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WEIGHTING THE RELEVANCE OF THE DIFFERENT COLOURS IN SUBJECTIVE ASSESSMENTS OF COLOUR PREFERENCE

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ABSTRACT

Observers made subjective colour preference judgements about different arrangements of coloured objects in different scenes. While doing so, observers had to assess the importance (so-called weight) of every one of seven colour groups or hue groups (skin tone, red, orange, yellow, green, blue and purple). The scenes were illuminated by high-CRI spectra at four different correlated colour temperatures (CCTs). Red and orange obtained the highest weights (this means that red and orange are the most important colours for subjective colour preference); yellow, green and blue were intermediate while skin tone had only a little weight. CCT had only a small effect while scene content (e.g. "office" vs. "painting") had a strong influence. Objects of higher chromaticity in the same colour group obtained a higher weight across the different scenes. Latter finding resulted into a predicting formula of the weights.

Keywords: colour preference, different hue groups, weighting colours, scene content, object context, colour preference model, hue dependence

1. INTRODUCTION

The subjective impression of *colour preference* has gained much attention in lighting research. Its definition can be formulated as the subjective extent of how an observer *likes* the colour appearance of the coloured objects in the room [1] depending on the viewing context or the application field of lighting [2]. Colour preference is known to be influenced by the following physical parameters of the lighting system: the chromaticity and hue of the object colours under the actual light source spectrum, the value of the colour fidelity index [3], the size of the colour gamut [4, 5], the shape of the colour gamut [6], the correlated colour temperature (CCT) of the light source [7, 8], and the characteristic *illuminance level* (in lx) [9-11] at the different surface in the room on which the coloured objects are arranged.

While subjects are making their colour preference judgements, they are scrutinizing the coloured objects in the room, paying more or less attention to the different colour categories or colour groups (e.g. red, orange, yellow, green, blue, purple) of the coloured objects in the illuminated scene. In other words, the different colour groups obtain different "weights" from the subjects. This "weighting" is the subject of the present article.

The issue of "weighting" is dealt with in literature as follows. Judd [12] used the following weights (W) in the definition of the so-called *flattery index* (a kind of colour preference index). He assigned the weight W=5 to the CIE test colour samples TCS-1 and TCS-3 to TCS-8, the weight W=15 to TCS-2 (dark greyish yellow) and TCS-14 (moderate olive green or leaf colour). He assigned the highest weight of W=35 to TCS-13 (i.e. to light yellowish pink or skin tone). However, these weight values were putatived, they did not result from visual experiments. Saturated object colours (red, yellow, green, blue and purple) were not included in the definition of the *flattery index* (see Table II in [12]).

Table 1. Percentage of Times that Each Hue Was Ranked in the Top Three Positions of Importance under Warm White and Cool White when Subjects Judged Colour Rendition [13]

Colour	Red	Orange	Yellow	Chartreuse	Green	Cyan	Blue	Purple
Warm white	91	69	71	12	27	8	2	20
Cool white	90	64	74	15	27	7	2	21

Table 2. Overall Mean Weights (W_i) and their STD Values for All Observers and All Scenes (i=1-7) in the Present Article

Colour (i)	W_i	STD	W_i'	C_i	W_i^*	[13]	[14]	[15]	[16]	[7]
1: brown/skin	1.69	1.11	1.72	24.1	0.50	–	0.75	–	–	–
2: red	3.40	1.10	3.36	68.5	1.00	1.00	1.00	1.00	1.00	1.00
3: orange	3.48	1.30	3.65	64.6	1.03	0.73	1.25	0.50	0.89	0.72
4: yellow	2.68	1.30	2.75	53.1	0.79	0.80	0.50	0.33	0.19	0.15
5: green	2.81	1.16	2.76	46.6	0.83	0.30	0.50	0.61	0.86	0.47
6: blue	2.89	1.19	2.80	45.6	0.85	0.02	0.50	0.28	0.35	0.37
7: purple	2.22	1.21	2.24	34.5	0.65	0.23	0.25	0.22	0.46	0.43
r_1						0.58	0.58	0.69	0.68	0.72
r_2						0.63	0.63	0.62	0.64	0.68

Note to Table 2. W_i': overall mean weights excluding the painting; C_i: characteristic CIECAM02 chromaticity value of a colour group resulting from the spectral measurements; last columns: comparison with the weights (relative to red) from the references [7, 13-16] indicated in the top row; W_I^*: W_I value, relative to red (red=1.00); r_1: Pearson's correlation coefficient between the weight from literature and the present W_I data (brown/skin was only included in case of ref. [14]); r_2: Pearson's correlation coefficient between the weight from literature and the present data excluding the painting.

