A Cross-Cultural Colour-Naming Study: Part II—Using a Constrained Method

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Abstract: This study aimed to investigate the differences in colour naming between the English (British) and Mandarin (Taiwanese) languages. A constrained method was employed, with 20 British and 20 Chinese adults. All the experiments were conducted under an artificial daylight, using 1526 colours from the Natural Color System (NCS). Each subject was asked to find the colour(s) corresponding to basic names, modifiers, and secondary names in terms of one colour (focal colour) or a colour region (colour volume). Little difference in chromaticness and hue was found between the two languages, but a systematic discrepancy was found in blackness. Because this could have been caused by different surrounds, i.e., gray and white walls used for the British and Chinese experiments, respectively, a verification experiment was carried out using a panel of ten Taiwanese subjects against a gray surround. The results proved that the lightness difference found earlier was indeed caused by the surround. © 2001 John Wiley & Sons, Inc. Col Res Appl, 26, 193–208, 2001

Key words: colour naming; colour categories; cross-cultural comparison; basic colour names; modifiers; focal colours; colour volume

INTRODUCTION

This study aimed to investigate the differences in colour naming between the English (British) and Mandarin (Taiwanese) languages. The cross-cultural comparison sought to reveal a clear picture of the linkage between the two languages and their inherent concepts of colour. Two experiments were carried out using an unconstrained and a constrained method, respectively. The results from Experiment I, which used the ISCC-NBS Colour Order System, were described in Part I,[1] and showed that there was a close agreement between the two languages in terms of colour categories. It was confirmed that the eleven basic names found by Berlin and Kay[2] were the most widely used for both languages. Large discrepancies were found in the use of secondary names, however, due to cultural differences.

Experiment I was conducted using an unconstrained method, in which observers were asked write down the name of each of 200 surface colour samples. Both British and Chinese colour names were collected, categorized, and subjected to codability analysis to determine the level of consensus amongst each group of observers. Some interesting issues arose from the cultural comparison. For example, Chinese subjects used more basic terms than British subjects, but some of these Chinese terms seemed to be synonymous. One purpose of Experiment II was, therefore, to clarify these issues.

The main aim of Experiment II was to map a focal colour or a colour volume corresponding to each of the important Basic, Modifier, and Secondary terms found in Experiment I. Because it was concerned with name-to-colour mapping, a constrained method was used. The objective was to map the colours for a selected set of names in a specified colour space so that any distinction between these possibly synonymous Chinese names could be clarified. Each colour name was described in terms of focal colour and colour centroid, using the NCS Atlas. The term "focal colour" is defined as the most typical physical colour to represent a colour term. Each focal colour represents a salient area of the colour space, which is the most linguistically "codable" and most easily remembered.[2] In our experiment, the focal colour for a basic name could be defined as the colour that subjects chose as the most typical physical colour corresponding to that particular name. The mean values of the NCS blackness

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(s), chromaticness (c), and hue (f) attributes were used to represent each subject group. When several colours were chosen for a given name, these colours formed a volume in colour space. The colour volume described by one person might overlap with those described by others. The centroid of the volume was, therefore, calculated to represent each subject group.[3]

Although the importance of modifiers is second only to that of basic terms, they cannot be used alone, because their meanings are determined by the appended basic terms. This explains in part why the uses of modifiers have not been well studied. Close examination shows that a modifier can generally be associated with the NCS attributes of chromaticness and blackness, rather than hue, which are somewhat similar to Munsell attributes. Hue distinguishes one colour family from another, as red from yellow, or green from blue. Value distinguishes a "light" colour from a "dark" one. Chroma distinguishes a "strong" colour from a "weak" one.

The use of modifiers greatly expands the number of colour names and renders them with a higher accuracy. The tendency of observers to combine modifiers with basic terms as colour names was found to be quite common in Experiment I. A general pattern was that one colour might be named with several different modifiers. For example, DEEP GREEN in the ISCC-NBS system, was named by the British using BRIGHT, DARK, DEEP, and MID GREEN; while the Chinese used BRIGHT, DARK, DEEP, FRESH, and LIGHT GREEN. On the other hand, different colours were sometimes given the same name. Therefore, the mapping between a modifier and a colour was not one-to-one — modifiers were relative terms of diverse application.

Berlin and Kay[2] found that, for each basic colour term, the focal colour had less cultural difference than the basic colour volume. However, little has been done to investigate cultural differences for modifiers and secondary terms. Although Experiment I showed clear cultural preferences for using some modifiers (e.g., British subjects liked to use DARK, whereas Chinese subjects preferred DEEP), they might actually have had the same meaning. Experiment II was, therefore, intended to map more accurately the regions of colour space associated with the modifiers.

EXPERIMENTAL SETUP

Natural Color System (NCS) and Color Atlas

Although subjects tended to name most colours consistently in both English and Mandarin languages, the 200 ISCC-NBS colours used in Experiment I were considered not to be precise enough. Experiment II used colours from the 1989 version of the NCS Atlas,[4] which contains 1526 samples in 40 hue pages. On each page, the samples are systematically arranged with chromaticness vs. blackness against a white paper background. Some of the colours on every other hue page are not available because of costs and production difficulties. Altogether the NCS Atlas contains 20 incomplete hue pages, in which the unavailable colours are predominantly in the area of high blackness and low chromaticness. These colours are considered to be less attractive to designers (who are the main users of the Atlas) and differ only slightly from colours on neighboring pages. Each colour sample in the NCS Atlas is painted in opaque semi-matt enamel on white paper of size 12×15 mm.

For colour measurement, samples of size 115×145 mm from the NCS Color Register were used, because the samples in the Atlas were too small to measure and could not easily be removed from the Atlas. Although the colour of corresponding samples in the two sets may differ, the differences should be small, because they are produced by the same pigment formulation. The samples were measured using a MS2020^{+} spectrophotometer, with conditions set to large aperture, UV included and specular included. Their CIELAB values were calculated from the reflectance values using D65 illuminant and CIE 1964 standard colorimetric observer (10°).

The 1526 sample colours are plotted in the CIELAB a^*b^* diagram in Fig. 1, separated into five different lightness ranges: $L^* \leq 30$, $30 < L^* \leq 40$, $40 < L^* \leq 60$, $60 < L^* \leq 80$, $80 \leq L^*$. It is evident that the samples cover a wide area of the visible colour gamut, similar to that of the ISCC-NBS colours used in Experiment I.

Experimental Procedure

The names used most frequently in the Basic, Modifier, and Secondary categories were chosen from the previous results of Experiment I. There were 12 English and 16 Chinese names in the Basic category, 9 English and 8 Chinese terms in the Modifier category, and 12 English and 12 Chinese names in the Secondary category. Each colour name was written on a 10×5 cm card and put into a folder. Each subject was then asked to select a card at random from the folder to perform the colour selection. This procedure randomized the sequence of colour naming to reduce systematic experimental error. Two corresponding sets of instructions were given in English and in Chinese. Table I lists the Basic, Modifier, and Secondary names studied in Experiment II for both English and Mandarin languages.

Each subject was first asked to select a colour and then to delineate a colour volume for each basic term from the pages of the Atlas. The subject was subsequently asked to map a colour volume for a given modifier in each of five hue pages (Y10R, Y90R, G10Y, R90B, and R50B). These five hues were selected, because they were the closest complete hue pages in the NCS Atlas to the four unique hues (red, yellow, green, and blue) plus purple. Finally, each subject was asked to map the colour volumes of the 12 secondary terms. The results were recorded as shown in Fig. 2.

For the Chinese experiments, the colour samples were illuminated by artificial daylight (a fluorescent lamp) having chromaticity close to the standard D65 illuminant. The experiment was conducted on a wooden table painted with wood stain against a white wall (surround). British subjects were tested under the same light source in a VeriVide viewing cabinet with gray interior walls having lightness

