Experimental Determination of Laws of Color Harmony. Part 7: Experiments Carried Out with Eyes Adapted to Light and Dark

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Received 14 December 2011; revised 21 April 2012; accepted 26 April 2012

Abstract: Within the framework of our series of experiments, 16 artists made judgments on the harmony content of color compositions using two different methods. First, using the traditionally accepted method, at natural daylight, with their eyes adapted to light, they judged the compositions. Following that, they used, the nowadays more popular, instrumental simulation of the experimental color objects. The second part of the experiment was performed in a dark room and the subjects had their eyes adapted to dark, before the experiment. According to the outcome of these experiments, the results were substantially different. These differences were recorded in diagrams and formulated in mathematical form. Our conclusion, based on these results, is that the simulated experimental results cannot be used for the description of the harmony content between colors at natural conditions. The importance of these results has strong relevance to the judgment of color harmony between colors on the TV screen. To describe this particular harmony, we need a different word. © 2012 Wiley Periodicals, Inc. Col Res Appl, 00, 000–000, 2012; Published online in Wiley Online Library (wileyonlinelibrary.com). DOI 10.1002/col.21752

Key words: color harmony; color composition; color science; color theory; coloroid color system; experimental color harmony; theory of color harmony

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INTRODUCTION

For two thousand years, the impression of the blending between colors in our environment has been called color harmony.[1–6] To find the rules of color harmony, experiments were performed since the 18th century. These experiments were performed by observing compositions at natural daylight. Naturally, the judgments were made by the observers with their eyes adapted to light. The relationships, found this traditional way, are called color harmony rules.[7–17] The preparation of identical copies of the color experimental samples, every time, however, was time consuming and difficult to achieve. This process, in the last couple of decades, became a lot easier due to technological advance.

Nowadays, the colors in a color composition can be reproduced on a screen of a monitor, therefore, be formulated mathematically. For this kind of experiment, the requirements are dedicated programs, well-calibrated monitors, and a dark room. The results observed by experimenters watching the color compositions, simulated on an instrument, in a dark room are also called the rules of color harmony, like in the natural case.[18–22] The differing experimental results however, cast question on the identity of the two sets of rules.

The problem springs from the everyday life of today's people. Today, the environment, dwellings, clothing, utensils even machinery are required not only to be practical but also to be pleasing to the eye. The designers are looking for the set of rules that are helpful to define color harmony in a particular design. On computer display units, TV monitors and cinematographic screens colors are combined and these colors must be harmonious to the eye. This trend creates an urge for looking for the governing rules by different methods.

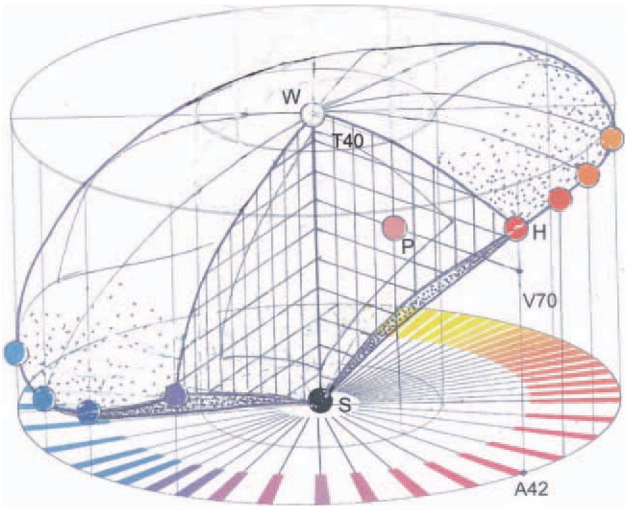

FIG. 1. The model of the Coloroid color scheme. The Coloroid coordinates of point *P*: Coloroid hue A42, Coloroid saturation *T*40, Coloroid lightness *V*70.

The two methods used in our investigations resulted in two sets of rules. The aim of the article is to find out whether the rules of color harmony under daylight are the same or different from those that govern the harmony of the colors, displayed on monitor screens. If they are identical, then the user of these results could be both the designer and the TV presenter. If however these rules are not identical, then we have to find a different word to describe them.

To answer this fundamental question, we performed two parallel experiments. Within the framework of these experiments, 16 artists made their judgments on the harmony content of the same color compositions, applying both methods.