In a more recent work, Rea and Freyssinier [13] obtained the percentages of times that each hue was ranked in the top three positions of importance under warm white and cool white illumination when the subjects judged the naturalness and vividness of coloured objects (fresh fruits, vegetables and a colour chart) illuminated by different light sources. The resulting weights of the different colour groups of the objects are listed in Table 1. (More precisely, the question asked of the observers was to rank the top three hues within the observed scene that most influenced their opinion [13]). As can be seen from Table 1, red-orange-yellow objects turned out to be most important and correlated colour temperature had only a slight influence on the weights.

In another experiment [14], a secondary task of the observers was to prioritise eight coloured objects (real objects, not artificial ones) in a scene according to their relevance while making a judgement about the *similarity* of colour appearance under two light sources (in a visual colour fidelity experiment). Subjects had to assign the numbers 1 (highest), 2, 3, 4 and 5 (lowest) only to five objects (to those considered most relevant) out of the entire set of eight objects. The following median values (in parentheses) were obtained: orange (1), red rose (2), own hand (3); lemon, banana, lettuce, blue-lilac rose (4), purple onion (5). This finding, in turn, emphasizes the important role of red-orange objects, see Table 2. Table 2 will be further explained and discussed in Sections 2, 3.

In a further study [15], eighteen participants made colour preference assessments of coloured objects (colourful textiles, colour chart, beverage cans, fruits) in a viewing booth [15]. The colours red, green, and orange influenced the participants' assessments most strongly (see Table 2). In another experiment [16], subjects rated a room filled with various coloured objects on three scales including saturated–dull, normal–shifted, and like–dislike. The percentage of the subjects who included a certain colour group in the top three most important ones when making these assessments equalled about 74 % for red, 66 % for orange, 14 % for yellow, 64 % for green, 26 % for blue, 34 % for purple and 14 % for white (by reading approximate percentage values from the diagram [16]). This finding accentuated, in turn, the importance of red and orange, generally playing a more important role than the other hues. Green also obtained a high percent-

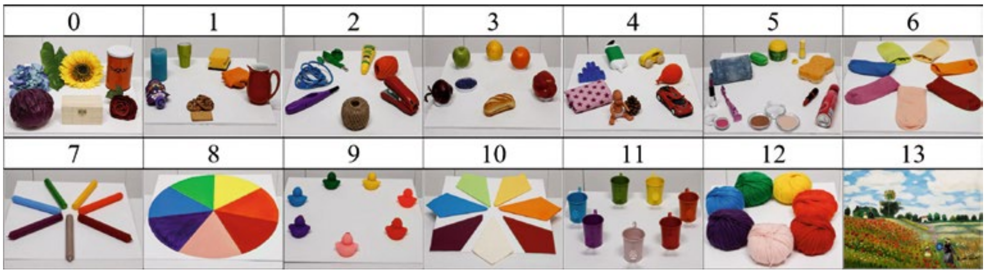

Fig. 1. Scenes arrangements of coloured objects or painting (upper row, from left to right: 0-training scene, 1-kitchen; 2-office; 3-food; 4-children's room; 5-bathroom; 6-textiles; lower row, from left to right: 7-candles; 8-colour circle; 9-ducks; 10-napkins; 11-watering cans; 12-wools; 13-painting (a hand-painted reproduction of Monet's poppy field))

age, possibly, because there were also some saturated green objects in the observed scene, see Table 2.

In another study [7], subjects rated the appearance of a room under different illuminating conditions concerning whether they felt that the lighting made the colour of the objects appear normal or shifted, saturated or dull, and whether their overall opinion was that they liked or disliked the way the lighting made the objects appear. Objects of various colours included printed artwork, clothing, various coloured consumer goods with packages, containing inks or dyes, and natural objects such as flowers. The percentage of the subjects who included a certain colour group in the top three most important ones when making these assessments equalled about 94 % for red, 68 % for orange, 14 % for yellow, 44 % for green, 35 % for blue, 40 % for purple, and 12 % for white (by reading approximate percentage values from the diagram [7]), see Table 2.

