# Investigation of Memory Colours across Cultures

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## Abstract

*Memory colours have been extensively investigated. They are important for different image applications, such as colour image reproduction. However, it is possible memory colours vary according to different cultures. The present experiments were conducted to investigate 22 memory colours, which are divided into three types: 12 common colours such as vegetables, fruits and flowers, 6 natural colours such as sky blue, grass, and skin colours, and 4 culture specific colours. Each colour was assessed by 25 Chinese observers and 30 German observers in each country. The inter-observer variations between two groups were compared in terms of mean of CIELAB colour differences in terms of MCDM measure and tolerance ellipses. Also, the colour centers are plotted in CIELAB a*b* diagram to show the culture differences. The intention here is to establish a methodology to study memory colours across different countries based on homogeneous colour patches.*

## Introduction

Memory colours have been extensively studied. Most of the studies have been focused on the application of graphic arts and imaging reproduction. Bartleson [1,2] investigated the memory colours, in which skin, blue sky and grass colours were most intensively studied, arguably the most important colours in reproduction. They also investigated the difference between memory colour, preferred colour and natural colour. Overall, there is a trend that memory colours are more saturated than natural colours with great hue constancy. This has been confirmed by many other researchers [3-7]. Bartleson [2] also found that memory colour is different from colour memory, defined as recollection of colours. Colour memory also increases in saturation and lightness contrast over time, and has less variation than memory colour. Bartleson and Bray [8] concluded that memory colour is not necessary to be preferred colours. However, many others find there is an increase of saturation for the preferred colours.

Many researchers studied different skin colour groups on preferred colours [9-13]. Zeng and Luo [13] calculated the CIELAB $a^*b^*$ values of the preferred skin colours and plotted them. It was found that all preferred skin colours had more or less constant hue angle around 54$^o$ and are more colourful than the actual measured colours. However, there is a large spread in chroma direction.

All above studies were conducted to study preferred colours to enhance image quality. Very few studies concern cross-culture on memory colours. Smet et al [5] first studied memory colours of the 9 objects projected by different coloured LED lights. Observers were asked to scale 'similarity' to what the objects look like in reality and the results were used to develop so called memory colour rendering index. At a later stage, he and his co-authors [14] studied 11 objects in terms of images across 7 different countries/regions using calibrated monitors. The results were analysed to reveal cross-culture difference. They found that although there is a significant difference between different cultures, it is considered to be unimportant due to large inter-observer variability within culture group. The typical variation of all objects is in the magnitude of Du'v' of 0.010. However, Tarczali et al [15] reported that there is a difference between Hungarian and Korean.

With above in mind, a research project is formed to investigate memory colours based on homogeneous colour patches and images on a self-luminance display between Chinese and German. The results in this paper are based on the colour patches participated by 25 Chinese and 30 German subjects.

## Experimental

The experiments were carried out in a darkened room on the same CG277 Eizo LED back-lighting display first in China and then in Germany.

### Display

The physical size of display is 27" in diagonal. The experimental conditions were strictly controlled and kept exactly the same between two locations. The equipment were transported to Germany after completion of the experiment in China. The display parameters were measured both in China and after transported to Germany using a Jeti Specbos 1211uv tele-spectroradiometer (TSR). The monitor was well calibrated with CCT close to CIE D65 illuminant at a luminance level about 110 cd/m$^2$, and the xy chromaticity at [0.311, 0.328]. The display characterization was implemented using GoG model developed by Berns [16] with a prediction of less than 0.5 $\Delta E^*_{ab}$ unit averaged from the 18 neural grey levels as test colours (0:15:255, RGB to XYZ). In comparison, the performance of channel additivity of the monitor was 0.45 $\Delta E^*_{ab}$ for the same 18 neural grey colours, indicating a good performance of the characterization model. The monitor performance kept stable with a variation of 0.60 $\Delta E^*_{ab}$ unit averaged from the 72 colours (four channels of R, G, B and white with 18 even step levels each) between the measuring results in China and those in Germany.

