Colour Emotion and Product Category

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Abstract: Colour emotion has been of interest in various areas and there have been fruitful research outcomes. However the existing studies have focused on the fundamental aspect of colour emotion, using context-less colour patches as the stimuli in the psychophysical experiments. It is unclear whether the results from such experiments can also apply to real-world product design. Thus, the present study aims to investigate colour emotion in various categories of product design, including food, clothing, housing and transportation. Images of these four categories, each manipulated in colour, were presented as the stimuli in a psychophysical experiment using the categorical judgement method. The experimental results show that the food images had the most different trend than the other product categories in terms of colour emotion responses, especially the like/dislike response. Hierarchical clustering based on colour preference data reveals 2 main clusters in terms of product category, clothing/food and housing/transportation, suggesting a somewhat similarity in colour preference between clothing and food, and a similarity between housing and transportation.

Key words: Colour emotion, product category, psychophysical experiments

1. Introduction

Colour emotion has been referred to as a psychophysical research area that aims to investigate the relationship between colour and connotative meaning. Such a relationship is of interest to researchers as colour not only plays a significant role in global marketing communication, helps enhance brand recognition, and translates intended visual impressions into design elements of a product, it can also create desired atmosphere in a retail outlet and influence consumers' behaviour.

Most of existing studies of colour emotion, however, have focused on the use of contextless colour patches as stimuli in the experiments [1-5]. It was unclear, however, whether the results from such research could also apply to real-world product design. To address this issue, the present study looked into colour emotion in various contexts, in terms of 4 product categories, food, clothing, housing and transportation, which may reflect the most common daily activities.

2. Methods

To achieve the aims of the present study, a psychophysical experiment was carried out, using digital images of various product designs, rather than colour patches, as the stimuli. The digital images consisted of 4 product categories: food, clothing, housing and transportation. The 4 categories can reflect the most common daily activities. For each of the 4 categories, 2 product images were selected, resulting in 8 original product images: cupcake, cocktail, female T-shirt, male T-shirt, house exterior, house interior, car exterior and car interior. We used cupcake and cocktail images to represent liquid and solid foods. The female and male T-shirt images were used to see whether there is any gender difference. For the housing and transportation categories we used interior and exterior images so that we can compare whether there is any difference between the two conditions.

2.1 Colour emotion scales

The authors' previous colour emotion studies [1-3] used 10 bipolar semantic scales, also called "colour emotion scales" in this paper: warm/cool, heavy/light, modern/classical, clean/dirty, active/passive, hard/soft, tense/relaxed, fresh/stale, masculine/feminine, and like/dislike. These were the most frequently used scales in early studies. For consistency, and for comparing the present experimental results with the previous findings, the present study continued to use these 10 scales in the psychophysical experiment. Each scale consisted of 6 levels (or categories) of intensity. Taking warm/cool as an example, the 6 levels included "very warm", "warm", "a little warm", "a little cool", "cool" and "very cool".

2.2 Colour stimuli

To see whether and how product colours can affect the observer's affective responses, the experimental images were generated from the 8 original product images mentioned above, each manipulated by colour for the main part of the product in each image, using the Matlab software. The authors' previous colour emotion studies [1-3] used 20 colours, which were selected from the NCS Colour Atlas and covered a reasonable range of hue, lightness, and chroma in CIELAB colour space. These 20 colours were again used in the present study in order that the present experimental results can be compared with the previous findings. Table 1 summarises CIELAB values of the 20 colours. A total of 8 (original product images) x 20 (colours) = 160 test images were generated for use in the experiment, as shown in Figure 1.