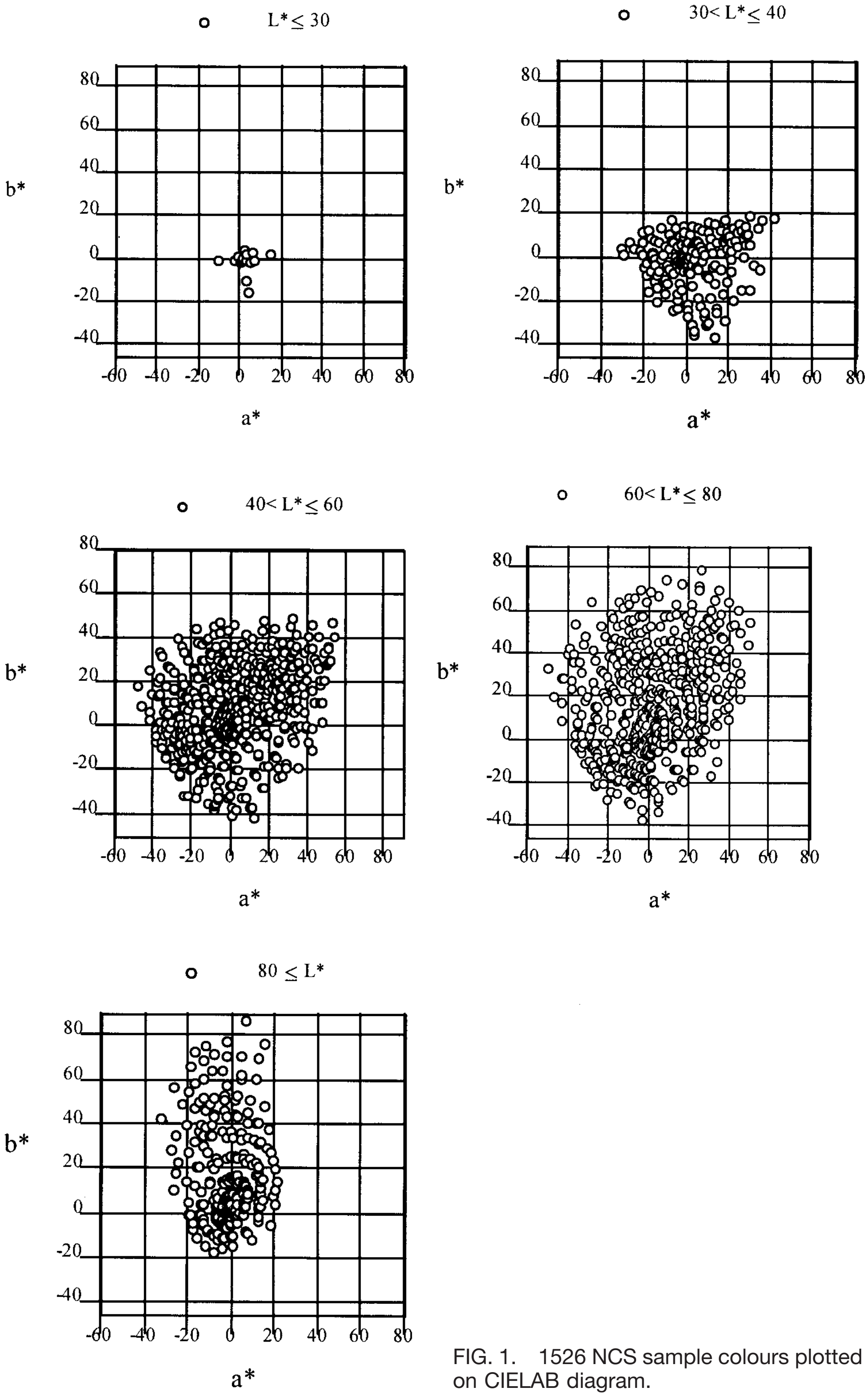

FIG. 1. 1526 NCS sample colours plotted on CIELAB diagram.

$L^* = 50$. The viewing cabinet provided a gray surround. The viewing/illuminating geometry was 45/0 for both groups.

All subjects passed the standard Ishihara test for deficient colour vision. In total 20 subjects in each culture (10 males and 10 females) participated in Experiment II. The British subjects ranged in age from 16–26 years and were students or staff in colleges or universities. The Chinese subjects were all Taiwanese nationals who speak Mandarin as their native language. Their ages ranged from 20–33 years and they were students or staff in the National Chon–Chen University in Taiwan. None of the subjects had any prior specialist knowledge of colour science.

TABLE I. Basic, modifier, and secondary names in English and Mandarin Chinese.

	English	Chinese
Basic names		
	1. BLACK	1. *BAI* WHITE
	2. BLUE	2. *HEI* BLACK
	3. BROWN	3. *HUEI* GREY
	4. GREEN	4. *HONG* RED
	5. GREY	5. *JU* RED
	6. PINK	6. *HUANG* YELLOW
	7. ORANGE	7. *LIUH* GREEN
	8. PURPLE	8. *CHING* GREEN
	9. RED	9. *LAN* BLUE
	10. WHITE	10. *DIANN* BLUE
	11. YELLOW	11. *JYU* ORANGE
	12. INDIGO	12. *CHEN* ORANGE
		13. *ZI* PURPLE
		14. *ZONG* BROWN
		15. *HUR* BROWN
		16. *FEEN-HONG* PINK
Modifiers		
	1. LIGHT	1. *CHEAN* LIGHT
	2. PALE	2. *DANN* PALE
	3. DEEP	3. *SHEN* DEEP
	4. DARK	4. *ANN* DARK
	5. BRIGHT	5. *LIANG* BRIGHT
	6. STRONG	6. *JONG* STRONG
	7. VIVID	7. *SHEAN* FRESH
	8. MID	8. *YANN* VIVID
	9. DULL	
Secondary names		
	1. MAUVE	1. *FEEN* POWDER
	2. LILAC	2. *TU* EARTH
	3. TURQUOISE	3. *NAI* MILK
	4. VIOLET	4. *CHIAFEI* COFFEE
	5. SKY	5. *TSAO* GRASS
	6. MUSTARD	6. *FU* SKIN
	7. OLIVE	7. *JOU* FLESH
	8. CREAM	8. *MI* RICE
	9. BEIGE	9. *TIEH* IRON
	10. FLESH	10. *SHUI* WATER
	11. LIME	11. *CHA* TEA
	12. SALMON	12. *CHIU* WINE

Data Analysis

During the experiment, the subjects chose colours from the NCS Atlas for each name and the experimenter recorded the chosen colours. Each colour was then coded with three NCS attributes: hue (*f'*), blackness (*s*), and chromaticness (*c*). Hue results were transformed onto a continuous scale from 0–400 (quadrants 0-100 for R-Y, 100-200 for Y-G, 200-300 for G-B, and 300-400 for B-R). This modified hue angle is designated as *f'* to differentiate it from normal NCS hue *f*. The blackness scale ranges from 0–100, and the chromaticness scale from 0–100. For example, in the colour 1070Y, the hue Y is encoded as $f' = 100$, blackness as $s = 10$, and chromaticness as $c = 70$. When analyzing the colours of a pure red, its hue could be encoded as either 0 or 400. If the hue range covered both sides of the pure red (say from 380 to 20), the colours would need to be treated arithmetically as a continuous scale, i.e., -20 to $+20$ or 380 to 420.

For each colour volume corresponding to a colour term; the mean (*M*) and standard deviation (*SD*) were calculated for each language group. The "spread" was defined as the number of hue pages covered. In addition, the number of colours selected within a volume was counted and designated the "response frequency" (*N*): the larger the *N* value, the larger the colour area covered. The *f'*, *s*, *c* values for each term were analyzed using a *t*-test to compare the differences of focal colours between British and Chinese subjects. However, one visible step in the NCS Atlas was also useful as an indicator of perceptual differences, i.e., 10 units apart for each attribute. If the *t*-test showed a difference in a given attribute between the two subject groups of less than 10 units, this difference was not considered to be significant.

As mentioned earlier, there were 20 incomplete hue pages in the NCS Atlas: Y, Y20R, Y40R, Y60R, Y80R, R, R20B, R40B, R60B, R80B, B, B20G, B40G, B60G, B80G, G, G20Y, G40Y, G60Y, and G80Y. It was assumed that subjects would have also chosen corresponding colours from these incomplete pages, if they chose the colours in both of the two neighboring hue pages. In other words, whenever subjects chose colours from two complete hue pages, any missing samples located between these two pages were also

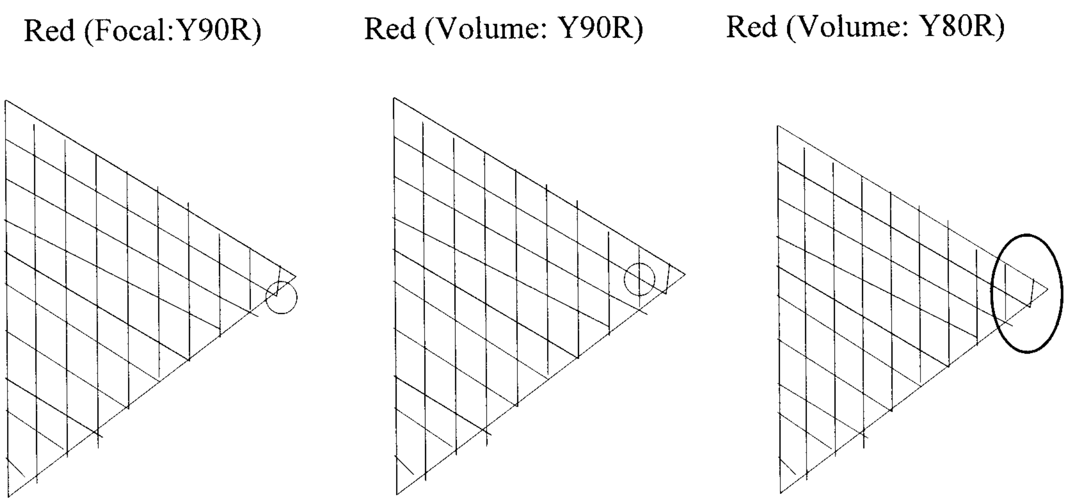

FIG. 2. Example of red naming tasks on a layout sheet.

included in the colour volume. For example, if a subject selected 7010G10Y and 7010G30Y, then 7010G20Y was also considered to be selected.

The centroid of a colour was defined by three NCS attributes: hue value, blackness, and chromaticness (*f’*, *s*, *c*). The hue value of the centroid was calculated as the sum of each hue value multiplied by its frequency, then divided by the total frequency. For example, if two subjects chose hue R (*f* ’= 0) and three chose hue R10Y (*f’* = 10), the total frequency would be $N = 2 + 3 = 5$ and the centroid hue value would be $(0 \times 2 + 10 \times 3)/5 = 6$.

RESULTS

Use of Basic Colour Names

Chromatic Colours. In Experiment I, it was found that there were five pairs of Chinese basic names that seem to be synonymous, and that among eight chromatic basic terms only YELLOW, PURPLE, and PINK have unique equivalent words in the British and Chinese languages. The five synonymous pairs were first examined using the focal colour results from a panel of 20 Chinese subjects.