### Selection of Objects

Twenty-two objects were selected in consideration of familiarity, colour distribution, cultures and importance in applications. Their original colour values for experiment were carefully selected from the internet images. The RGB signals from a representative region were averaged and then transformed using the GOG model developed. They were then transformed to CIELAB values. The colours selected were divided into three categories: 1) cultural-specific colours, 2) common vegetable and fruit colours in both cultures, and 3) common natural colours such as skin, sky blue and green grass. Category 1 is aimed to compare memory colours with culture specific such as those historical colours in the work of museum conservation. The chosen representative Chinese colours were festival red, imperial robe yellow, Cantonese sausage and blue-and-white Chinese porcelain, while German colours were papaver rhoeas, beer of Pils, salami and green asparagus. Categories 2 and 3 objects were familiar across cultures for various applications.

However, Category 3 is considered to be important memory colours associated with geographic locations such as environmental effect.

### *Experimental software*

A software was implemented for performing the experiment. Figure 1 shows the experimental display. The test colour was placed in the centre of screen with a grey background having L* of 50. The test colour had a physical size of 2cm by 2cm extending a viewing field of 2° having a viewing distance about 60 cm from observer's eyes. Each observer manipulated the CIELAB L*, $C^*_{ab}$ and hue angle through three separate control bars with intervals of 0.5, 0.5 and 0.5 units respectively. There is a 'reset' button to return to the original colour values which was set by an arbitrary colour extracted from images, and a 'next' button to proceed into next colour after completing a colour patch satisfactorily. The descriptive names on the interface in two laboratories are in Chinese and German respectively. The 22 memory colours were manipulated twice with random patches appearance order. Each observer took 40 to 50 minutes to complete a session. In total, there are 25 Chinese and 30 German observers participated in the experiment. They all passed the Ishihara colour vision test.

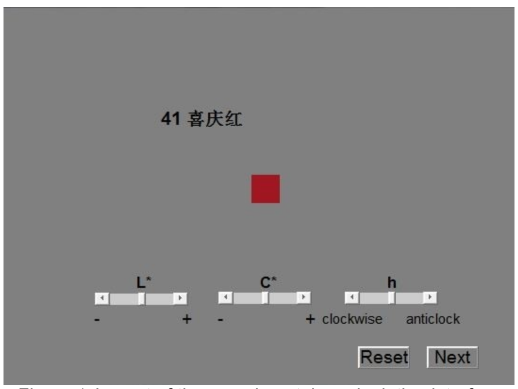


*Figure 1.* Layout of the experimental manipulation interface

## Results and Discussion

The results from all observers were first averaged in terms of CIE L*a*b* values for each object to represent the memory colour. Table 1 lists the experimental results for Chinese observers including the averaged memory colours in terms of $L^*$, $C^*_{ab}$ and hue angle values together with the inter-observer variation in terms of MCDM measure and chromatic tolerance ellipses described by semi-long axis (A), shape of ellipse (ratio between the semi-long and semi-short axes, A/B), orientation of ellipse ($\theta$) and ellipse area represented by πAB. The colour centres and variation ellipses of German results will be shown in Figure 3b. All these will be explained in this article later.

The measure of MCDM (mean of colour difference from the mean) was used to indicate the inter-observer variability. For each colour, the mean from all observers was first calculated. The colour difference from the mean and each individual observer's results were then worked out. Finally, the mean of all colour differences from each individual was calculated as MCDM. For a perfect agreement (all observers match the same colour), MCDM will be zero. In fact, the order of list in Table 1 is followed the MCDM in ascending order. The overall MCDM values for Chinese subjects are 13.45 and 11.22, and for German subjects are 16.31 and 12.77, for $\Delta E^*_{ab}$ and chromatic $\Delta E^*_{ab}$, respectively.

Table 1 shows that the objects with the smallest variation of Chinese observers are aubergines, Caucasian face skin colour and African face skin colour, while those with the biggest variation are blue sky, kiwi and broccoli. Figure 2 shows the chromatic ellipses of Chinese group giving the smallest (10.3) and largest (20.6) MCDM values for the aubergine and blue sky in CIE a*b* diagram, respectively. It can be seen that the distribution of all individuals in the ellipse. The blue line in the figure is the hue angle of the colour centre. Finally, the tolerance ellipses were derived based on the Johnson and Wichern method [17]. The boundary of each ellipse corresponds to 95% of statistical confident interval. The values of ellipse axis, shape, orientation and area of Chinese observers corresponding to each centre are also given in Table 1. It can be seen that the ellipses size are in good agreement with MCDM, i.e. a larger ellipse represents a larger observer variability.