EXPERIMENT

As we said before, in these experiments, the judgments were made on harmony content of simple samples, made up in two colors using both methods. The harmony between the colors of a color composition is measured on a scale graduated between 0 and 100. The result of one single experiment is regarded as a relative harmony content. First, at natural light, the observers made their judgments with eyes adapted to light. Following that, we simulated the same compositions on the screen of monitors. The monitors were placed in a dark room because of dimmer picture conditions. The behavior of the eyes adapted to dark, relative to the dimmer picture was similar to that of the natural condition. The experimental subjects therefore made their judgments on the simulated samples with eyes adapted to dark in the second case.

Our experiments aimed and structured to produce the rules of color harmony, first at natural daylight, second using colors reproduced on monitors. Our aim was to find out the difference between the two sets of judgments if there was any.

We used the Coloroid system for the definition of the colors in the experimental samples. The reader is reminded that the Coloroid hue is symbolized by *A*, the saturation by *T*, and the lightness by the letter of *V*, as depicted in Fig. 1. Within the Coloroid color space lays the Coloroid color body with the color surfaces. The vertical lines of the Coloroid axel intersections represent the same saturation, whereas the lines running perpendicularly to the gray axis are the loci of the colors of the same lightness.[23–26]

For these experiments, we selected two Coloroid hues, on the axial intersection (Coloroid color plane), namely the *A*12 registration, containing warm yellow and another hue, called *A*56, with green/blue colors. With identical experimental steps and conditions, the results have proved to be the same, therefore in the following, we limited ourselves to experiments performed on *A*12 hue only.

The Compositions, to be Judged, as Presented to the Participants

The formal presentations and the selections of colors were identical in both sets of experiments. Both experiments were performed in three identical steps; the test procedures between steps however were different.

The first step in the experiment was to select color pairs from colors, laying on the *A*12 hue axis. The members of the pairs had the same *T*15 saturation but different Coloroid lightness. One member in each of the pairs had the same *V*95 lightness. In one pair, both colors had the same lightness, whereas the following color lightness diminished in the subsequent pairs gradually by identical 5 *dV* step intervals. These steps have given us 11 compositions, out of which four are depicted in Fig. 2. The color details of the 11 color pairs are tabulated in Table I.

In the second step, we selected colors from the same *A*12 Coloroid axial intersection (Coloroid color plane)

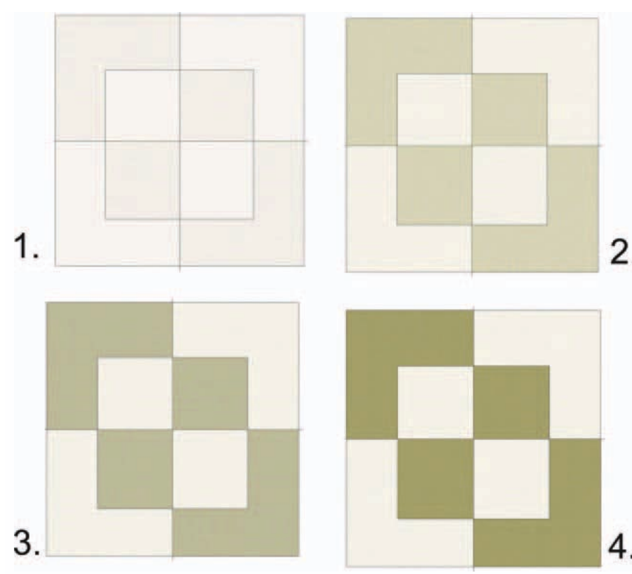

FIG. 2. Results of four tests for judging the harmony content at different lightness. The difference in lightness: Test 1. *dV*5, Test 2. *dV* 20, Test 3. *dV*35, Test 4. *dV* 50.

TABLE I. Data of the investigation on the harmony content at different lightness (daylight experiment).