Table 1. CIELAB specifications of the 20 colour samples used in this study

Sample	NCS notation	L^*	a*	b*	C^*_{ab}	h_{ab}
1	R-1080	45.9	61.7	29.1	68.2	25
2	Y-1070	84.8	6.3	82.0	82.3	86
3	G-2060	61.4	-49.7	17.8	52.8	160
4	R90B-3050	49.6	-8.9	-33.2	34.4	255
5	R70B-3060	38.0	13.8	-42.0	44.2	288
6	Y60R-5040	42.2	25.9	26.5	37.0	46
7	G80Y-4040	58.3	-3.2	40.3	40.4	94
8	B50G-5040	39.3	-28.2	-5.8	28.8	192
9	R70B-5030	41.4	5.0	-24.3	24.8	282
10	R-1020	84.7	17.1	5.6	18.0	18
11	Y-1030	89.0	1.6	39.4	39.4	88
12	B30G-1040	78.4	-26.7	-10.9	28.8	202
13	R60B-1040	74.0	11.3	-23.7	26.3	296
14	G50Y-4020	64.2	-8.2	19.0	20.7	113
15	B50G-5030	47.1	-22.0	-5.7	22.7	195
16	R50B-5020	49.8	10.8	-11.9	16.1	312
17	N-9000	15.7	0.3	-1.5	1.6	282
18	N-7000	43.2	0.3	0.2	0.4	37
19	N-3500	72.1	0.4	0.6	0.7	58
20	B-0502	97.7	-2.1	0.4	2.1	168