The above findings corroborate that the *weights* W_i of the different colour groups (e.g. *i*=red, orange, yellow, green, blue etc.) have a significant influence on colour preference judgements and this should be considered in the definition of a colour preference index *CP*. This definition can be written e.g. in the form of equation below

$$CP = (W_1 \cdot CP_1 + W_2 \cdot CP_2 + ... + W_N \cdot CP_N) \qquad (1)$$

In Eq. (1), the symbol W_i means the weights of the different colour groups ($i = 1..N$) and CP_i means a special colour preference index defined for each *i number* of colour group. Despite their importance, weights are not considered in today's widely used colour rendition metrics. The dependence of the weights on *object scene composition* (e.g. the presence of saturated green objects in the scene or the inclusion of objects with strong cognitive clues like paintings) combined with the effect of the CCT of the light source has not been investigated systematically. Accordingly, the aim of the present article is to answer the following questions:

1. What are the weights of the different groups of coloured objects (e.g. red, orange, yellow, green, etc.) in a colour preference task? A colour preference metric should consider this weighting, see the general Eq. (1);
2. Is the effect of CCT significant? Table 1 does not suggest a significant CCT effect;
3. Does the composition of the scene with the coloured objects affect the weights of the different colours?

The scene may e.g. contain a painting possibly with strong cognitive or emotional clues for the subject or the emotionally more neutral objects of an office. The scene can also be filled with more or less saturated objects in a certain hue group, and these chromaticity differences might influence the weights of the different colours. E.g. if *saturated* green happens to be included to represent the green hue group then this might obtain a higher weight.

To answer the above questions, a visual psychophysical experiment was carried out, see Section 2.

2. EXPERIMENTAL METHOD

Observers had to consider whether and to what extent they *liked* the colour appearance of one of twelve different arrangements of coloured objects plus a painting (so called scenes, see Fig. 1) under the current correlated colour temperature levels, 3200 K, 4200 K, 5000 K or 5500 K of the light source illuminating the scene. While considering this, subjects had to assess on the rating scale of the questionnaire *how much attention* they were paying to each one of the following colour groups (briefly: colours): brown or skin tone (this was considered as a single category): red, orange, yellow, green, blue and purple (see Fig. 2). Observers had to mark *only one* rating category for each colour, 0

Table 3. Gender (G), Age (A in Years) and Cultural Background (C) of the Individual Observers (g: German, c: Chinese, v: Vietnamese)

O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
G	f	m	m	f	m	m	m	m	m	m	f	m	m	m	m	m	m	m	m	m	m	f	m
A	34	29	24	25	24	23	25	21	47	33	31	28	27	30	31	33	27	22	36	24	26	24	53
C	g	g	g	g	g	g	g	g	g	g	c	g	g	g	g	v	g	g	g	g	g	g	g

Table 4. Colorimetric Properties of the Four Spectra (3200 K, 4200 K, 5000 K, and 5500 K) Used in the Experiment

CCT level	3200 K	4200 K	5000 K	5500 K
R_a	95	96	95	95
R_f	92	91	91	91
R_g	105	103	103	104
Duv	–0.0006	–0.0003	0.0017	0.0019
CCT (K)	3228	4184	5000	5541

for “not any”, 1 for “very little”, 2 for “little”, 3 for “some”, 4 for “much” or 5 for “very much”. These ratings will be called the “*weights*” of the individual colours (as mentioned in the Introduction). Every scene was constructed from different coloured artificial objects (except the painting which was purchased as a whole) so that all scenes contained all seven colours.

Observers had to fill a separate questionnaire for every one of the 13 scenes and for every one of the 4 CCTs. The coloured objects and the painting were arranged on a white plate on the horizontal plane of the table on which the horizontal illuminance equalled 2300 lx ± 4% (maximal difference) across the four CCTs and the different positions on the table. The reason of choosing this high illuminance level was the intent of investigating the weights at the *best* level of colour preference i.e. in case of >2000 lx according to a previous finding [11]. The four CCTs equalled 3228±55 K, 4184±110 K, 5000±24 K, and 5541±114 K measured on a horizontal white standard on the table. The ± sign indicates maximal CCT differences across different positions on the table (see Fig. 1).

Twenty three observers (4 women and 19 men) took part in the experiment (see Table 3), 21 German, 1 Vietnamese and 1 Chinese. All of them are living for at least three years in Germany at the time of the experiment. All observers were co-workers of the Laboratory of the authors showing interest for and having (more or less) experience in lighting engineering. They were aged between 21 and 53 years (mean 29.4). All observers had good or corrected visual acuity and normal colour vision.