The mean (*M*) and standard deviation (*SD*) of hue value (*f’*), blackness (*s*), and chromaticness (*c*) for each of five pairs of basic names are given in Table II. Among the five pairs of Chinese basic terms, *JYU* ORANGE and *CHEN* ORANGE were significantly different in hue value (*JYU* ORANGE: *f’* = 40.5; *CHEN* ORANGE: *f’* = 61.5) as shown by an unpaired *t*-test ($p < 0.001$, $df = 38$) and visual step inspection. (If the means differ by more than 10 units, the difference can be considered to be significant.) These results suggest that *CHEN* ORANGE is yellower than *JYU* ORANGE, which may lead to the possibility of two basic Chinese terms for British ORANGE. However, Chinese children rarely use *CHEN* ORANGE today.

The blackness and chromaticness values of *HONG* RED and *JU* RED were different in *t*-tests ($p < 0.05$ in blackness; $p < 0.01$ in chromaticness with $df = 36$), but the difference was within one visual step. Therefore, *JU* RED should be considered to have the same hue value as *HONG* RED, but to be darker and weaker. *JU* RED was used in China for thousands of years as a dye to produce various shades of *HONG* RED but is less frequently used today.[5]

The results for *CHING* GREEN were particularly interesting. The same character for *CHING* GREEN is still used in Japan and is pronounced as *AO* BLUE. *CHING* GREEN had a large standard deviation ($SD = 53.54$) in hue value, meaning that it was used inconsistently compared with *LIUH* GREEN. As already described in Part I, *CHING* is an ancient word and people who use it usually do not know its original meaning. For instance, *ching grass* (green grass), *ching vegetable* (green vegetable), and *ching sky* (blue sky) are everyday terms, but people rarely use *ching* independently as a basic colour term.

Some basic terms were used less confidently than others. For example, 18 out of 20 subjects when presented with *JU* RED made a colour selection, but two subjects gave the “I do not know” response. Other nil responses were one to *CHING* GREEN, three to *DIANN* BLUE, and two to *HUR* BROWN.

Amongst the hue spread of the five pairs of basic names, some pairs overlapped considerably, such as *ZONG*

TABLE II. Comparison of the mean (*M*) and standard deviation (*SD*) of focal colours for five pairs of Chinese basic names.

HONG RED ($N = 20$)		*JU* RED ($N = 18$)				
	M	*SD*	*M*	*SD*	*t*	*P*
ϕ'	9.00	5.53	8.89	14.51	0.03	.9748
s	11.50	3.66	18.33	12.95	−2.27*	.0296
c	87.00	4.70	77.22	11.79	3.42**	.0016
JYU ORANGE ($N = 20$)		*CHEN* ORANGE ($N = 20$)				
	M	*SD*	*M*	*SD*	*t*	*P*
ϕ'	40.50	14.32	61.50	18.14	−4.06***+	.0002
s	0.50	2.24	0.50	2.04	0.00	
c	87.50	9.11	85.00	10.99	0.63	.5346
LIUH GREEN ($N = 20$)		*CHING* GREEN ($N = 19$)				
	M	*SD*	*M*	*SD*	*t*	*P*
ϕ'	190.00	11.70	213.59	53.34	−1.90	.0659
s	24.00	15.01	30.53	50.50	−0.56	.5804
c	70.00	9.18	65.79	17.10	0.97	.3408
LAN BLUE ($N = 20$)		*DIANN* BLUE ($N = 17$)				
	M	*SD*	*M*	*SD*	*t*	*P*
ϕ'	315.00	8.27	320.59	10.29	−1.83	.0755
s	29.50	7.59	32.94	16.87	−0.82	.4171
c	66.50	6.71	60.59	13.91	1.69	.1005
ZONG BROWN ($N = 20$)		*HUR* BROWN ($N = 18$)				
	M	*SD*	*M*	*SD*	*t*	*P*
ϕ'	63.16	31.81	66.84	24.27	−0.40	.6905
s	47.90	15.12	51.05	14.10	−0.67	.5098
c	48.42	12.59	40.00	16.33	1.78	.0835

Note 1: ‘*’ indicates $p < 0.05$, ‘**’ $p < 0.01$, ‘***’ $p < 0.001$.
Note 2: ‘+’ indicates the difference is more than one NCS visual step.

TABLE III. Comparison of the mean (*M*) and standard deviation (*SD*) for eight basic colours between Chinese and British subjects.

	TOTAL $N = 40$		CHINESE $N = 20$		BRITISH $N = 20$			
	M	*SD*	*M*	*SD*	*M*	*SD*	*t*	*P*
1. RED								
ϕ'	12.75	7.16	9.00	5.53	16.50	6.71	−3.86***	.0004
s	8.75	5.52	11.50	3.66	6.00	5.03	3.96***	.0003
c	88.00	4.05	87.00	4.70	89.00	3.08	−1.59	.1198
2. YELLOW								
ϕ'	95.25	7.16	97.00	5.71	93.50	8.13	1.58	.1234
s	0.00	0.00	0.00	0.00	0.00	0.00		
c	80.50	4.50	80.00	3.24	81.00	5.53	−0.70	.4984
3. GREEN								
ϕ'	189.00	20.61	190.00	11.70	188.00	27.07	0.30	.7623
s	19.25	15.09	24.00	15.01	14.50	13.95	2.07*	.0449
c	71.25	10.18	70.00	9.18	72.50	11.80	−0.77	.4443
4. BLUE								
ϕ'	314.00	10.39	315.00	8.27	313.00	12.18	0.61	.5472
s	24.75	9.06	29.50	7.59	20.00	7.95	3.87***	.0004
c	67.25	5.99	66.50	6.71	68.00	5.23	−0.79	.4354
5. ORANGE								
ϕ'	43.25	12.89	40.50	14.32	46.00	10.95	−1.364	.1805
s	0.25	1.58	0.50	2.24	0.00	0.01	−1.000	.3236
c	88.25	6.75	87.50	9.11	89.00	3.08	−0.698	.4894
6. PURPLE								
ϕ'	347.50	13.54	344.50	10.99	350.50	15.38	−1.42	.1639
s	30.00	7.16	32.00	8.34	28.00	5.23	1.82	.0770
c	54.50	8.46	52.50	10.20	56.50	5.87	−1.52	.1367
7. BROWN	N = 39		N = 19		N = 20			
ϕ'	65.13	25.43	63.16	31.81	67.00	18.09	−0.47	.6434
s	52.41	12.53	47.90	15.12	56.50	7.45	−2.19*	.0347
c	42.05	12.39	48.42	12.59	36.00	8.83	3.58**+	.0010
8. PINK								
ϕ'	393.33	18.96	386.81	14.93	399.50	20.64	2.18*+	.0353
s	3.64	4.83	4.21	5.07	3.10	4.64	0.71	.4799
c	38.72	16.41	44.74	15.04	33.00	15.93	2.36*+	.0235

Notes: 1. '*' indicates $p < 0.5$, '**' $p < 0.01$, '***' $p < 0.001$.
2. 'N' indicates the response number, for instance, the response number for Chinese brown is 19.
3. '+' indicates the difference is more than one NCS visual step.
4. $0 \leq \phi' \leq 400$, $0 \leq s \leq 100$, $0 \leq c \leq 100$.

BROWN and *HUR* BROWN, to the extent that these two names appear to be completely synonymous. Other pairs, however, had quite different distributions, such as *JYU* ORANGE and *CHEN* ORANGE. Some names covered a small range of hues, such as *HONG* RED, which spreads over only three NCS hue pages. In comparison, *JU* RED, *CHEN* ORANGE, *CHING* GREEN, *DIANN* BLUE, and *HUR* BROWN spread more than their counterparts, especially *CHING* GREEN, which spreads over 14 hue pages. A large hue spread together with a low frequency of responses for any colour term indicates that it is less qualified to be a basic name. Therefore, the names *HONG* RED, *JYU* ORANGE, *LIUH* GREEN, *LAN* BLUE, and *ZONG* BROWN should be preferred as the more precise Chinese focal colours.

Achromatic Colours. The results of Experiment I showed that WHITE and BLACK were the most consistent names for both British and Chinese subjects, which agreed with studies by Berlin and Kay,[2] Ratliff,[6] and Jiyima, Wenning, and Zollinger.[7] These findings were again confirmed in Experiment II. Not only did these colours have higher codabilities, but they also had smaller colour volumes. The high consistency of WHITE and BLACK as focal colours was demonstrated in that the great majority of subjects chose NCS 0500 as WHITE (70% of the Chinese and 90% of the British) and NCS 9500 as BLACK (80% of the Chinese and 85% of the British), these being the two extremes of the NCS blackness scale.

GRAY is a mixture of white and black, with intermediate values of blackness, but also the possibility of various shades (nonzero chromaticness). The colour selected for GRAY was NCS 3000 for 45% of the British subjects, which was slightly darker than NCS 2500 for 30% of the Chinese subjects. In addition, British GRAY had a narrower range of selected colours than Chinese *HUEI* GRAY. In Chinese, the word *HUEI* GRAY is an object name (also used by the Japanese), which means ashes, burnt things, dust, or pale colours. This might explain why Chinese *HUEI* GRAY is lighter than British GRAY.