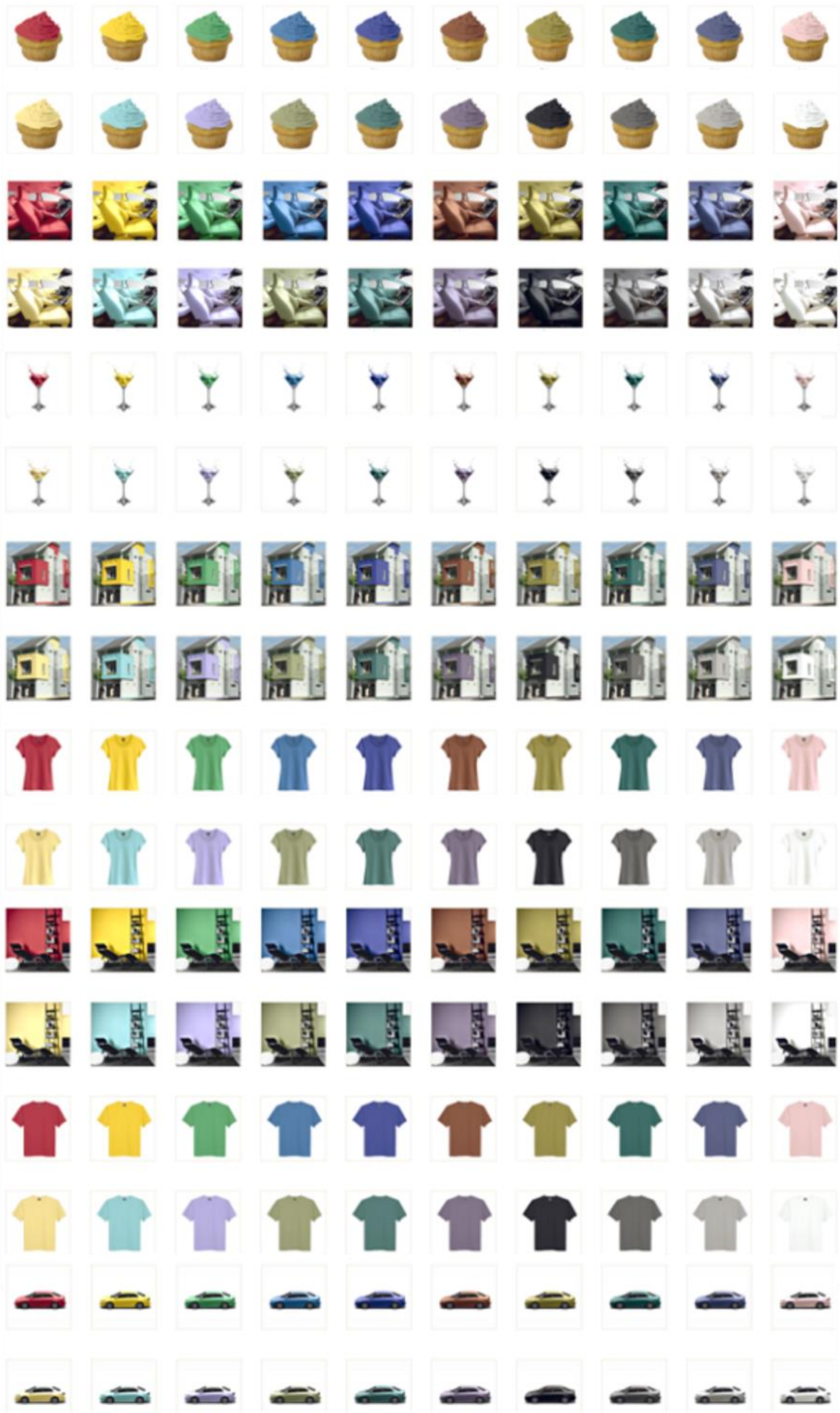


Figure 1. The 160 test images

2.3 Display

An Eizo ColorEdge CG241W liquid crystal display (LCD) calibrated by an i1 Display was used in this study to present the experimental images. The display was set to have the sRGB colour gamut. The display peak white had the correlated colour temperature of 6500K with a display luminance of 70 cd/m^2. During the experiment, the display was placed at a desk, situated in a darkened room. The only light source was the display itself, which shows the 160 test images, one at a time in random order.

2.4 Observers

Thirty observers, including 15 males and 15 females, took part in the experiment. All observers were at the age rage of 18 to 30 years and have passed Ishihara's test for colour deficiency. The observers were all citizens of Taipei, Taiwan, and were either staff members or students at the National Taiwan University of Science and Technology.

During the experiment, each observer was asked to sit in front of the experimental display, with a viewing distance of about 50 cm. Each observer rated the 160 test images using the 10 colour emotion scales. The categorical judgment method was used for data collection. All observers did the experiment twice so that a repeatability test can be performed.

3. Results

3.1 Data reliability

Two measures were used to examine the reliability of the experimental data: inter-observer variability and intra-observer variability. The former indicates how well the observers agreed with each other in terms of the visual responses. The inter-observer variability was determined by the Root Mean Square (RMS):

$$\mathrm{RMS} = \sqrt{\frac{\sum_i (x_i - \bar{x_i})^2}{N}} \quad (1)$$

where x_i represents an observer's colour emotion response to stimulus *i*; $\bar{x_i}$ represents the mean value by all observers for stimulus *i*; *N* is the total number of stimuli. The lower the RMS value is, the more closely the observers agreed with each other.

Intra-observer variability, on the other hand, is concerned with how repeatable each observer's response was. This was determined also by Eq. (1), with $\bar{x_i}$ being replaced by y_i, the response for stimulus *i* when presented for the second time. The lower the RMS value is, the more repeatable the observer's response.

Table 2 shows the results of inter- and intra-observer variability. As the table demonstrates, observers had the lowest inter-observer variability for tense/relaxed (1.64) and hard/soft (1.67). This suggests that the two scales, tense/relaxed and hard/soft, had the most consistent observer responses. In terms of intra-observer variability, on the other hand, heavy/light (1.42), clean/dirty (1.43) and warm/cool (1.46) are the lowest. The result suggests that observers' responses were most repeatable for heavy/light, clean/dirty and warm/cool.

Table 2. Inter-observer and intra-observer variability for this study

	Like/ dislike	Warm/ cool	Hard/ soft	Active/ passive	Clean/ dirty	Modern/ classic	Fresh/ stale	Feminine/ masculine	Heavy/ light	Tense/ relaxed
Inter-observer variability	1.83	1.71	1.67	1.83	1.79	1.71	1.80	1.82	1.78	1.64
Intra-observer variability	1.65	1.46	1.70	1.56	1.43	1.65	1.53	1.48	1.42	1.54