		Color 01							Color 02						
		Coloroid			CIELAB				Coloroid			CIELAB			
Test	*V*1–*V*2	*A*	*T*	*V*	*L**	*a**	*b**	λ	*A*	*T*	*V*	*L**	*a**	*b**	λ
1	*dV*0	12	15	95	96.1	−1.18	10.39	574.38	12	15	95	96.1	−1.18	10.39	574.38
2	*dV*5	12	15	95	96.1	−1.18	10.39	574.38	12	15	90	92.13	−1.27	11.24	574.38
3	*dV*10	12	15	95	96.1	−1.18	10.39	574.38	12	15	85	88.09	−1.37	12.22	574.38
4	*dV*15	12	15	95	96.1	−1.18	10.39	574.38	12	15	80	83.97	−1.49	13.38	574.38
5	*dV*20	12	15	95	96.1	−1.18	10.39	574.38	12	15	75	79.76	−1.63	14.76	574.38
6	*dV*25	12	15	95	96.1	−1.18	10.39	574.38	12	15	70	75.45	−1.78	16.43	574.38
7	*dV*30	12	15	95	96.1	−1.18	10.39	574.38	12	15	65	71.04	−1.97	18.5	574.38
8	*dV*35	12	15	95	96.1	−1.18	10.39	574.38	12	15	60	66.52	−2.19	21.14	574.38
9	*dV*40	12	15	95	96.1	−1.18	10.39	574.38	12	15	55	61.87	−2.47	24.63	574.38
10	*dV*45	12	15	95	96.1	−1.18	10.39	574.38	12	15	50	57.08	−2.81	29.53	574.38
11	*dV*50	12	15	95	96.1	−1.18	10.39	574.38	12	15	45	52.12	−3.24	37.16	574.38

The details of the color samples for the first and the second methods were the same for all practical purposes. The first experiment color samples were simulated on the monitor in the second experiment. The tests showed that the ΔE difference between the two sets of data for the respective colors were minimum 0.85 and maximum 1.58, respectively, calculated in the CIELAB color space.

with *V*80 Coloroid lightness but different saturation conditions. The saturation of the selected colors were gradually increased step by step by 5*dT*, starting from the gray saturation. To start, we paired up the V80 gray with identical saturation, followed by pairing up with other colors with different saturation state. The details of the resulting 11 color pairs are summarized in Table II. Using the 11 color pairs, we prepared 11 compositions. Out of these four are shown in Fig. 3.

In the third step, out the *A*12 hue, we selected the colors with 12-60-80 (Coloroid coordinates) saturation states and paired up with colors of the same saturation and also with 23 different other hues. The resulted 24 color pairs were used for 24 compositions. Four compositions out of the set are depicted in Fig. 4. We gave the color details of the 24 color pairs in Table III.

Observers

In both sets of experiments, the experimental subjects were the same 16 artists. These subjects, recruited from the artist community, were selected from the age group of 30–50 years.

Experimental Process

The method in both experiments were identical, namely the color comparison method between two colors. Its present version has been published by Guilford in 1928.[27] The subjects judged the pair of compositions separately, one at the time. At the start of the judgment, the harmony content of one composition pairs was known to the subjects. This harmony content served as a reference for the judgment of the second composition. The reference composition in all three steps made up from one color for obvious reason. We equated the numerical value of the harmony content of these colors with the numerical value their own color preference, based on the results of the color preference experiments, performed previously.[28–32]

During the experiment, the compositions were presented to the subjects in all possible combinations. From the 2 × 11 compositions of the first and second steps, we created 55–55 different pairs. The 24 compositions of the

TABLE II. Data of the investigation on the harmony content of different saturation levels (daylight experiment).

		COLOR 01							COLOR 02						
		COLOROID			CIELAB				COLOROID			CIELAB			
Test	T1-T2	*A*	*T*	*V*	*L**	*a**	*b**	λ	*A*	*T*	*V*	*L**	*a**	*b**	λ
1	dT0	12	0	80	83.97	0	0	574.38	12	0	80	83.97	0	0	574.38
2	dT5	12	0	80	83.97	0	0	574.38	12	5	80	83.97	−0.5	2.19	574.38
3	dT10	12	0	80	83.97	0	0	574.38	12	10	80	83.97	−0.99	8.68	574.38
4	dT15	12	0	80	83.97	0	0	574.38	12	15	80	83.97	−1.49	13.38	574.38
5	dT20	12	0	80	83.97	0	0	574.38	12	20	80	83.97	−1.99	18.39	574.38
6	dT25	12	0	80	83.97	0	0	574.38	12	25	80	83.97	−2.49	23.74	574.38
7	dT30	12	0	80	83.97	0	0	574.38	12	30	80	83.97	−2.99	29.5	574.38
8	dT35	12	0	80	83.97	0	0	574.38	12	35	80	83.97	−3.5	35.78	574.38
9	dT40	12	0	80	83.97	0	0	574.38	12	40	80	83.97	−4	42.69	574.38
10	dT45	12	0	80	83.97	0	0	574.38	12	45	80	83.97	−4.51	50.43	574.38
11	dT50	12	0	80	83.97	0	0	574.38	12	50	80	83.97	−5.01	59.29	574.38

The details of the color samples for the first and the second methods were the same for all practical purposes. The first experiment color samples were simulated on the monitor in the second experiment. The tests showed that the ΔE difference between the two sets of data for the respective colors were minimum 0.85 and maximum 1.58, respectively, calculated in the CIELAB color stimuli space.