After entering the experimental room (with white painted walls), the subject had to adapt for 2 minutes to a randomly selected initial CCT. In this period, the task and the questionnaire were explained. Then, the subject had to look at scene No. 0 (training scene, see Fig. 1) under this CCT for 30 seconds and then fill the questionnaire (Fig. 2). After this, the 13 scenes were looked at (every scene for 30 seconds) and assessed (with no time limitation) one after each other. After this, the next randomly chosen CCT followed and the subject had to adapt to it for 2 minutes and carry out the above *weight assessment* procedure. Every subject assessed every scene under every CCT once (there were no repetitions).

The four spectra (3200 K, 4200 K, 5000 K and 5500 K) were generated by a stable, high-pow-

	Not any 0	Very little 1	Little 2	Some 3	Much 4	Very much 5
Brown or skin tone						
Red						
Orange						
Yellow						
Green						
Blue						
Purple						

Fig. 2. Questionnaire to assess the degree of attention (this is called *weight* in the present article) paid to the individual colour groups (briefly: colours) while considering the preference of the colour appearance of the arrangements of coloured objects or the painting (so-called scenes, see Fig. 1)

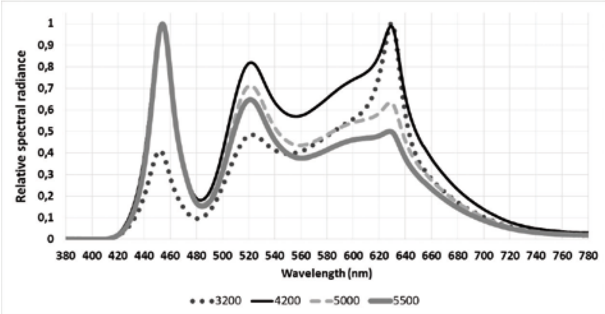

Fig. 3. Relative spectral radiance of the four spectra (3200 K, 4200 K, 5000 K, and 5500 K) used in the experiment

er, high-end, four-channel LED engine comprising red, green, blue, and warm white LED channels. Fig. 3 shows their relative spectral radiance. Table 4 shows the colorimetric properties of these spectra. As can be seen from Table 4, every spectrum had a high colour fidelity index (R_f= 91-92) with a white point in the neighbourhood of the blackbody or daylight loci ($|Duv|<0.002$).

The spectral reflectance of the coloured objects in the scenes (see Fig. 1) was measured at them illuminating by a halogen lamp. The 1° measuring field of a Konica-Minolta CS 2000 spectroradiometer was used. First, we measured the spectral radiance of a horizontal white standard on the table and then we replaced the white standard by the object, measured the spectral radiance of the object at the same position, and calculated the spectral radiance factor. We repeated this procedure for every object and every scene. Thirty-two characteristic surface elements (that represented the seven colour groups, see Fig. 2) were measured in case of the painting. Fig. 4 shows the spectral radiance factors of the objects of the "kitchen" scene as an example.

From the measured spectral reflectance curves, the CIECAM02 *H*, *C* and *J* values were computed for all measured coloured surfaces with the following CIECAM02 parameters: D=1 (forced), F=1.0, c=0.69, and N_c=1.0 (average surround). Fig. 5 shows the measured colours of the objects in the 13 scenes in a CIECAM02 *H-C* diagram under the 3200 K spectrum, as an example.

3. RESULTS AND DISCUSSION

3.1. Overall Mean Weights of the Colours and Inter-Personal Differences

Table 2 contains the overall mean weights of the seven colours, their standard deviation (STD) values, characteristic chromaticity values of the different colours resulting from the spectral measurements (Section 2) as well as the literature data described in Section 1 for a comparison. As can be seen from Table 2, red and orange obtained the highest mean ratings (3.4 – 3.5 i.e. between "some" and "much"), yellow, green and blue were intermediate (2.7 – 2.9 i.e. "some"), purple had a smaller weight (2.2 i.e. "little") while brown/skin exhibited "little" - "very little" (1.7). It can also be seen from Table 2 that the overall standard deviation (STD) of the weights found by the observers (representing inter-observer variability) across all CCTs (4), scenes (13) and colours (7) equalled to 1.3.