It was noted that NCS 0502Y was chosen by 30% of the Chinese and 10% of the British subjects as focal WHITE. This may indicate that some subjects preferred a colour with a slightly yellowish chromaticness for WHITE. Similar perceptual mixtures with yellowish or reddish hues were also noted for BLACK and GRAY, but only for a small percentage of subjects. NCS 0500 and NCS 0502Y were selected within the WHITE volume with nearly the same

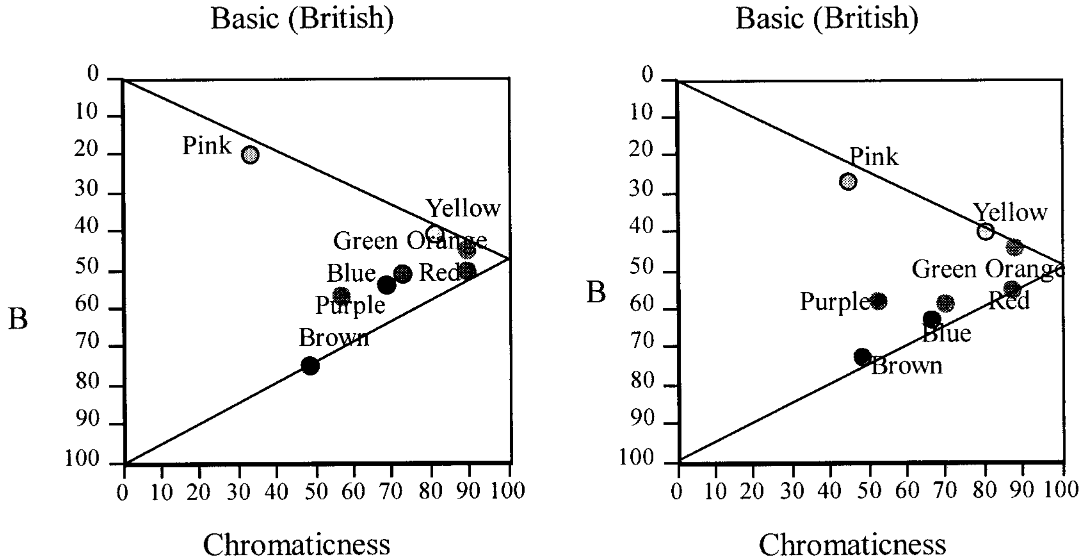

FIG. 3. Foci of eight basic colours.

frequency (18 and 17 Chinese responses, plus 9 and 8 British responses, respectively). This suggests that a small chromaticness in yellow could also be considered as WHITE.

Colours NCS 9500 (17 Chinese and 18 British) and NCS 9000 (17 Chinese and 20 British) were chosen for the BLACK volume. The blackness range (NCS 2000 to NCS 7500) for GRAY was much larger than that of WHITE (NCS 0500) and BLACK (NCS 8000 to NCS 9500). Thus, to cover the gray volume, subjects also selected some chromatic colours such as NCS 2502Y, NCS 2502R, and NCS 2502G.

Overall, WHITE was most consistently used, with the majority of people choosing only two colours, followed by BLACK. GRAY, having the largest hue spread, was used less consistently. The results show that the focal and volume colours for the achromatic terms were identical, i.e., NCS 0500, NCS 8000-9500, and NCS 2000-7500 for WHITE, BLACK, and GRAY, respectively.

Focal Colours. The eight basic colour names were compared between the two language groups in terms of three variables (*f'*, *s*, *c*) together with the unpaired *t*-test and visual unit inspection, as shown in Table III. Although in some cases the *t*-test results showed significant differences between the two subject groups, they were all less than one visual step (10 NCS units) in the NCS Atlas, except for the chromaticness of BROWN and PINK. In general, agreement between the two cultures was considered to be good, especially for YELLOW, ORANGE, and PURPLE.

The mean hue angles (*f'*) for the four unique hues RED, YELLOW, GREEN, and BLUE were 13, 95, 189, and 314, respectively, rather than the canonical values of 0, 100, 200, and 300 defined for the NCS unitary hues. Comparison of the four focal hues indicated little difference between cultures, except that British RED deviated more from NCS R than did Chinese RED.

Overall, the focal colours for YELLOW, ORANGE, and PURPLE showed no cultural difference, whereas for BROWN and PINK Chinese subjects preferred a higher chromaticness than British subjects. In general British subjects tended to select lower blackness (*s*), i.e., lighter colours, to describe RED, GREEN, BLUE, and BROWN than Chinese subjects. The systematic differences in blackness were significant for RED ($p < 0.001$, $df = 38$), GREEN ($p < 0.05$, $df = 38$) and BLUE ($p < 0.001$, $d f = 38$). There were significant differences in the standard deviation of hue angle (*f'*) for GREEN and PINK, where the British spread was larger, and for BROWN, where the Chinese spread was much larger. When the eight focal colours for Chinese and British subjects are plotted in the NCS chromaticness versus blackness (*s*-*c*) plane, as shown in Fig. 3, it is clear that all eight basic colours lie near the edges of the triangles, i.e., near the NCS gamut boundary.

Colour Volumes. Table IV lists the centroid NCS coordinates of the colour volume mapped for each basic name, together with the number of occurrences (*N*) and the spread (*s*), which is the number of hues covered by the colour volume. The results clearly show that centroids were close to the focal colours listed in Table III, except that they had lower chromaticness. Thus, when subjects chose a focal colour, they tended to select the most chromatic.

RED: When choosing a volume, British RED had a spread of five hues, smaller than Chinese *HONG* RED with six hues. British RED also includes more yellowish reds.

YELLOW: Yellow was the only primary colour where both cultures agreed and coincided with the NCS unique hue Y. The YELLOW volume had the smallest spread compared with the other seven chromatic colours. British YELLOW covered the same spread of four hues as Chinese YELLOW, although Chinese included more greenish yellows.

GREEN: GREEN covered by far the largest volume and had the largest spread of hues of all basic colours in both languages. British GREEN had a spread of 17 hues, larger than Chinese GREEN with 16 hues. Some colours near the borderline of green and yellow, such as hue G90Y, were more likely to fall within the yellow range. The Chinese subjects chose fewer colours ($N = 1332$) than the British ($N = 1948$).

TABLE IV. Centroids of eight basic colour volumes for Chinese and British subjects.

	TOTAL					CHINESE					BRITISH				
	ϕ'	s	c	N	σ	ϕ'	s	c	N	σ	ϕ'	s	c	N	σ
Red	9.87	12.05	80.61	313	6	7.94	12.84	78.91	175	6	12.32	11.09	82.75	138	5
Yellow	93.94	1.75	68.42	246	5	96.64	2.42	65.39	128	4	91.02	1.02	71.70	118	4
Green	177.85	26.28	47.14	3280	17	183.74	25.34	48.94	1332	16	173.83	26.92	45.90	1948	17
Blue	306.47	22.50	47.06	807	9	308.21	24.68	55.72	173	8	306.48	21.94	44.77	634	9
Orange	48.65	2.90	79.63	348	8	48.43	3.41	77.65	217	8	49.01	2.06	82.90	131	6
Purple	348.73	30.25	42.23	534	6	348.56	29.80	45.92	234	5	348.87	30.60	39.35	300	6
Brown	64.81	48.33	39.43	838	14	59.31	47.37	44.80	256	13	67.23	48.33	39.43	582	11
Pink	396.45	5.75	35.30	475	10	385.25	6.42	40.14	141	7	399.82	5.47	33.29	334	9

Note: N = Number of occurrences, σ = Spread (number of hues covered).

BLUE: British subjects ($N = 634$) chose more BLUE colours than the Chinese ($N = 173$). The volume of British blue covered a spread of 9 hues, larger than the 8 hues for Chinese blue.

ORANGE: The ORANGE centroid hue difference was as small between the two groups as for focal ORANGE (48.43 for the Chinese subjects, 49.01 for the British). The British ORANGE volume had a spread of 6 hues, smaller than Chinese ORANGE with 8 hues. British subjects chose fewer colours ($N = 131$) than Chinese subjects ($N = 217$).

PURPLE: There seemed to be little difference of centroid PURPLE between the two groups. The colour chosen with the largest number of occurrences was R50B. This was also consistent with the mean hue for centroid PURPLE (348.55 for the Chinese and 348.87 for the British). British PURPLE covered a spread of 6 hues, larger than Chinese 5 hues. British subjects also chose more colours ($N = 300$) than the Chinese ($N = 234$).

BROWN: The cultural difference for BROWN was small. The brown colour with the largest number of occurrences was the same, viz. Y30R. The hue difference (59.31 for the Chinese, 67.23 for the British) for the BROWN centroid was as little as that for focal brown. The British BROWN volume had a smaller hue spread than the Chinese. The much larger number for the British ($N = 582$) than for the Chinese ($N = 256$) shows that British subjects tended to use BROWN to cover more colours, but with smaller spread.

PINK: The PINK centroid had mean hue of 385.25 for the Chinese, and 400.18 for the British. The cultural difference was large in hue, but small in chromaticness. The colour with the largest number of occurrences (N) was R30B for the Chinese and R for the British. The PINK volume had a larger spread of hues for the British and covered more colours ($N = 340$) than for the Chinese ($N = 141$). Chinese PINK covered some purples, while British PINK covered some yellows.

Use of Modifiers

Comparison of Seven Pairs of British and Chinese Modifiers. In Experiment I, it was found that some pairs of modifiers seemed to be synonymous with each other. These pairs were further investigated in Experiment II, including four pairs of modifiers used in both cultures: LIGHT vs. PALE, DEEP vs. DARK, BRIGHT vs. VIVID, and STRONG vs. BRIGHT. Also three pairs of culture-specific modifiers were investigated: Chinese STRONG vs. DEEP, Chinese FRESH vs. VIVID, and English MID vs. DULL.