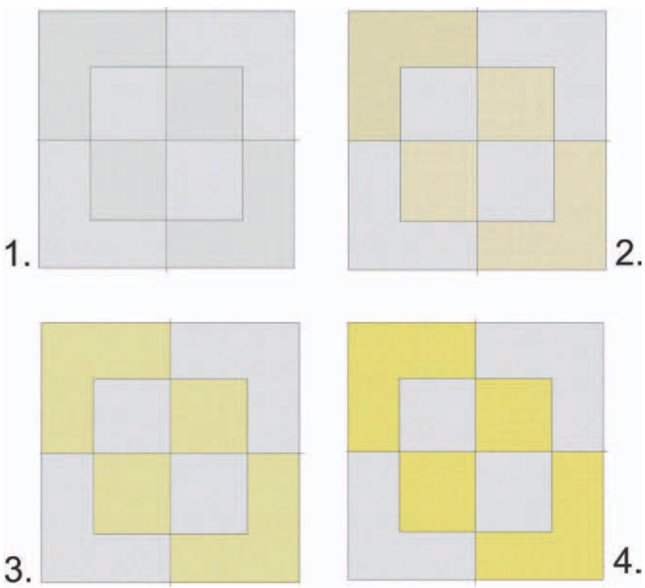

FIG. 3. Results of four tests for judging the harmony content at different saturation conditions. The difference in saturation: Test 1. *dT*15, Test 2. *dT*20, Test 3. *dT*35, Test 4. *dT*50.

third step lead to the creation of 276 different pairs. At the judgment of the composition pairs, the reference harmony content was represented in the harmony content of the second, third, fourth, and so forth colors.

The leader of the experiment has explained the test to the subjects and described their task. The available time for making the judgment on the harmony content of the next composition was 2–3 min. The judgment was based on the reference composition. The maximum deviation from the reference was ±5 units. The numerical value of the judgment in each case was recorded on a printed form. The judging was performed with eyes adapted to light.

The Technical Facilities of the Experiments

The slight difference between the executions of the two experiments was caused by the available technical facilities at the time.

The color compositions used in the first method were 18 × 18 cm^2 in size and produced by printing. Both colors of the printed compositions were checked using a spectrophotometer. In case of unsatisfactory result, the composition was reprinted. The experiments were performed in a room illuminated by natural light, (standard D65 illumination) reflected from the northern sky, near to a window, where the illumination level was between 1600 and 1800 lux. The compositions were placed on vertical birch plates. The environment consisted of a gray surface of $Y = 30$ light density. The illumination came in 45° (approximately) and the observation was in 90° from a distance of 100 cm.

The leader of the experiment has explained the test to the subjects and described their task. The available time for making the judgment on the harmony content of the next composition was 2–3 min. The judgment was based on the reference composition. The maximum deviation from the reference was ±5 units. The numerical value of the judgment in each case was recorded on a printed form. The judging was carried out with eyes adapted to light.

In the second method, the experiment was performed in a dark room, with the previously used samples simulated on a cathode ray tube monitor. Specific software was written for every experiment, generating the mid-gray background, which imitated the conditions of the test performed at natural illumination. The size of the screen of the monitor was $17'(\text{cd/m}^2 = 250)$. The two 16 × 16 cm^2 big compositions were positioned in 3 cm distance from each other. The reference was placed on the left and the one to be judged on the right, similarly to the experiments performed at natural light. The observations were made from a distance of 80 cm. The screen color components (*CIE XYZ*) of the simulated compositions were checked using a spectroradiometer (Konica Minolta CS1000S), 30 min after switching on the instruments. When the difference was larger than $\Delta E = 1.6$, as calculated in the CIELAB color stimuli space, then we applied corrections. We used the same subjects in both experiments, doing identical tasks in both cases. Before the start of the judging, all subjects spent 10 min in a dark room to adapt their eyesight to the dark environment.

