRed Cluster***	***Goldenrod Cluster***
	Weight:	0.067	0.367	0.089	0.078	0.400
Poor	N=4	***Chocolate Cluster***	***Gainsboro Cluster***	***SaddleBrownCluster***	***Indigo Cluster***	
	Weight:	0.222	0.511	0.211	0.056	
Powerful	N=5	***Gold Cluster***	***DarkViolet Cluster***	***Red Cluster***	***DarkSlateBlue Cluster***	***Lime Cluster***
	Weight:	0.211	0.156	0.233	0.367	0.033
Religious	N=5	***Gold Cluster***	***DarkOrchid Cluster***	***Gray Cluster***	***FireBrick Cluster***	***Lime Cluster***
	Weight:	0.178	0.144	0.067	0.167	0.444
Rich	N=2	***Gold Cluster***	***FireBrick Cluster***			
	Weight:	0.722	0.278			
Safe	N=4	***SlateBlue Cluster 1***	***Yellow Cluster***	***LimeGreen Cluster***	***LightBlue Cluster***	
	Weight:	0.189	0.378	0.278	0.156	
Sweet	N=4	***Gainsboro Cluster***	***OrangeRed Cluster***	***Violet Cluster***	***Yellow Cluster***	
	Weight:	0.311	0.244	0.267	0.178	
Traditional	N=5	***Red Cluster***	***MediumBlue Cluster***	***LimeGreen Cluster***	***Gray Cluster***	***Gold Cluster***
	Weight:	0.100	0.367	0.100	0.089	0.344
Unlucky	N=3	***DimGray Cluster***	***Red Cluster***	***BlueViolet Cluster***		
	Weight:	0.733	0.178	0.089		
Urban	N=4	***BlueViolet Cluster***	***Lime Cluster***	***DarkOrangeCluster***	***Gray Cluster***	
	Weight:	0.133	0.133	0.189	0.544	
Young	N=4	***Gold Cluster***	***PaleTurquoise Cluster***	***Violet Cluster***	***Lime Cluster***	
	Weight:	0.122	0.233	0.433	0.211	

**N: the number of clusters;*
Weight: the weight of each cluster in the palette.

From this analysis, two main characteristics of associations from word to colour were summarised:

1) Related colour distribution of words:

The related colours have different numbers of the colour cluster for different words.

Some words are associated with two main colours (such as 'clean', 'cold', 'rich'); some words are associated with three main colours (such as 'female', 'fresh', 'health'), and some words associated with more main colours (such as 'active', 'cultural', 'dead').

2) Related colour tendency of words:

Different words are associated with different colour tendencies. It could divide into two categories by the weight of each cluster: a word have a single colour tendency of the associated colours (one cluster presents a much larger weight than other clusters); a word has several colour tendencies of associated colours (more than one clusters present a much larger weight than others). For example, the words' dead' and 'modern', they associated with a single colour tendency obviously; on the contrary, 'female' and 'fresh', they associated with more than one colour tendency (Figure 7).