LIGHT vs. PALE: The overall results showed that LIGHT and PALE were not well distinguished. Although the *t*-test showed that British LIGHT YELLOW had a larger chromaticness than PALE YELLOW ($p < 0.05$), and LIGHT GREEN had a smaller blackness than PALE GREEN ($p < 0.01$), and that Chinese *CHEAN* LIGHT GREEN and *CHEAN* LIGHT BLUE had larger chromaticness than *DANN* PALE GREEN ($p < 0.01$) and *DANN* PALE BLUE ($p < 0.05$), respectively, none of the differences reached one visual step.

Figures 4 and 5 plot the centroid of each modifier in 5 hue pages for the British and Chinese subject groups, respectively. A pattern can be found in Fig. 4 that British pale and light reds had the largest chromaticness, followed by pale and light greens. The pattern in Fig. 5 is similar for Chinese subjects, except that Chinese pale and light reds were far less chromatic than British ones. All pale and light colours for both cultures were located between 20–30 on the blackness scale, except for British pale and light red, which both had blackness closer to 40.

DARK vs. DEEP: The visual-step comparisons show that DEEP and DARK may be used synonymously except with green and blue for English and with yellow for Chinese. A persistent difference was that DARK colours were darker and less chromatic than DEEP colours, as suggested by the PCCS and ISCC-NBS systems.

The British results in Fig. 4 show that dark and deep red colours had the largest chromaticness, followed by dark and deep yellow, while dark and deep blue and green colours had the smallest chromaticness. The pattern was similar for Chinese subjects, but deep and dark greens were not so far apart as British greens. Just as the two languages used PALE and LIGHT differently for greens, they also used DARK GREEN and DEEP GREEN in distinctive ways. DARK GREEN was darker and less chromatic than DEEP GREEN for British subjects ($p < 0.01$); whereas they were synonymous for Chinese subjects.

Certain traits appeared in the use of PALE vs. LIGHT and

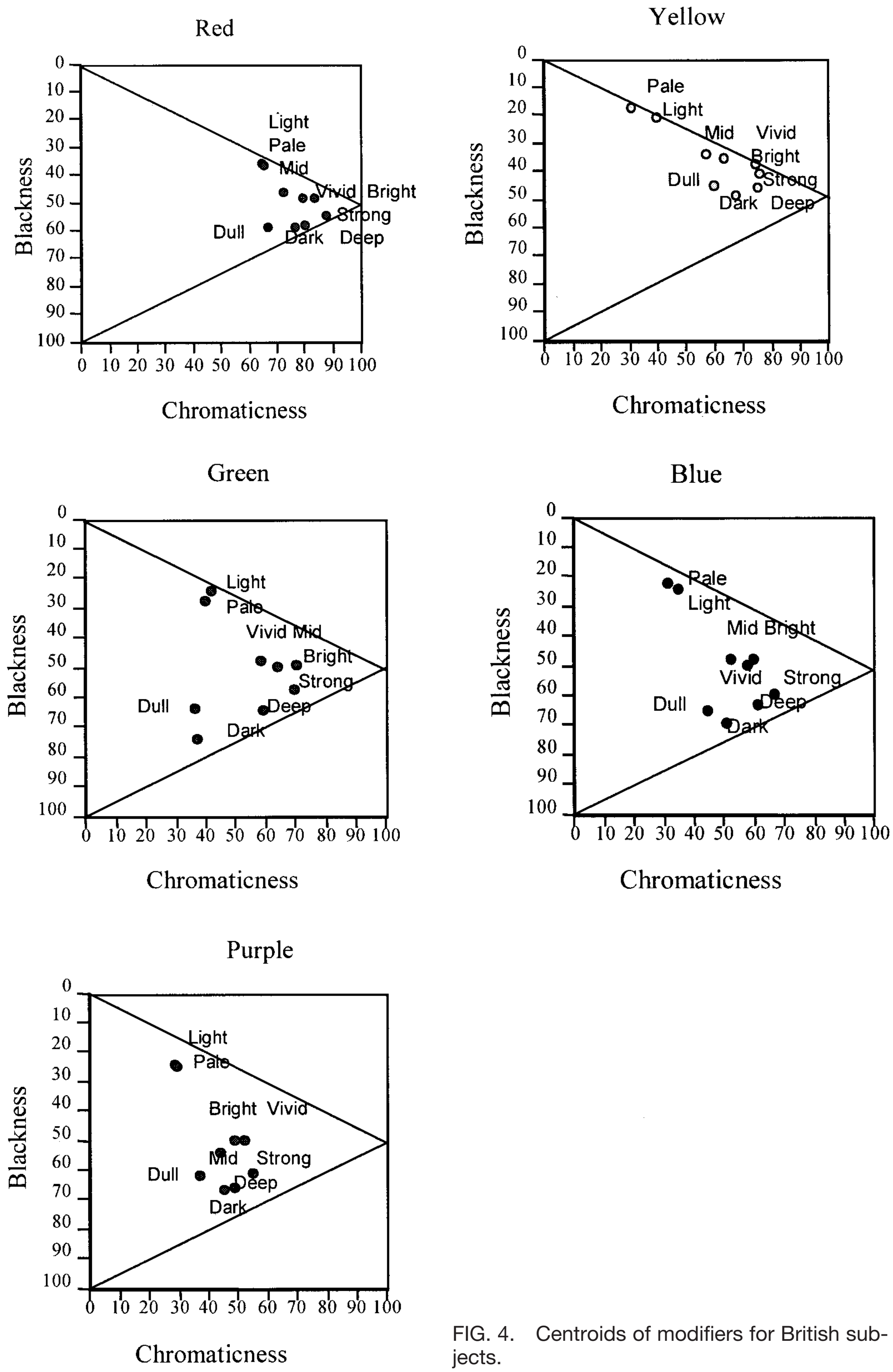

FIG. 4. Centroids of modifiers for British subjects.

DEEP vs. DARK for red and purple, both of which had small volumes in the NCS Atlas. Perhaps in order to differentiate dark red from "brown," the dark red was pushed towards "deep." making deep red and dark red identical. The same may also have occurred for yellow, given that dark yellow tends toward "brown." Purple generally had lower chromaticness than the other hues.

BRIGHT vs. VIVID: The relative positions of BRIGHT and VIVID colours were consistent for Chinese as shown in Fig. 5: "*liang* bright" colours were brighter and less chromatic than "*yann* vivid" colours, except for the green hue. However, this was not the case for British subjects, as shown in Fig. 4, where BRIGHT and VIVID were used synonymously for most hues except yellow. Vivid yellow

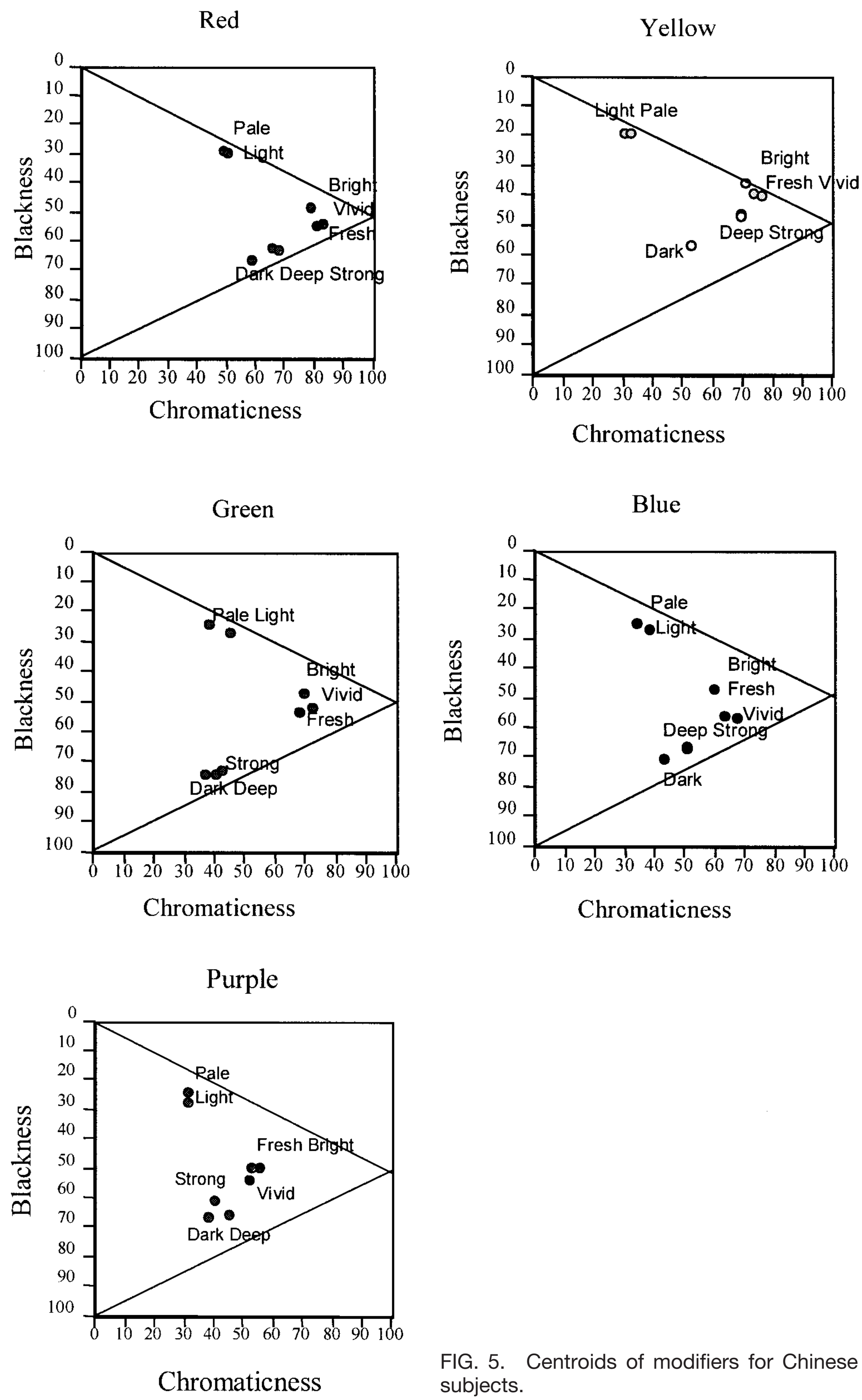

FIG. 5. Centroids of modifiers for Chinese subjects.

was found to have a lower chromaticness than bright yellow, the difference exceeding one visual step.