RESULTS

Preceding the processing of the experimental data, we tested the reliability of the collated information. By applying the root mean square method, we calculated the individual deviations between the judgments of the subjects.

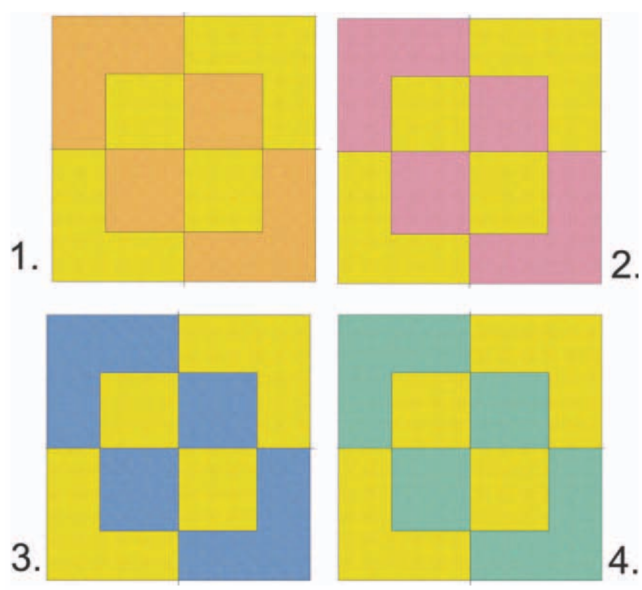

FIG. 4. Results of four tests for judging the harmony content at different hues. The hue angles: Test 1. 30°, Test 2. 90°, Test 3. 180°, Test 4. 285°.

TABLE III. Data of the investigation on the harmony for different hues (daylight experiment).

		COLOR 01							COLOR 02						
		COLOROID			CIELAB				COLOROID			CIELAB			
Test	$A1\varphi$-$A2\varphi$	*A*	*T*	*V*	*L**	*a**	*b**	λ	*A*	*T*	*V*	*L**	*a**	*b**	λ
1.	0°	12	60	80	83.97	−6.03	83.13	574.4	12	60	80	83.97	−6.03	83.13	574.4
2.	15°	12	60	80	83.97	−6.03	83.13	574.4	14	60	80	83.97	4.99	77.77	577.7
3.	30°	12	60	80	83.97	−6.03	83.13	574.4	21	50	70	75.45	25.24	71.71	584.5
4.	45°	12	60	80	83.97	−6.03	83.13	574.4	26	50	70	75.45	53.73	49.01	597.7
5.	60°	12	60	80	83.97	−6.03	83.13	574.4	31.5	30	60	66.52	47.07	19.5	616
6.	75°	12	60	80	83.97	−6.03	83.13	574.4	32.5	40	60	66.52	52.95	15.35	649
7.	90°	12	60	80	83.97	−6.03	83.13	574.4	35	40	60	66.52	50.01	−5.18	500
8.	105°	12	60	80	83.97	−6.03	83.13	574.4	40	50	60	66.52	59.6	−13.2	−504.8
9.	120°	12	60	80	83.97	−6.03	83.13	574.4	41.4	50	60	66.52	58.1	−21.3	−516.2
10.	135°	12	60	80	83.97	−6.03	83.13	574.4	44	60	60	66.52	64.26	−41.8	−549.5
11.	150°	12	60	80	83.97	−6.03	83.13	574.4	44.6	60	60	66.52	63.26	−45.8	−553.8
12.	165°	12	60	80	83.97	−6.03	83.13	574.4	46	50	50	57.08	60.76	−62.7	−552.9
13.	180°	12	60	80	83.97	−6.03	83.13	574.4	52	60	50	57.08	7.35	−55.2	475.45
14.	195°	12	60	80	83.97	−6.03	83.13	574.4	53	60	50	57.08	−7.27	−45.8	475.5
15.	210°	12	60	80	83.97	−6.03	83.13	574.4	55	60	60	66.52	−20.72	−27.8	484.3
16.	225°	12	60	80	83.97	−6.03	83.13	574.4	56	60	60	66.52	−29.90	−21.25	487.3
17.	240°	12	60	80	83.97	−6.03	83.13	574.4	61	50	65	71.04	−34.33	−7.5	492.72
18.	255°	12	60	80	83.97	−6.03	83.13	574.4	62	50	65	71.04	−40.87	−3.35	495.28
19.	270°	12	60	80	83.97	−6.03	83.13	574.4	63	45	65	71.04	−44.08	1.01	498.45
20	285°	12	60	80	83.97	−6.03	83.13	574.4	65	30	65	70.04	−48.54	12.94	509.19
21.	300°	12	60	80	83.97	−6.03	83.13	574.4	66.4	25	70	75.45	−52.54	24.24	526.78
22.	315°	12	60	80	83.97	−6.03	83.13	574.4	71	30	70	75.45	−51.9	41.57	548.15
23.	330°	12	60	80	83.97	−6.03	83.13	574.4	72.5	40	70	75.45	−48.57	67.21	558.45
24.	345°	12	60	80	83.97	−6.03	83.13	574.4	75	50	80	83.97	−26.83	64.69	566.73
25.	360°	12	60	80	83.97	−6.03	83.13	574.4	12	60	80	83.97	−6.03	83.13	574.4