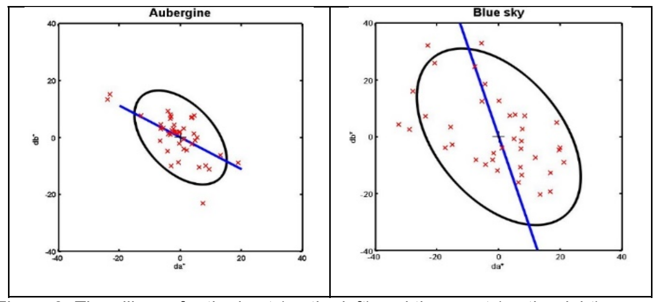


*Figure 2. The ellipses for the best (on the left) and the worst (on the right) variation of Chinese subjects*

The 22 tolerance ellipses of both cultural groups are plotted in CIELAB $a^*b^*$ diagram as shown in Figures 3a and 3b for Chinese and German observers. The red crosses are the memory colour centres. The ellipses plotted with different colours represent different hue ranges. It can be seen that most of memory colours agreed well with each other in terms of ellipse parameters, especially three skin colours. However, some systematic trends can be found between cultures such as three fruit colours in the yellow region, i.e. Chinese ellipses are more relaxed in hue direction, but German ellipses are in chroma direction. The largest differences can be found in blue sky for Chinese and green grass for German.

Comparing colour centres, Figure 4 is plotted between the two culture groups. It can be seen that aubergine, red rose and strawberry are the closest to each other, which means the effect of cultural difference is not significant. The largest difference between two groups are blue sky, nectarine and kiwi. The total $\Delta E^*_{ab}$ and chromatic $\Delta E^*_{ab}$ between Chinese and German groups are 8.71 and 6.75 respectively.

There is a tendency that larger ellipses are located in higher chroma area. This could be due to the poor uniformity of CIELAB space as pointed by many researchers [18]. It can also find that some of the colours (such as face skin colours, blue sky) had chromaticity ellipses pointed in the neutral point (chroma direction orientated), but some are hue direction orientated such as broccoli and orange. According to MCDM or ellipse area, it can be concluded that the three categories of colour objects are 'equally spread'. There is no significant difference between three categories. For example, in Category 2, the blue sky and green grass have large MCDM, but skin colours from this category had small MCDM. For the cultural colours, there are large variations, as well as small ones. The inter-observer variation of cultural-specific objects of both Chinese and German are object-dependent.