STRONG vs. BRIGHT: British STRONG colours in Fig. 4 showed a significantly greater blackness than BRIGHT colours. However, for Chinese subjects *JONG* STRONG colour did not coincide in chromaticness with the British STRONG colour. Systematic differences in usage of STRONG and BRIGHT colours between the two languages could be found, i.e., a smaller blackness for bright colours than for strong colours. Chinese subjects showed a much larger variation than British subjects. These two modifiers were not synonyms and could not be used interchangeably.

TABLE V. Mean (*M*) and standard deviation (*SD*) for five Chinese "STRONG" and "DEEP" basic colours.

		STRONG			DEEP				
		M	*SD*	*N*	*M*	*SD*	*N*	*t*	*p*
1. Red (Y90R)	*s*	29.00	14.81	60	29.00	14.81	60	0.00	
	c	67.67	15.22	60	65.67	14.31	60	0.74	.4598
2. Yellow (Y10R)	*s*	12.25	10.50	40	11.58	11.31	57	0.30	.7677
	c	69.00	11.05	40	68.95	10.64	57	0.02	.9812
3. Green (G10Y)	*s*	51.77	15.83	85	53.88	14.55	98	−0.94	.3481
	c	41.77	16.34	85	39.90	14.89	98	0.81	.4199
4. Blue (R90B)	*s*	47.14	12.11	63	41.16	13.58	86	2.78**	.0062
	c	48.73	12.64	63	50.58	13.58	86	−0.85	.3987
5. Purple (R50B)	*s*	50.94	12.54	32	41.11	10.03	54	4.00***	.0001
	c	40.31	8.98	32	44.63	9.26	54	−2.11*	.0375

Note: 1. '*' indicates $p < 0.05$, '**' $p < 0.01$, '***' $p < 0.001$.
2. '+' indicates more than one visual step in NCS.

STRONG vs. DEEP for Chinese Group: Chinese JONG STRONG colours may be quite different from British STRONG colours, being darker and less chromatic. It was found that *JONG* STRONG was actually much closer to *SHEN* DEEP in terms of blackness and chromaticness, as shown in Table V. The results showed that the pair could be used synonymously, as the overall differences were smaller than one visual step.

FRESH vs. VIVID for Chinese Group: SHEAN FRESH and YANN VIVID were frequently used together, indicating that they were not independent in both blackness and chromaticness. The results confirmed that all differences were smaller than one visual step.

MID vs. DULL for British Group: MID was important for British subjects, implying that they had a concept of a range of colours for which MID represented the middle of the chromaticness range. The actual extent of the MID range remains unclear, as only five hue pages were investigated. The meanings of MID and DULL were distinctively different as shown in Table VI, with DULL colours having greater blackness and smaller chromaticness than MID colours.

The most marked difference between British and Chinese usage of modifiers was that the British used MID to describe the colours between LIGHT and DARK, whereas the Chinese had no comparable term. VIVID in British was used for colours with lower chromaticness than in Chinese.

Cultural Comparison of Six Common Modifiers. Each of six common modifiers was compared in five focal hues between the British and Chinese subject groups. The results are summarized in Figs. 4 and 5, in which the centroids are plotted on the NCS gamut triangle.

PALE: Cultural differences in the use of PALE were not significant, except that English PALE had higher chromaticness and higher blackness in red than Chinese *DANN* PALE. In Figs. 4 and 5, all other PALE colours in both languages lie near the top edge of the gamut triangle with blackness in the range 20–30 and chromaticness in the range 30–40.

LIGHT: The usage of LIGHT was frequent in both languages, but not significantly different in green, blue, and purple hues. For red and yellow hues, British LIGHT colours tended to be more chromatic than Chinese *CHEAN* LIGHT colours. In the NCS triangle, all light colours lie close to PALE colours with the highest chromaticness for red.

DEEP: Chinese subjects used "DEEP" most frequently in Experiment I. For the purple hue, its meaning was similar for both languages, but for red, yellow, green, and blue hues, British DEEP had smaller blackness and was more chromatic than Chinese *SHEN* DEEP. In the NCS triangle, all deep colours lie toward the bottom edge except for yellow, with blackness in the range 50–70 and chromaticness in the range 40–70.

TABLE VI. Mean (*M*) and standard deviation (*SD*) for five British "MID" and "DULL" basic colours.

		MID			DULL				
		M	*SD*	*N*	*M*	*SD*	*N*	*t*	*p*
1. Red (Y90R)	*s*	10.00	5.48	21	25.42	9.32	24	−6.64***+	.0001
	c	72.38	6.25	21	66.25	12.09	24	2.09*	.0425
2. Yellow (Y10R)	*s*	5.22	5.93	23	15.19	9.76	27	−4.27***	.0001
	c	56.96	10.20	23	59.26	13.57	27	−0.67	.5070
3. Green (G10Y)	*s*	18.33	8.68	24	45.58	15.17	43	−8.08***+	.0001
	c	57.92	10.62	24	35.81	12.95	43	7.12***+	.0001
4. Blue (R90B)	*s*	21.60	7.46	25	42.86	9.57	35	−9.27***+	.0001
	c	51.60	8.51	25	44.00	11.17	35	2.86**	.0059
5. Purple (R50B)	*s*	31.67	10.50	24	43.21	13.07	28	−3.47**+	.0011
	c	43.75	6.47	24	36.43	11.93	28	2.69**	.0098

Note: 1. '*' indicates $p < 0.05$, '**' $p < 0.01$, '***' $p < 0.001$.
2. '+' indicates more than one visual step in NCS.

DARK: British subjects used DARK most frequently in Experiment I. For green, its meaning was similar for both languages. For red, yellow, blue, and purple, English DARK had smaller blackness and was more chromatic than Chinese *ANN* DARK. In the NCS triangle, all DARK colours except for yellow lie close to, but always less chromatic than DEEP colours near the bottom edge.

BRIGHT: Both languages used BRIGHT consistently in both blackness and chromaticness, and the numbers of bright colours chosen by both languages for the five hues were very similar. In the NCS triangle, all bright colours lie toward the apex at the right, with blackness in the range 40–50 and chromaticness in the range 50–80. Both languages gave BRIGHT RED the highest chromaticness and BRIGHT PURPLE the lowest.

STRONG: The two languages had quite a different concept of "strong" colours consistently across the five hues. The British preferred STRONG for colours with smaller blackness and larger chromaticness than Chinese *JONG* STRONG, i.e., the British used STRONG to mean as chromatic as BRIGHT, but darker by 10–15 NCS units. It was significantly "stronger" than the Chinese, for whom it was almost synonymous with DEEP. It would seem more appropriate to translate "*jong*" to "deep" than to "strong."

Overall the most universal modifier across two languages and five hues was BRIGHT, followed by PALE and LIGHT. Except for red and green hues, DEEP showed no cultural differences. DARK showed differences only in red and yellow hues. STRONG was used in significantly different ways for all five hues between the British and Chinese speakers. It would cause a lot of controversy, if STRONG were included in a universal colour-naming model.

Topology of Modifiers for Two Languages. Unlike their use of basic colour names, British subjects tended to cover a smaller area for the modifiers than the Chinese subjects. This was shown by the smaller number (N) of the colours chosen for each modifier by the British than by the Chinese for five hues.

British modifiers: As shown in Fig. 4, LIGHT and PALE were very close to each other, as were DEEP and STRONG. BRIGHT and DARK were clearly different in blackness and chromaticness. DULL was less chromatic than BRIGHT in most hues. The use of the nine modifiers did not extend to some parts of NCS space, such as the area in the red hue with chromaticness lower than 60. For all hues there was an absence of modifiers for moderate colours, i.e., neither strongly chromatic nor achromatic, with chromaticness in the range 5–30 (greater for medium levels of blackness).

Near the lower edge of the NCS triangle, the three groups of modifiers in descending order of chromaticness and blackness were STRONG, (DEEP and DARK), and DULL. Near the top edge of the triangle, the three groups of modifiers of small blackness in descending order of chromaticness were BRIGHT, VIVID, and (LIGHT and PALE).

Chinese modifiers: A similar pattern to British modifiers is found in Fig. 5, in which some Chinese modifiers could be grouped together. For instance, LIGHT and PALE were mixed and used interchangeably. Two pairs of modifiers – FRESH and VIVID, DEEP and STRONG – were likely to be synonymous. Like the British modifiers, Chinese BRIGHT and DARK were distinctively different in blackness and chromaticness. Some areas of NCS space were not covered at all, such as those in which chromaticness was smaller than 50 in the red hue, or smaller than 30 for the other hues.

Near the lower edge of the modifier triangle, the three groups of modifiers in descending order of chromaticness and blackness were (VIVID and FRESH), (STRONG and DEEP), and DARK. Along the top edge of the triangle, two groups of modifiers of low blackness in descending order of chromaticness were BRIGHT and (LIGHT and PALE).