The details of the color samples for the first and the second methods were the same for all practical purposes. The first experiment color samples were simulated on the monitor in the second experiment. The tests showed that the ΔE difference between the two sets of data for the respective colors were minimum 0.85 and maximum 1.58, respectively, calculated in the CIELAB color stimuli space.

With the first method, the maximum spread in the judgments, at different lightness was 1.6 harmony content units, whereas in the second method, it was two harmony contents. For 95% of the judgments, this value was less than 0.8 or 1.6 units, respectively. The distribution curves for both experimental results (at natural illumination as well as in a dark room) are depicted in Fig. 5.

The Gaussian distribution functions y_{5r} (red line) and y_{5b} (blue line) (see Fig. 5), describing the first and the second method are given in Eqs. (1) and (2), respectively.

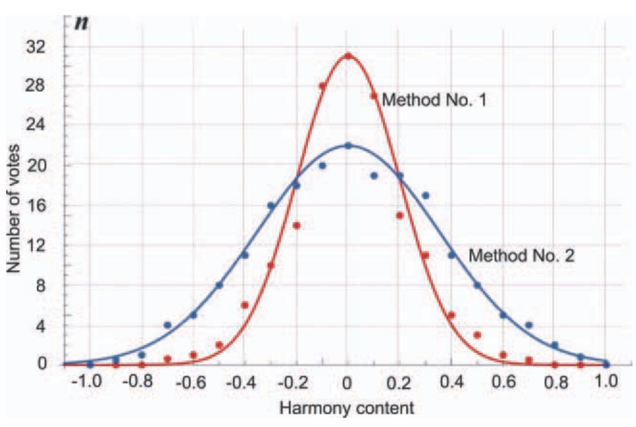

FIG. 5. Distribution functions representing the experimental results of the test carried out on the harmony content at different lightness. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

$$y_{5r} = 31 \exp\left(-\left(\frac{x-11}{2.8}\right)^2\right) \quad (1)$$

$$y_{5r} = 31 \exp\left(-\left(\frac{x-11}{2.8}\right)^2\right) \quad (2)$$

The judgments related to the relative harmony content at different Coloroid lightness is shown in Fig. 6. The results are collated from the 95% of the total number of votes. The data of the graph was calculated using the mathematical averaging of the votes. The difference between the two results is small but significant amount. The first results can be modeled by Eq. (3) and the second one by Eq. (4).

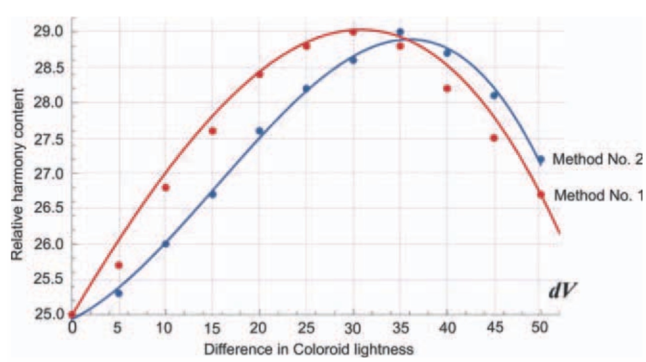

FIG. 6. The judgments on the harmony content at different lightness. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