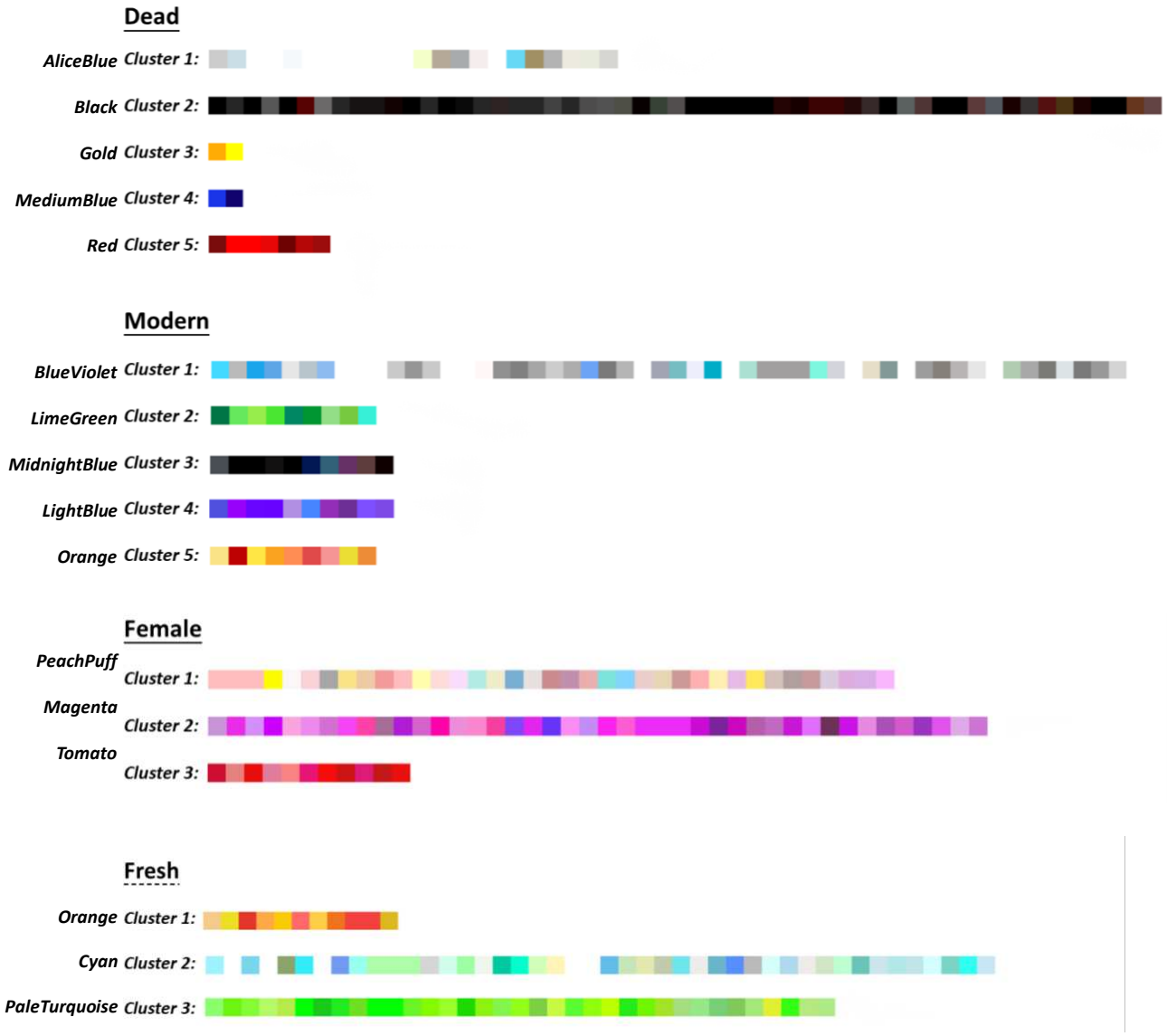


Figure 7 The clusters of 'dead', 'modern', 'female' and 'fresh'. The words' dead' and 'modern', they associated with a single colour tendency obviously; on the contrary, 'female' and 'fresh', they associated with more than one colour tendency;

5 Discussion and Conclusion

The main contribution of this study is to explore the specific characteristic of the association from a word to colours, identified and summarised the main the characteristics of the associations from word to colour. A psychophysical experiment was employed to collect data on word and colour associations.

First, this work indicated and evident the basic characteristic of work to colours associations: the stronger association from the word to colour, the larger the colour similarity of the related colours. The results of each word collected the most-related colour (Palette 1) and for the other two related colours (Palette 2). Note, the subjective strength of the association between each set of Palette 1 and Palette 2 is obtained: the participants were asked to select a most related colour and another two related colours. For each word, the strength of association for Palette 1 is stronger than for Palette 2. Thus, it is reasonable to consider that: the relational degree from word to colours, corresponds to the related colour similarity.

Then, an analysis method was introduced to investigate the specific characteristics of the associations from word to colours, and *Three-Aspect Characteristic Model* were summarised based on this study (Table 6):

Table 6 The characteristic of the associations from word to colour modelling.

Three-Aspect Characteristic Model
• ***The extent of the association***   *The stronger association from the word to colour, the larger the colour similarity of the related colours.*
• ***Related Colour distribution of words***   *For different words, the related colours have a different number of colour clusters.*
• ***Related colour tendency of words***   *Different words are associated with different colour tendencies. These can be divided into two categories by the weight of each cluster:*   *-words that have a single associated colour;*   *-words that have several associated colours.*

An analysis method of the associations was introduced, based on K-means clustering. This method applies not only to the sample words in this study but also to any other

words to investigate the specific characteristic of the associations from word to word colour. In this study, the experiment only used 30 sample words. However, the conclusion of characteristic categorising and the three-aspect model was also practicable for any other words in the related research. This work presents a meaningful and clear method of analysis of the associations from words to colours. It is also hoped that this work could attract more attention to the colour association discussion, especially the colour association from concept to colour.

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