Considering the scenes separately, the highest overall STD occurred in case of No. 13 i.e. the painting (1.5), possibly, due to the high cognitive inter-personal differences when assessing this more complicated and more emotional pictorial content (Monet's poppy field) compared to the lowest STD (1.2) of the decorative, simplistic arrangement of No. 4 (children's room). We also calculated the overall mean ratings excluding the painting (W_i' in the fourth column of Table 2) and obtained slightly different values from those including the painting (W_i

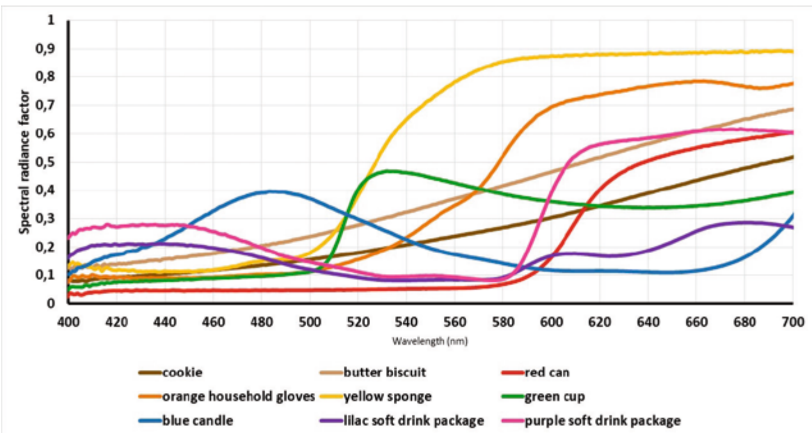

Fig. 4. Spectral radiance factors of the objects of the "kitchen" scene, Fig. 1

Table 5. Result of a Three-Way ANOVA With SPSS(R) Effect Size Estimation (Partial Eta Squared, η^2)

Variables	df	*F*	sig.	partial eta squared, η^2
CCT	3	8.747	0.000	0.003
Scene	12	19.109	0.000	0.030
Colour	6	384.351	0.000	0.234
CCT * Scene	36	0.568	0.982	0.003
CCT * Colour	18	2.927	0.000	0.007
Scene * Colour	72	24.191	0.000	0.188
CCT * Scene * Colour	216	0.602	1.000	0.017

in the fourth column of Table 2). The overall STD values of the weights among the four CCTs ranged between 1.27 and 1.36. Considering the colours separately, yellow and orange exhibited an overall STD of 1.3, brown/skin and red about 1.1 and green, blue and purple about 1.2.

The last columns of Table 2 compare the mean weights W_i with literature data from the references described in the Introduction. These data were transformed into relative weight values related to the weight of the red colour group (=1.00). In case of reference [13], we calculated the average of the warm white and cool white data from Table 1 [13] and found a moderate positive correlation with the W_i data of the present article (r_1=0.58; see Table 2). For reference [14], we subtracted the median *priority* data from 6 and then related them to red, see Table 2. A moderate positive correlation (r_1=0.58) was found between these data and the W_i data of the present article. In case of references [7, 15, 16], moderate-good correlations (with r_1 values between 0.68 and 0.72) were found.

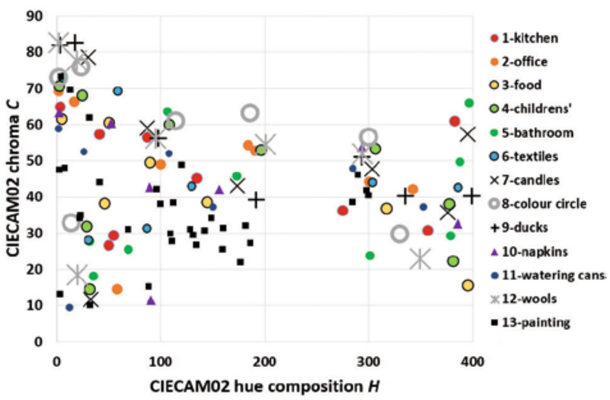

Fig. 5. Colours of the objects of the scenes in the CIECAM02 *H*-*C* diagram under the 3200 K spectrum, Fig. 3 (*H*=0 and *H*=400: unique red, *H*=100: unique yellow, *H*=200: unique green, *H*=300: unique blue)

The differences between literature data and the present paper's findings may have the following reasons:

1. Difference between the tasks, e.g. similarity judgement of colour appearance between two light sources [14] vs. colour preference assessment under one given light source;
2. Viewing cube [14] vs. free viewing (present article);
3. Difference between the choice of the coloured objects being assessed (e.g. several saturated green objects were included in [16]).

We also computed Pearson's correlation coefficients between the present result *excluding* the painting and literature data; see the last row of Table 2. We denoted this by r_2 (in contrast to r_1 which *includes* the painting). The difference between r_1 and r_2 was not significant for any one of the five literature data (p>0.88 with Fisher's r-to-z, two-tailed).