Comparison with Other Colour-Naming Systems. Although many colour-naming systems use modifiers, their meanings are not the same. The modifiers in the PCCS and ISCC-NBS systems were expressed in Munsell Value and Chroma. A comparison of 11 modifiers in PCCS and ISCC-NBS against the results of Experiment II showed that PCCS might be closer to common linguistic use, because VIVID is used to describe the largest chroma, resembling the results for FRESH and VIVID in Chinese. The three modifiers having Munsell Chroma in descending order are BRIGHT, STRONG, and DEEP, and these were used by British subjects in a similar way. The four modifiers with a smaller chroma in descending order of Munsell Value are PALE, LIGHT, DULL, and DARK. PALE and LIGHT are not much different in either language, but DULL and DARK have different meanings for British subjects. The remaining three achromatic tones (LIGHT GRAYISH, GRAYISH, DARK GRAYISH) are categorized into compound names.

In the ISCC-NBS system most modifiers are not used often, such as BRILLIANT, MODERATE, VERY DEEP, VERY DARK, VERY LIGHT, and VERY PALE. Achromatic modifiers are WHITISH, GRAYISH, and BLACKISH. The other modifiers, such as PALE, LIGHT, DEEP, DARK, STRONG, and VIVID in the ISCC-NBS system, are used in both languages.

Uses of Secondary Names

In the Universal Color Language[8,9] the only secondary names were VIOLET and OLIVE. However, secondary or traditional names were often chosen by other systems for practical or commercial use — the JIS system uses Japanese traditional names for half the colours, and systematic names for the other half, while the ICI "Colour Dimensions" system manages to give every colour a name including a secondary name. Secondary names have also been symbolically used for some specific colours, e.g., OXFORD BLUE and BRITISH RACING GREEN. Some secondary names are derived from dyes, for example, PINK, which was originally a dye similar to YELLOW LAKE and not a colour.[10]

It is possible to make a distinction between naming colour samples and naming object colours in terms of cognitive mechanisms. Davidoff[11] suggested that both types of naming require colour categorization in an internal colour space through different routes, namely the pictorial register and "has a" storage memory. In Experiment I, it was found that subjects from both British and Chinese cultures used secondary names where no object forms were shown, but less frequently than basic colour names. In a more primitive society like the Uzbeks of the Southern USSR, people frequently use the names of objects as colour names, for example, PIG CHEAN or DECAYED TEETH. This may be the reason why it is very difficult for them to sort colours into categories. However, most languages rely on object names as labels for colour names when a more elaborate differentiation is needed within basic colour categories, such as MUSTARD GREEN, LEMON YELLOW, and CHOCOLATE BROWN.

In other words, although the use of object names as secondary colour names is universal, it is subject to cultural variation due environmental differences, dietary habits, etc.[12] Therefore, it is not surprising that in our study the 12 most commonly used Chinese and British secondary names were very different, as shown in Table I. Only FLESH appeared in both languages and the colour was similar, a light brown.

British Secondary Names are compared in terms of the spread of hue, blackness and chromaticness in Table VII. The colours named OLIVE covered the largest spread of hue (14) and blackness (8), suggesting that it may be inappropriate to describe any colour with such an ambiguous name. LILAC had a spread of 8 in chromaticness; MAUVE and FLESH also had a large spread of hues (10), indicating that British people may interpret these terms loosely. According to Zimmer,[13] TURQUOISE is a distinctive German term for a specific region of the spectrum, but its English equivalent shows no such focal hue.

Chinese Secondary Names, as shown in Table VIII, are more vague than British secondary terms in that most cover larger regions of colour space. POWDER was actually spread across all 40 hue pages and was frequently used as a modifier with LIGHT or PALE. Other broad hue spreads were MILK (25), EARTH (16), GRASS (15), WINE (12), COFFEE (11), and SKIN (11). Among these, GRASS had the largest spread of blackness (8), whereas TEA and SKIN had the largest spread of chromaticness (8).

TABLE VII. Spread of twelve British secondary names.

Secondary	Hue (h)	Blackness (s)	Chromaticness (c)
1. MAUVE	10	4	5
2. LILAC	9	4	8
3. TURQUOISE	8	4	6
4. VIOLET	7	6	6
5. SKY	5	2	6
6. MUSTARD	5	5	5
7. OLIVE	14	8	7
8. CREAM	4	1	3
9. BEIGE	9	5	4
10. <u>FLESH</u>	<u>10</u>	<u>2</u>	<u>3</u>
11. LIME	9	3	5
12. SALMON	6	3	6

Notes: 1. Underlined name indicates that it was used by both languages.
2. Ranges: $0 \leq$ spread (h) ≤ 40, $0 \leq$ spread (s) ≤ 10, $0 \leq$ spread (c) ≤ 10.

TABLE VIII. Spread of twelve Chinese secondary names.

Secondary	Hue (h)	Blackness (s)	Chromaticness (c)
1. POWDER	40	4	6
2. EARTH	16	7	7
3. MILK	25	2	5
4. COFFEE	11	7	7
5. GRASS	15	8	7
6. SKIN	11	4	8
7. <u>FLESH</u>	<u>10</u>	<u>5</u>	<u>7</u>
8. RICE	5	3	7
9. IRON	9	7	5
10. WATER	9	3	5
11. TEA	8	7	8
12. WINE	12	7	6

Notes: 1. Underlined name indicates that it was used by both languages.
2. Ranges: $0 \leq$ spread (h) ≤ 40, $0 \leq$ spread (s) ≤ 10, $0 \leq$ spread (c) ≤ 10.

Overall, the broad spread of Chinese secondary terms indicates that they were used more like modifiers rather than designators of specific colours. For instance, MILK was used to describe creamy colours spreading over 25 hues. Because many secondary names have a large spread of hues, blackness, and chromaticness, they could not easily be codified in a universal colour-naming model.

Verification Experiment

Among the four primary hues investigated in Experiment II, only focal YELLOW showed no statistical or perceptual difference between the two cultures. There were systematic differences in blackness for RED, GREEN, and BLUE, as shown in Table III. In one respect, it is not inconceivable that British basic colour terms should be darker than their Mandarin counterparts. The phenomenon of "darkening" is well known, and has been studied specifically by MacLaury.[14,15] It was surmised by the authors of the present study, however, that a more likely explanation was that, because the Chinese subjects undertook the experiment with a white surround, not with the gray surround of the VeriVide viewing cabinet, a simultaneous contrast effect served to darken the colours they perceived.

Therefore, a verification experiment was carried out to check this point, with 10 Chinese subjects (all Taiwanese students studying in the UK) repeating the same procedure of Experiment II under exactly the same conditions as the British subjects had encountered previously, i.e., using the VeriVide cabinet. There is an epistemological issue in the design of the verification experiment, in that it involved Mandarin speakers resident in England, who were bilingual and separated from their native culture. Caskey–Sirmons and Hickerson[16] found that such a displacement may influence the meaning of basic colour terms. Thus, it is arguable that, to perform a proper corrective, the verification experiment should instead have tested British subjects in England against white surrounds.

The results of the verification experiment are shown in Table IX, with the results of the British subjects copied from Table III for comparison, and it is clear that the systematic differences in blackness (*s*) for focal red, green, and blue colours between the two groups have become negligible. The focal pink and orange colours for both groups were also very close. Focal brown colours were the only ones for which a significant difference remained between the groups, in both blackness and chromaticness.

The cultural differences for strong colours remained consistent with the results of Experiment II. The Chinese strong colours were darker and less chromatic than the British strong colours, as shown in Table X. The results of Experiment II showed that there are systematic cultural differences in focal colour and colour volumes for some of the names studied. The largest difference occurred in lightness (blackness), where most Chinese results appeared to be lighter for most of the names studied. However, this difference was not evident in the results of the Verification Experiment, e.g., for focal green, focal blue, focal pink, pale red, light red, and light yellow. Of the pale and light colours, the only cultural difference remaining was that British pale green had a higher chromaticness than Chinese pale green. Most dark colours were close between the two groups, except that Chinese dark red was darker than British dark red. The bright colours were close between the two cultures, except that Chinese bright green was brighter than British bright green.

The comparison between British and Chinese groups in the verification experiment showed that most of the cultural differences in colour naming had disappeared. This result could have been due to the smaller number of subjects used in verification experiment, or its design (see above), but was more likely due to the influence of surround lightness in the original experiment, which was different for the two groups.

DISCUSSION

During Experiment II, British and Chinese colour names from three name categories were investigated. First, it was

TABLE IX. Comparison of mean (*M*) and standard deviation (*SD*) for eight basic names between Chinese and British subjects (verification experiment).