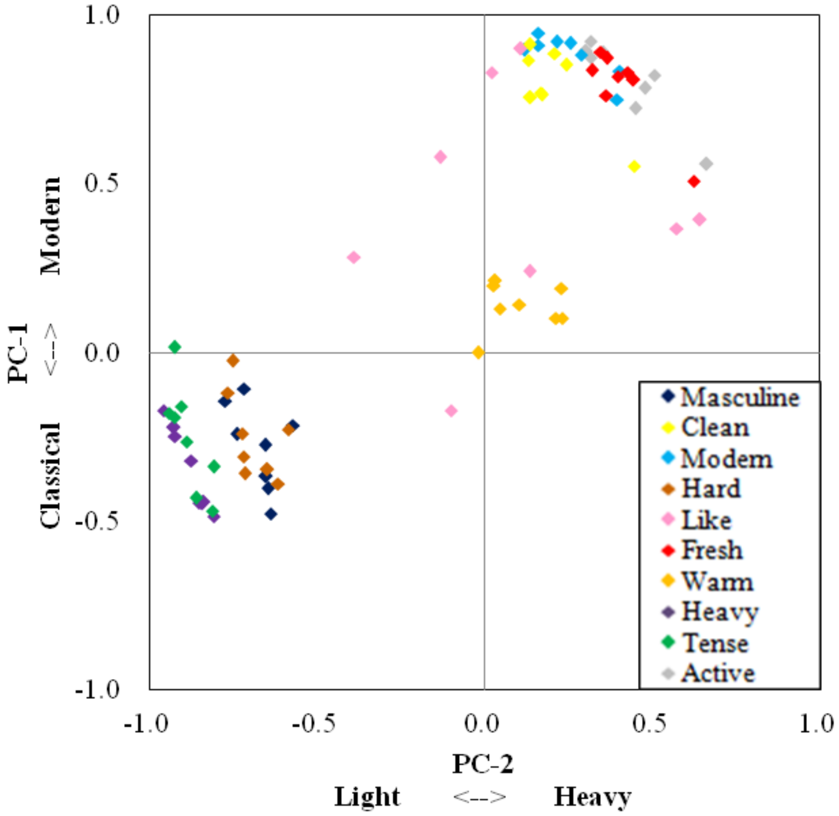
3.2 Principal component analysis

To investigate the interrelationship between observers' responses for the 10 colour emotion scales, based on the 8 product categories (i.e., 1: cupcake, 2: car interior, 3: car exterior, 4: cocktail, 5: house exterior, 6: female T-shirt, 7: house interior, 8: male T-shirt), principal component analysis was carried out using the SPSS statistical analysis software.

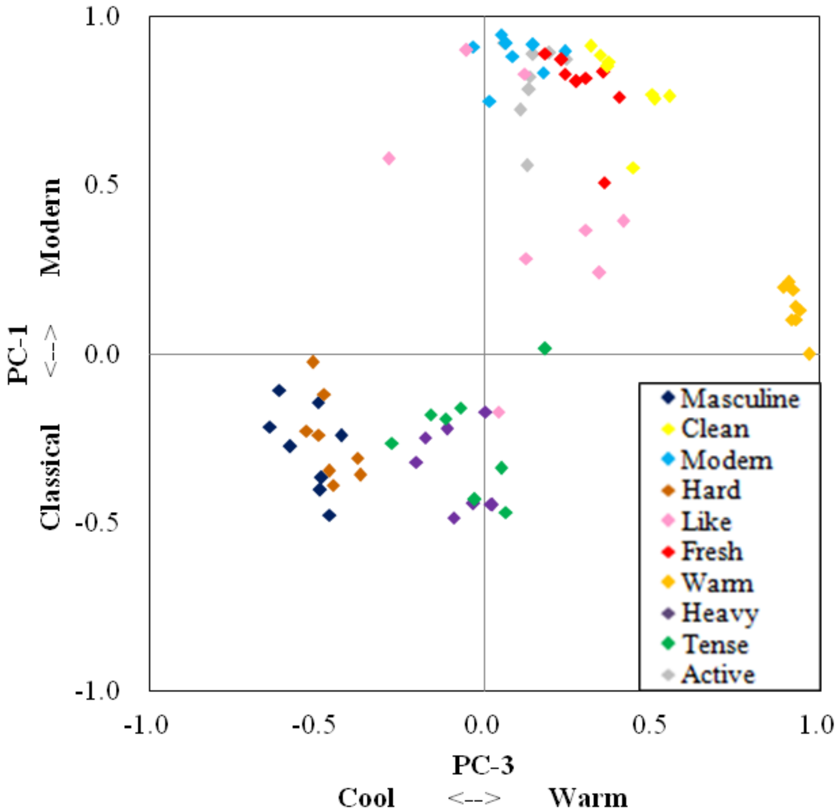
Table 3 shows component loadings of each color emotion scale for the three principal components extracted, "modern-ness", "weight" and "warmth", which accounted for 83.3% of the total variance. Figures 2 (a) and (b) illustrate the interrelationships between each scale on the basis of the component loadings shown in Table 3, with each coloured dot representing the observer response to test images. There are 80 coloured dots in either graph. Dots of the same colour represent the observer response for a specific colour emotion scale. For instance, the 8 orange dots represent the distribution of observer responses for the 8 product categories in terms of warm/cool.