3.2. Combined Effect of the Independent Variables Colour, Scene, and CCT

Table 5 contains the result of a three-way ANOVA with SPSS(R) effect size estimation.

As can be seen from Table 5, although the effect of CCT on the subjects' ratings was significant, its effect size is small (0.003). The largest effect (0.234) took place in case of the independent variable "colour" while the variable "scene" also exhibited a considerable effect (0.030). The interactions CCT*colour (small effect size 0.007) and scene*colour (large effect size 0.188) turned out to be significant.

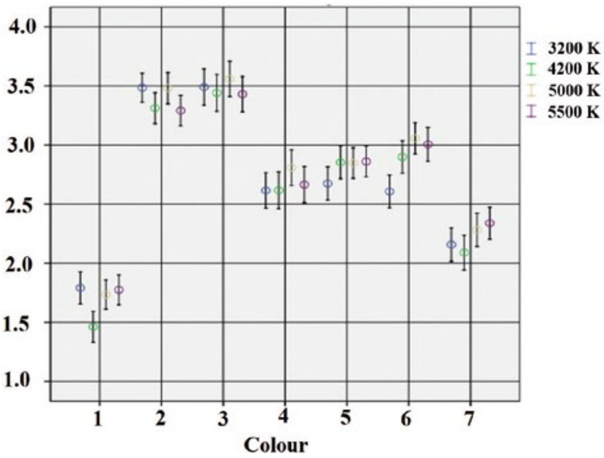

Fig. 6. Weak $\eta^2 = 0.003$ but significant effect of CCT on the weights for the different colours (ANOVA; df=3, F=8.747; p<0.0001)
(1: brown/skin; 2: red; 3: orange; 4: yellow; 5: green; 6: blue; 7: purple; intervals represent 95% confidence intervals (inter-personal variability) of the mean weights)

3.3. Effect of CCT

The weak but significant effect of CCT $\eta^2 = 0.003$ on the weights is shown in Fig. 6.

Two pairs of non-overlapping confidence intervals can be seen in Fig. 6:

1. "Brown/skin" (No. 1) obtained a lower weight (i.e. less attention when the subjects judged colour preference) in case of 4200 K than in case of the other CCTs;

2. "Blue" (No. 6) obtained a lower weight in case of 3200 K than in case of the other CCTs (i.e. "blue" obtained less attention in a *warm white* environment).

3.4. Effect of Scene

Fig. 7 visualises the effect of the interaction *Scene*Colour* $\eta^2 = 0.188$ on the variable *relative weight* (relative to the weight of "skin/brown", No. 1, in case of every scene) defined as $R_{ik} = W_{ik} / W_{1k}$. The symbol W_{1k} represents the weight of "skin/brown" while the symbol W_{ik} represents the mean weight found by all observers in case of the different colours (i=1-7; see the colour numbers in Table 2) and different scenes (k=1-13, see Fig. 1).

Conspicuous differences can be seen from Fig. 7 among the relative weight distributions of the seven colours. Using the 13 x 7 mean relative weights R_{ik} shown in Fig. 7 as input, the 13 scenes were grouped automatically by an SPSS(R) K-Means *cluster analysis* with the fixed number of four clusters. The 13 scenes were grouped according to the similarity or dissimilarity of their relative weight distributions among the seven colours, see Fig. 7. Table 6 shows the resulting relative weights of the seven colours in the four *scene cluster centres* found by the SPSS(R) K-Means algorithm - compared to the overall relative weights (last column of Table 6) calculated from the data of Table 2.

As can be seen from Table 6, the four cluster centres exhibit characteristic *relative weight distributions* among the seven colours. These distributions are different from the one of the *overall* relative weights in the last column. For instance, the painting's cluster centre's "red" has a relative weight of 2.86 and this is greater than the overall mean relative weight of red, 2.00. We named the four clusters in the following way in order to represent the membership of the scenes in a given cluster: "Office", "Painting", "Kitchen", "Napkins". The scenes "office" and "watering cans" belong to the 1st cluster ("Office"), "painting" belongs to the 2nd cluster ("Painting"), "kitchen", "food", "children's room", "bathroom", "textiles" and "ducks" belong to the 3rd cluster ("Kitchen") while "candles", "colour circle", "napkins" and "wools" belong to the 4th cluster ("Napkins"). The painting obtained an individual cluster possibly due to its more complicated pictorial content evoking a strong cognitive and emotional response in the subject when assessing the colour preference of the difference paint colours on its surface.