	CHINESE					
	N = 10		N = 20		BRITISH	
	M	*SD*	*M*	*SD*	*t*	*P*
1. RED						
ϕ'	10.00	6.67	16.50	6.71	−2.51*	.0183
s	7.00	4.83	6.00	5.03	0.52	.6071
c	89.00	3.16	89.00	3.08	0.00	
2. YELLOW						
ϕ'	98.00	4.22	93.50	8.13	1.63	.1134
s	0.00	0.00	0.00	0.00		
c	78.00	4.22	81.00	5.53	−1.51	.1431
3. GREEN						
ϕ'	187.00	6.75	188.00	27.07	−0.11	.9099
s	15.00	15.09	14.50	13.95	0.09	.9288
c	74.44	10.14	72.50	11.80	0.45	.6597
4. BLUE						
ϕ'	313.00	8.23	313.00	12.18	0.00	
s	19.00	7.38	20.00	7.95	−0.33	.7421
c	65.00	7.07	68.00	5.23	−1.32	.1988
5. ORANGE						
ϕ'	42.00	11.35	46.00	10.95	−0.93	.3594
s	0.00	0.00	0.00	0.01	0.00	
c	87.00	4.83	89.00	3.08	−1.38	.1774
6. PURPLE						
ϕ'	349.00	7.38	350.50	15.38	−0.29	.7738
s	29.00	3.16	28.00	5.23	0.55	.5845
c	60.00	0.00	56.50	5.87	1.87	.0722
7. BROWN						
ϕ'	68.00	13.17	67.00	18.09	0.16	.8780
s	46.00	15.78	56.50	7.45	−2.50*+	.1860
c	50.00	13.33	36.00	8.83	3.45**+	.0018
8. PINK						
ϕ'	393.00	15.67	399.50	20.64	−0.88	.3891
s	3.00	4.83	3.10	4.64	−0.06	.9566
c	37.00	15.67	33.00	15.93	0.65	.5198

Notes: 1. '*' indicates $p < 0.05$, '**' $p < 0.01$, '***' $p < 0.001$.
2. '+' indicates more than one visual step in NCS.
3. 'N' indicates the response number, e.g. 10 for Chinese brown.
4. Ranges: $0 \leq \phi' \leq 400$, $0 \leq s \leq 100$, $0 \leq c \leq 100$.

TABLE X. Comparison of mean (*M*) and standard deviation (*SD*) for STRONG basic colours between British and Chinese groups (verification experiment).

		BRITISH			CHINESE				
		M	*SD*	*N*	*M*	*SD*	*N*	*t*	*p*
1. Red (Y90R)									
	s	10.83	2.82	24	28.50	17.33	10	−4.94***+	.0001
	c	87.50	4.42	24	71.50	17.33	10	4.28***+	.0002
2. Yellow (Y10R)									
	s	2.69	4.52	26	15.00	17.16	10	−3.43**+	.0016
	c	75.77	5.78	26	72.00	15.49	10	1.08	.2880
3. Green (G10Y)									
	s	22.73	11.80	33	50.50	17.07	10	−5.86***+	.0001
	c	69.09	8.79	33	46.50	18.86	10	5.32***+	.0001
4. Blue (R90B)									
	s	25.93	7.47	27	39.00	15.24	10	−3.51**+	.0013
	c	66.30	5.65	27	57.50	17.20	10	2.38*	.0230
5. Purple (R50B)									
	s	33.20	6.27	25	46.50	12.92	10	−4.13***+	.0002
	c	54.80	7.14	25	43.50	11.56	10	3.52***+	.0013

Notes: 1: '*' indicates $p < 0.05$, '**' $p < 0.01$, '***' $p < 0.001$.
2: '+' indicates more than one visual step in NCS.

found that, for the 11 basic names mapped in the NCS Atlas using focal and volume colours, achromatic colours appeared to be the most consistent, followed by YELLOW. This appeared to be a shared attribute for both languages. In fact, yellow was the only primary colour having a close agreement with the NCS unique hue Y. Second, 8 Chinese and 9 English modifiers in 5 constant hues were examined; PALE and LIGHT appeared to be synonymous in both languages, and BRIGHT colours appeared to be the same in both languages. Third, the large spread of hue, blackness, and chromaticness for secondary names from this experiment indicated a large difference between the most frequently used 12 British and 12 Chinese secondary names.

Eleven Chinese Basic Colours

In Experiment I, Chinese colour names were translated into English to investigate the universality of colour language. It was found that the Chinese have 16 basic names including two reds (*HONG* and *JU*), two oranges (*JYU* and *CHEN*), two greens (*LIUH* and *CHING*), two blues (*LAN* and *DIANN*), and two browns (*ZONG* and *HUR*), although, as previously discussed in Part I, the second term of each of the five pairs may be considered recessive, and hence not a basic name.

The results of Experiment II showed that three pairs of colour words were more likely to be synonymous: *LIUH* GREEN vs. *CHING* GREEN, *LAN* BLUE vs. *DIANN* BLUE, and *ZONG* BROWN vs. *HUR* BROWN. *JU* RED has the same hue as *HONG* RED, but it is darker and weaker; whereas *CHEN* ORANGE is yellower than *JYU* ORANGE. *HONG* RED, *JYU* ORANGE, *LIUH* GREEN, *LAN* BLUE, and *ZONG* BROWN were used with a smaller standard deviation (*SD*) than the counterpart in each of the 5 pairs. These terms had a closer resemblance to the values of the corresponding 5 English basic colours, and so are chosen as the equivalents of English RED, ORANGE, GREEN, BLUE, and BROWN.

On the other hand, no synonym was used for WHITE, BLACK, or GRAY. These achromatic names were used consistently by both languages, whatever the focal colour. The universal use of the achromatic colours has a survival significance in recognition of forms or patterns.[6] For example, people with colour deficient vision can still manage by recognizing the distinction between light and dark colours and the effects of different shades.

Cultural Comparison of Eleven Focal Colours

From the results of Experiment II, among the four primary hues only focal YELLOW showed no cultural difference. English RED appeared yellower and lighter than Chinese *HONG* RED. English GREEN was lighter than Chinese *LIUH* GREEN. English BLUE was lighter than Chinese *LAN* BLUE. Among the other basic names, focal ORANGE and PURPLE showed no cultural differences. English BROWN was darker and less chromatic than Chinese *ZONG* BROWN, whereas English PINK was less purplish and less chromatic than Chinese *FEEN-HONG* PINK. In comparison, Chinese *ZONG* BROWN had a much larger standard deviation than English BROWN.

The mean hues of three primary basic colours found in this experiment also differed from the three NCS unique hues. Perceived red and green were both yellower, and perceived blue was redder than the unique equivalent, but the degree of variation was not large. The colours chosen for GREEN showed a very large standard deviation for both languages and the results confirmed that green colours occupied larger colour volume than the other basic colours, as found in Experiment I.

Cultural Comparison of Eleven Basic Colour Volumes

When a colour volume was selected, the cultural differences varied although the average colours selected were generally less chromatic than the focal colours. The cultural difference for the red centroid was smaller than for focal red, whereas the cultural difference for the green centroid was larger, implying that the boundary between yellow and green was vague. The British green centroid was much yellower than the Chinese green centroid. The ORANGE and PURPLE centroids showed no cultural differences, whereas the British PINK centroid was less purplish than the Chinese *FEEN-HONG* PINK centroid, and the same pattern was shown for the focal pink difference between the two languages. For British subjects, with pink and brown hues, the focal and centroid colours were almost the same.

Some researchers have suggested that the environment may have a significant effect on colour naming.[10] Others have speculated that the boundary between colour names might be subject to the environment that shapes people's colour lexicon.[17] Even though people everywhere have a similar physiological response to colour stimuli (subject to observer metamerism and colour-deficient vision), exposure to specific colorants and coloured objects should certainly be one factor affecting how people learn colour names. McNeil suggested that the areas mapped for basic colours are less affected by words imported from other languages, whereas focal colours can be directly associated with learned vocabulary.[18] If this were the case, the hue differences of the 11 colours between the two languages in the present study should be smaller for the centroids of colour volumes than for the foci. Comparing Tables IV and III, the results support this proposition for the four primary colours plus orange and purple; only for pink and brown does it not hold.

About Modifiers

The results of Experiment I showed that some colours, such as green, were more often associated with modifiers. In Experiment II, GREEN was found to contain a broad spread of hues. The use of many modifiers could cover the large space of GREEN. The same could be said of BLUE. English BLACK, however, is not associated with any modifier.

By comparing four pairs of English and Chinese modifiers, it was found that the differences between PALE and LIGHT were within one visual step in all three NCS attributes, i.e., the two terms were not well distinguished. The visual-step comparison confirmed that DEEP and DARK had similar meaning except with English GREEN and BLUE; and in Chinese YELLOW. Moreover, the pair BRIGHT and VIVID was used synonymously except with English YELLOW. On the other hand, BRIGHT colours were found to be different from STRONG colours in blackness and chromaticness for all five hues for both languages. The use of STRONG is different between the two cultures. Chinese subjects used the modifiers STRONG and DEEP similarly for the five hues, likewise FRESH and VIVID. British subjects used MID and DULL with varying meanings of blackness and chromaticness for the five hues.

Of six commonly used modifiers, only BRIGHT had a universal meaning for all five hues. LIGHT and PALE were used similarly for many hues except red. English DEEP had a smaller blackness and larger chromaticness than Chinese DEEP, as did DARK and STRONG. From inspection of Figs. 4 and 5, all modifiers appear to be contained in the NCS blackness-chromaticness plane by a triangle with vertices at (English STRONG or Chinese VIVID), (PALE or LIGHT), and (DEEP or DARK).

About Secondary Names

There is a universal tendency to use secondary names to describe colours, for instance, Dani people use "FRESH LEAF" for green and "CUT ORCHID-FIBRE" for yellow. However, the large variety of secondary terms in different languages shows that these terms are culture-dependent.

The large spread of hues for the top 12 British and 12 Chinese secondary terms found in this study suggests that it would be inappropriate to include secondary terms in a colour-naming system. For instance, Chinese POWDER appeared in 40 hues and MILK in 25 hues, making the terms so vague as to render them useless for colour specification. People usually take secondary terms for granted as colour names and are unaware of their limitations. If people used secondary terms alone, out of context and without mentioning basic colours, it would give no clue at all as to the meaning. The sole use of secondary terms would, therefore, be inappropriate in a colour-naming system. However, since their relative occurrence was low, as shown in Part I, it is unlikely that this restriction would prove to be problematic. The simple colour-naming model developed in Part III, therefore, codifies only the 11 basic colour names.

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