Table 3. Principal component matrix of colour emotions scales used in this study (1: cupcake, 2: car interior, 3: car exterior, 4: cocktail, 5: house exterior, 6: female T-shirt, 7: house interior, 8: male T-shirt)

	PC-1 (modern-ness)	PC-2 (weight)	PC-3 (Warmth)
Modern_8	**.947**	.161	.051
Clean_5	**.922**	.317	.059
Modern_5	**.921**	.216	.065
Modern_6	**.917**	.256	.145
Active_5	**.913**	.135	.316
Modern_1	**.910**	.161	-.034
Like_8	**.901**	.109	-.054
Modern_7	**.897**	.119	.241
Clean_8	**.894**	.304	.194
Fresh_6	**.891**	.347	.182
Clean_6	**.890**	.354	.145
Active_6	**.886**	.210	.346
Modern_2	**.883**	.288	.084
Clean_7	**.875**	.318	.244
Fresh_5	**.873**	.365	.230
Active_8	**.867**	.130	.373
Active_1	**.852**	.244	.368
Fresh_3	**.837**	.321	.355
Modern_3	**.836**	.404	.174
Like_6	**.832**	.022	.121
Fresh_8	**.830**	.429	.240
Clean_1	**.823**	.508	.135
Fresh_2	**.819**	.399	.304
Fresh_1	**.809**	.445	.275
Clean_3	**.785**	.479	.133
Active_2	**.770**	.168	.501
Active_7	**.764**	.170	.552
Fresh_7	**.761**	.364	.402
Active_3	**.756**	.138	.507
Modern_4	**.749**	.396	.016
Clean_2	**.724**	.450	.106
Like_5	**.579**	-.132	-.287
Active_4	**.554**	.446	.446
Like_2	**-.172**	-.099	.042
Light_2	.172	**.958**	-.004
Relaxed_4	.180	**.943**	.162
Light_4	.222	**.928**	.112
Relaxed_2	-.016	**.927**	-.181
Relaxed_3	.192	**.926**	.117
Light_3	.248	**.925**	.178
Relaxed_7	.160	**.907**	.071
Relaxed_1	.264	**.889**	.276
Light_7	.320	**.875**	.202
Relaxed_6	.432	**.861**	.029
Light_5	.445	**.854**	-.019
Light_8	.448	**.846**	-.021
Light_6	.444	**.839**	.032
Relaxed_8	.471	**.813**	-.064
Relaxed_5	.339	**.809**	-.050
Light_1	.487	**.809**	.092
Feminine_2	.143	**.775**	.496
Soft_1	.120	**.766**	.478
Soft_2	.026	**.752**	.513
Feminine_3	.243	**.740**	.428
Soft_5	.239	**.723**	.496
Soft_6	.309	**.720**	.379
Feminine_4	.108	**.718**	.613
Soft_8	.359	**.717**	.372
Clean_4	.558	**.663**	.127
Feminine_8	.275	**.654**	.579
Feminine_5	.367	**.654**	.488
Soft_3	.347	**.648**	.464
Feminine_1	.404	**.646**	.492
Like_1	.394	**.643**	.414
Feminine_6	.478	**.638**	.463
Fresh_4	.509	**.625**	.358
Soft_4	.390	**.617**	.453
Soft_7	.229	**.586**	.532
Like_4	.369	**.574**	.303
Like_3	.283	**-.389**	.124
Warm_2	-.002	-.019	**.970**
Warm_8	.131	.046	**.944**
Warm_1	.103	.231	**.930**
Warm_6	.143	.105	**.928**
Warm_4	.190	.231	**.923**
Warm_7	.101	.214	**.916**
Warm_3	.213	.032	**.908**
Warm_5	.197	.028	**.893**
Feminine_7	.217	.573	**.641**
Like_7	.240	.135	**.343**



(a)



(b)

Figure 2. Principal component plots (a) PC-1 (modern-ness) versus PC-2 (weight) and (b) PC-1 (modern-ness) versus PC-3 (warmth). Each dot represents a product category.

The distance between any two dots of the same colour in the graph can be seen as the dissimilarity of the two product categories; the closer the two dots are located, the more similar the two product categories were rated by a specific colour emotion scale. For instance, all the 8 orange dots are located quite close to each other, indicating that in terms of warm/cool, the observer responses to the 8 product categories are quite similar. As the two graphs demonstrate, like/dislike is the only scale that show a wide spread of 8 dots (i.e. the 8 pink dots), suggesting a strong impact of product category on colour emotion for the like/dislike scale.