3.5 Interpretation of the Weight Distribution Differences among the Scenes and Prediction of the Weights

In order to interpret the weight distribution differences among the scenes (Fig. 7) and the existence of scene clusters (Table 6), we hypothesized that the reason of the strong interaction (*Scene*Colour*) depicted in Fig. 7 is that objects of a particular scene with *higher chromaticity* in the *same* colour group attract *more* attention when evaluating colour preference. The objects of a given colour had different chromaticity values in the individual scenes; see the scattering chromaticity values in Fig. 5.

To examine this hypothetic role of the chromaticity of the objects, we calculated a characteristic chromaticity value C_{ik} for every colour (i=1-7) and every scene (i=1-12) i.e. except the painting) by *averaging* the chromaticity of the measured ob-

Table 6. Output of the Cluster Analysis

Cluster No.	1	2	3	4	Overall
Scenes in this cluster	2, 11	13	1, 3-6, 9	7, 8, 10, 12	
Cluster name	«Office»	«Painting»	«Kitchen»	«Napkins»	
brown/skin	1.00	1.00	1.00	1.00	1.00
red	2.27	2.86	1.84	2.07	2.00
orange	1.90	1.07	1.95	2.64	2.06
yellow	1.76	1.32	1.39	1.95	1.58
green	1.89	2.52	1.32	2.01	1.66
blue	2.03	2.88	1.29	2.13	1.70
purple	1.98	1.40	1.13	1.35	1.31

Note to Table 6: Cluster centres i.e. *characteristic relative weight (R) distributions* (relative to the weight of "skin/brown") of the seven colours in case of the four clusters of scene, and we named the clusters in order to represent the membership of the scenes in a given cluster; relative overall weights computed from Table 2 are 1-kitchen; 2-office; 3-food; 4-children's room; 5-bathroom; 6-textiles; lower row, from left to right: 7-candles; 8-colour circle; 9-ducks; 10-napkins; 11-watering cans; 12-wools; 13-painting; overall relative weights were calculated from the data of Table 2.

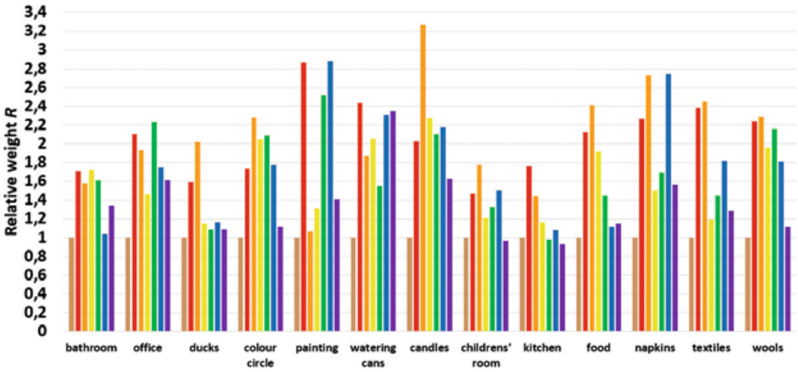

Fig. 7. Effect of the interaction *Scene*Colour* ($\eta^2 = 0.188$); mean *relative weight* (relative to the weight of "skin/brown" in case of every scene) found by the subjects (1st coloured column: brown/skin; 2nd: red; 3rd: orange; 4th: yellow; 5th: green; 6th: blue; 7th: purple)

jects (if there was more than one object of the same colour then we averaged the C values of those objects) *among the four CCTs*. We did not include the painting because, as mentioned above, the painting represents a highly cognitive context when assessing colour preference. Red (poppy flower) and blue (sky, umbrella) obtained higher weights as these colours tend to get consciously in the focus of the viewer's attention due to the cognitive context of the painting.

In a second step, we computed the mean chromaticity of every colour (i=1-7) across the different scenes except the painting (k=1-12), C_i=Mean (C_{ik}, k=1-12). After this, we computed a relative chromaticity $C_{ik,rel}$ for every colour and every scene: $C_{ik,rel}= C_{ik} / C_i$. If the value of this relative chromaticity $C_{ik,rel}$ is high in case of a given colour and given scene, this means that that colour has a relatively high chromaticity in that particular scene. Multiplying the value of $C_{ik,rel}$ by the overall mean weights W_i from Table 2, we obtain a hypothetical predictor quantity of the weights, $W_{ik,pred}$, see Eq. (2).

$$W_{ik,pred} = C_{ik,rel} \cdot W_i, \text{ with } C_{ik,rel} = C_{ik} / C_i$$
$$i = 1-7 \text{ and } k = 1-12 \quad (2)$$

Pearson's correlation coefficient between W_{ik} and $W_{ik,pred}$ equalled to 0.84, see Fig. 8.