**Table 1. The $L^*$, $C^*_{ab}$, h, MCDM and ellipse parameters of Chinese people for all objects**

| Group No. | Colour centre | MCDM | $L^*$ | $C_{ab}^*$ | h | Ellipse A | Ellipse A/B | Ellipse orientation angle | Ellipse area |
|---|---|---|---|---|---|---|---|---|---|
| 2 | Aubergine (peel) | 9.72 | 15.65 | 27.93 | 326.28 | 7.89 | 1.70 | 129.92 | 114.97 |
| 3 | African face skin | 10.01 | 22.41 | 12.73 | 75.84 | 7.57 | 1.83 | 45.96 | 98.33 |
| 3 | Caucasian face skin | 10.30 | 78.88 | 13.44 | 43.11 | 6.35 | 2.10 | 39.14 | 60.45 |
| 2 | Strawberry | 10.33 | 45.63 | 82.98 | 35.24 | 7.34 | 1.42 | 65.21 | 119.69 |
| 2 | Nectarine (peel) | 10.65 | 33.46 | 57.97 | 30.23 | 6.47 | 1.15 | 75.84 | 114.26 |
| 1 | Imperial robe | 11.93 | 82.04 | 81.62 | 84.93 | 8.72 | 1.48 | 5.74 | 161.56 |
| 2 | Red rose | 11.94 | 37.31 | 72.49 | 34.75 | 6.93 | 2.37 | 83.11 | 63.49 |
| 2 | Pink lotus | 12.52 | 72.91 | 40.91 | 338.04 | 12.16 | 2.57 | 163.46 | 181.07 |
| 2 | Lavender | 12.61 | 41.24 | 59.15 | 301.35 | 11.14 | 2.31 | 131.14 | 168.66 |
| 2 | Lemon (peel) | 12.87 | 87.77 | 85.21 | 97.64 | 8.51 | 1.35 | 170.00 | 167.97 |
| 1 | Chinese festival red | 13.38 | 39.27 | 75.73 | 34.13 | 7.09 | 2.41 | 90.78 | 65.54 |
| 2 | Banana (peel) | 13.72 | 81.70 | 81.35 | 90.08 | 8.88 | 1.40 | 179.76 | 177.32 |
| 3 | Oriental face skin | 14.01 | 67.59 | 29.72 | 50.35 | 9.28 | 2.20 | 71.39 | 122.83 |
| 3 | Blue jean | 14.19 | 30.76 | 29.49 | 272.53 | 10.28 | 1.90 | 105.27 | 174.92 |
| 3 | Green grass | 14.59 | 66.10 | 75.88 | 125.06 | 10.62 | 1.21 | 172.73 | 291.94 |
| 1 | Cantonese sausage | 14.67 | 31.16 | 51.01 | 35.25 | 10.07 | 1.31 | 56.18 | 243.74 |
| 2 | Orange (peel) | 14.77 | 68.90 | 81.13 | 63.07 | 12.10 | 2.19 | 8.23 | 209.62 |
| 2 | Green apple (peel) | 15.15 | 72.48 | 71.39 | 123.84 | 10.38 | 1.07 | 162.58 | 315.10 |
| 1 | Blue and White Chinese porcelain | 15.64 | 36.56 | 51.77 | 284.36 | 13.20 | 2.18 | 126.30 | 250.82 |
| 2 | Broccoli | 16.47 | 42.63 | 53.47 | 144.67 | 13.47 | 1.98 | 14.80 | 287.82 |
| 2 | Kiwi (flesh) | 17.61 | 72.13 | 75.21 | 117.04 | 11.36 | 1.17 | 163.66 | 346.78 |
| 3 | Blue sky | 18.93 | 49.64 | 73.68 | 286.59 | 14.34 | 1.67 | 125.62 | 386.05 |

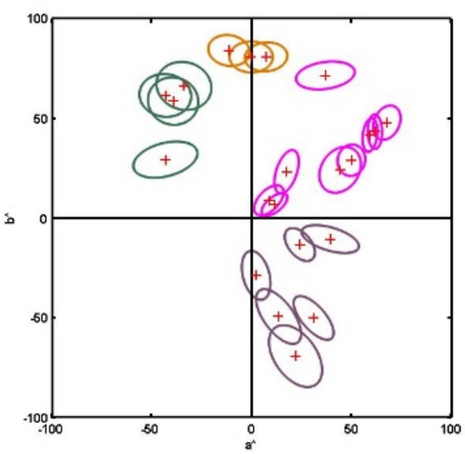

*Figure 3a. The Chinese group colour centers and tolerance ellipses for the 22 memory colours in $a^*b^*$ plan with size reduced by 2 times*

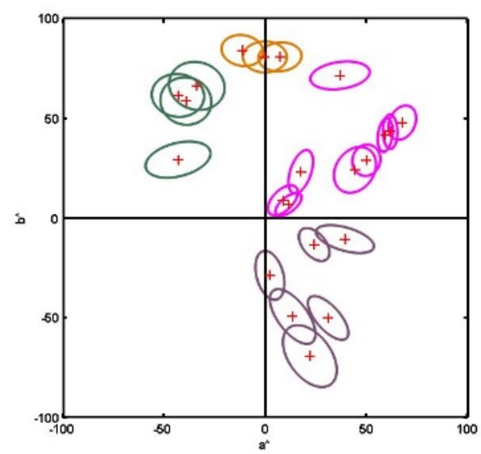

*Figure 3b. The German group colour centers and tolerance ellipses for the 22 memory colours in $a^*b^*$ plan with size reduced by 2 times*

Overall, the inter-culture group difference is small, i.e. 8.7 and 6.75 for total and chromatic $\Delta E^*_{ab}$ in average, which is approximately half size of the inter-observation variation. The difference of the common fruit and skin colours are relatively small, but that of blue sky, nectarine, kiwi and broccoli, green grass are large. The possible reason for the large variety of sky blue is that the sky colour has a big variation in nature according to different weather condition, daytime range, season and range. The green grass changes between seasons and different period of daytime. As for the two vegetables, there is a variety of species and different ripeness degree. In general, the cross-cultural difference is not as large as intra-group variation, which confirms Smet et al's [14] findings.