3.3 Correlation between like/dislike and other colour emotion scales

Table 4 shows correlation coefficients between like/dislike and the other colour emotion scales for each of the 8 product categories, indicating that different product categories had different key affective quality in association with liking. For instance, the liking for “cupcake” is highly correlated with feelings such as relaxed, light and feminine, while the liking for “female T-shirt” is correlated closely with feelings of clean, modern and active.

Note that the images that were selected originally on the basis of the same product category tend to have similar trends regarding the correlation coefficients. For instance, “cupcake” and “cocktail” are under the food category, and they both shows low correlation coefficients for modern and warm. On the basis of correlation coefficients shown in Table 4, hierarchical clustering was used to classify the 8 sets of experimental images. Figure 3 shows the dendrogram, indicating that images of the same product category are in the same cluster at the highest precision level. A coarser clustering shows that the 4 product categories can be divided roughly into two clusters, clothing/food and housing/transportation, suggesting a somewhat similarity in colour preference between clothing and food, and a somewhat similarity between housing and transportation.

Table 4. Correlation coefficients between like/dislike and the other colour emotion scales for each of the 8 image category

	Warm/ cool	Hard/ soft	Active/ passive	Clean/ dirty	Modern/ classic	Fresh/ stale	Feminine/ masculine	Heavy/ light	Tense/ relaxed
Cupcake	0.60	-0.66	0.65	0.71	0.34	0.70	0.83	-0.85	-0.86
Car interior	0.11	0.14	-0.01	0.16	-0.23	-0.21	0.02	-0.02	-0.07
Car exterior	0.26	0.19	0.37	0.28	0.17	0.25	-0.14	0.20	0.25
Cocktail	0.49	-0.76	0.76	0.79	0.47	0.76	0.65	-0.68	-0.71
House exterior	-0.10	0.01	0.40	0.50	0.37	0.41	0.02	-0.24	-0.18
Female T-shirt	0.29	-0.36	0.80	0.81	0.80	0.71	0.47	-0.44	-0.39
House interior	0.44	-0.32	0.42	0.45	0.29	0.32	0.31	-0.27	-0.15
Male T-shirt	0.06	-0.38	0.74	0.87	0.85	0.78	0.35	-0.57	-0.55

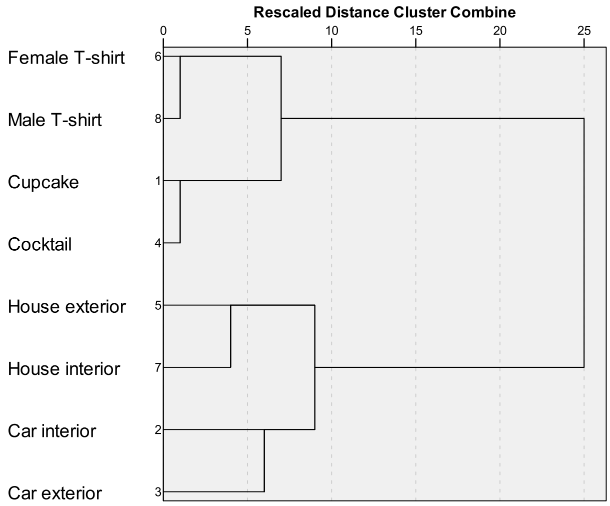


Figure 3. Hierarchical clustering dendrogram for the 8 image categories based on the correlation coefficients between like/dislike and the other scales (as shown in Table 4)

4. Conclusion

In this study, a psychophysical experiment was carried out to investigate the influence of product category on colour emotion. The principal component analysis shows that among the 10 colour emotion scales, only "like/dislike" shows a wide spread of data points in the principal component plot, indicating a strong impact of product category on colour preference for product images, as demonstrated in Figures 2 (a) and (b).

The relationships between colour preference and the other colour emotion scales were studied using the experimental images. Figure 3 illustrates that product category again has a strong impact on the hierarchical clustering based on data shown in Table 4, indicating that the images that were selected originally on the basis of the same product category tend to divided into the same cluster. Based on psychophysical data collected from this study, predictive models of like/dislike can be developed for different product categories, which can then help provide more realistic predicted values of like/dislike for real-world products.

5.Acknowledgementa

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6.References

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