The strong positive correlation (Fig. 8) between W_{ik} and $W_{ik,pred}$ (r=0.84) implies that if the chromaticity of an object of a given colour group (e.g. orange) is relatively high in a particular scene then that object will obtain a higher weight in that particular scene. The value of C_i (see the last column of Table 2) resulting from the measurements of the present article can be considered as an estimate of the characteristic chromaticity of a certain colour group.

This way, Eq. (2) can be applied to predict the weights in any new scene ("k=14") that consists of the colour groups investigated in the present article (brown/skin, red, orange, green, blue and purple). If the characteristic CIECAM02 chromaticity values of the colours in this new scene ("k=14") are known (C_{i14}) then the predicting quantity $W_{ik,pred}$

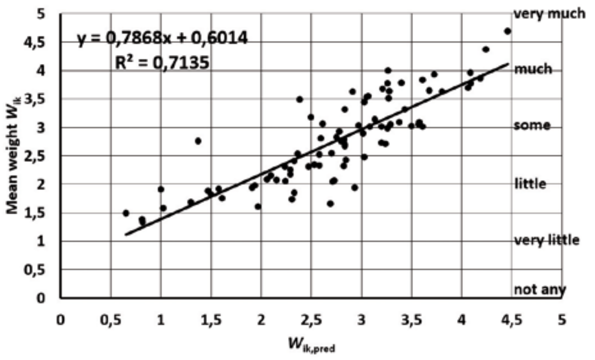

Fig. 8. Prediction of the mean weights (W_{ik}) of the different colours (i=1-7) and scenes (k=1-12) by the quantity $W_{ik,pred}$ of Eq. (2) (the painting is not included)

can be calculated using the values of W_i and C_i in Table 2. In order to predict the rating categories (0-"not any", 1-"very little", 2-"little", 3- "some", 4-"much", 5-"very much") of the weights in the new scene, the quantity $W_{ik,pred}$ of Eq. (2) has to be re-scaled according to the best fit line in Fig. 8, see Eq. (3). The re-scaled quantity is denoted by $W_{ik,pred}$'.

$$W_{ik,pred}' = 0.7868 \cdot W_{ik,pred} + 0.6014 \quad (3)$$

It should be noted that - for the sake of a usable prediction - the new scene in which the weights should be predicted should not comprise cognitively emphasized elements like the brush strokes of a painting. In a painting, certain colours are important because they represent the artist's intent e.g. purple brush strokes are *by themselves* emphasized if the painting depicts a person in purple clothes who constitutes the main topic of the painting.

4. CONCLUSIONS

While making colour preference judgements in different scenes of coloured objects, the observers of the psychophysical experiment described in the present article assessed the weights of the different colour groups (or hue groups) according to how much attention they paid to the seven different colour groups (brown or skin tone, red, orange, yellow, green, blue and purple objects). The scenes were illuminated by four spectra at a high colour-rendering index (CRI) level and different correlated colour temperatures (CCTs). The CCT of the illuminant had a small but significant effect on the weights of the different colours. Partially in accordance with literature findings, red and orange obtained the highest overall mean ratings (3.4 – 3.5 i.e. between "some" weight and "much" weight); yellow, green and blue were intermediate (2.7 – 2.9 i.e. "some" weight), purple had a smaller weight (2.2 i.e. "little") while brown/skin exhibited only "little" – "very little" (1.7).

Scene content (e.g. "painting" vs. "typical coloured objects in an office") had a strong influence on the weights of the seven colours. Accordingly, four scene clusters (office, painting, kitchen and napkins) with characteristic cluster centres (i.e. weight distributions among the seven colours) were identified. To interpret the weight distribution differences among the scenes (except for the painting), we hypothesized that objects of higher chromaticity in the same colour group obtain a higher weight. This hypothesis resulted in Eq. (3) via Eq. (2). Equation (3) can be used to predict the weights in any new scene that consists of objects of the same colour groups (brown or skin tone, red, orange, yellow, green, blue and purple) excluding scenes of high cognitive content (e.g. paintings). Colour preference metrics should consider the weighting of the different hue groups in the future possibly by the use of Eq. (3). The painting itself constituted an individual cluster due to its complicated pictorial content (shape, size, location) evoking a strong cognitive and emotional response. Paintings of different pictorial content shall be examined in a separate study.

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