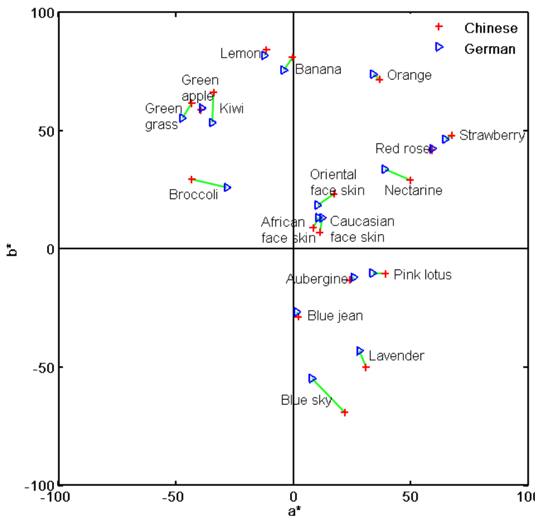


*Figure 4. The colour centers of common 18 objects between Chinese and German observers*

## Comparing with the other researchers' results

Both Chinese and German results were compared with those of Smet et al [14] which were based on images on displays. The Smet et al's data included 11 memory colours, assessed by 100 observes from 7 countries and each colour centre having over 100 rendered images. In total, about 210,000 ratings were gathered. The MCDMs were reported in terms of Du'v' units. So they were transformed to CIELAB and MCDM was calculated with an average about 10 units. Both the present Chinese and German data are plotted against the Smet et al's data in Figure 5. It can be seen that both Figures 5a and 5b gave very similar pattern. This implies that the two datasets agree well with each other. In general, the $\Delta E^*_{ab}$ and $\Delta E^*_{ab}$ in chromaicity between Chinese and that of Smet's of 8 common objects are 18.04 and 15.18, respectively. And that of German are 19.89 $\Delta E^*_{ab}$ and 15.86 chromatic $\Delta E^*_{ab}$. It can be seen that these values are much higher than across-cultural difference between Chinese and German.

## Conclusions

An experiment was carried out to investigate the memory colours between Chinese and German observers. Twenty-two familiar objects divided into 3 categories were studied. Experiments were conducted by colour matching through three attributes, L*, $C^*_{ab}$ and hue angle in CIELAB colour space, to match a specific memory colours. Experimental data were based on 110 observations for each object (50 observations in China and 60 in Germany). The results were analysed to establish tolerance ellipses and MCDM to

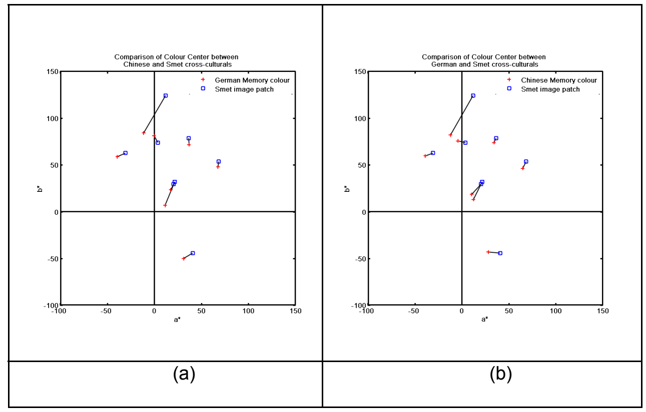


*Figure 5. Comparison of Colour Centres, a) between Chinese memory colour and Smet et al's data, b) between German memory colour and Smet et al's data.*

define inter-observer variability. It was found that the typical variation is about 13.5 MCDM units for Chinese and 16.3 MCDM units for German. Finally, the results of two cultural groups were compared. The overall mean colour difference is 8.7 $\Delta E^*_{ab}$ and 6.75 chromatic $\Delta E^*_{ab}$. The results show that the cross-cultural variation of memory colours are smaller than intra-group variation. It can be seen that the cross-cultural variation of memory colours are smaller of most familiar objects, but larger for some natural colours. In addition, the present memory colour results are quite different from the other studies based on the images on displays. In general, the present results showed a larger observer variability (MCDM, 13.5□$\Delta E^*_{ab}$ units) than the other datasets (typically less than 10 units) because the present data is based on colour patches without the form of object or image context.

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