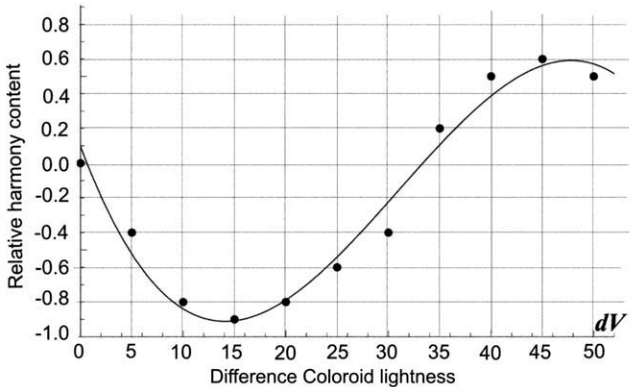

FIG. 7. A graph, showing the difference between the two experiments, carried out with eyes adapted to light and dark.

$$y_{6r} = 24.84 + 0.223x - 0.0017x^2 - 0.00004x^3 \quad (3)$$

$$y_{6b} = 25 + 0.0648x + 0.00557x^2 - 0.00012x^3 \quad (4)$$

The subjects, with eyes adapted to lights, assessed at 30 dV the maximum difference in harmony content, whereas with eyes adapted to dark, this has changed to 35 dV. At 35 dV, the subjects judged the dV harmony content less harmonic, when their eyes adapted to light and consequently, with eyes adopted to dark this judgment was reversed. The difference is shown in graphical form in Fig. 7, which can be formulated as shown in Eq. (5).

$$y_{6\Delta} = 0.095 - 0.0158x + 0.0072x^2 \quad (5)$$

The maximum spread of the votes for the saturation difference in the first method (light adaptation) was 2.4 harmony content units, whereas with the second method (dark adaptation), it was 3.2 harmony contents. For the 95% of the votes however, this figure was within 1.2 and 2 correspondingly. The distribution curves for both methods are shown in Fig. 8 and the corresponding describing functions, y_{8r} (red line) and y_{8b} (blue line), are in Eqs. (6) and (7), respectively.

$$y_{8r} = 14 \exp\left(-\left(\frac{x-13}{5.6}\right)^2\right) \quad (6)$$

$$y_{8b} = 10 \exp\left(-\left(\frac{x-13.5}{7.6}\right)^2\right) \quad (7)$$

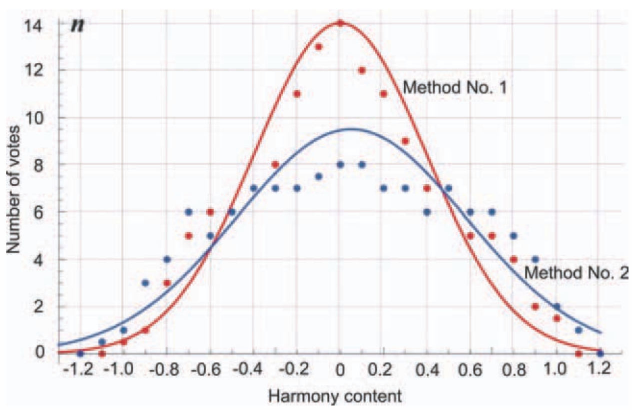

FIG. 8. Distribution functions representing the experimental results of the test carried out on harmony contents at different saturation levels. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

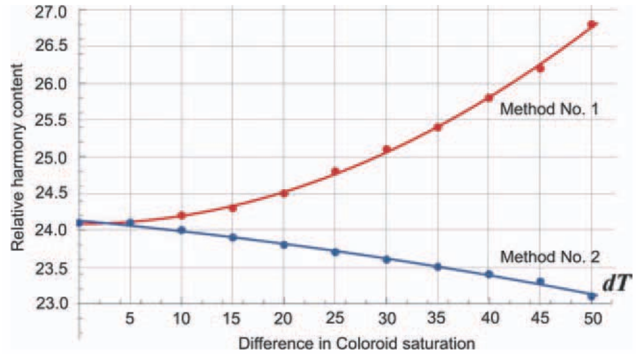

FIG. 9. Judgments on the harmony contents at different saturation levels. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

The judgments on the relative harmony contents for different Coloroid saturations are shown in Fig. 9. This represents the results of 95% of the judgments made on the compositions. The data of the graphs were calculated also with the mathematical averaging of the votes. We have concluded that the experimental results, regarding the difference in lightness differ substantially, contrary to previous practical experience. The experimental subjects, with light adaptation, attributed larger harmony content at larger saturation difference. Equally, they felt that growing saturation difference had smaller harmony content, when their eyes were adapted to dark.

The two graphs are shown in Fig. 9 and are fitted with y_{9r} (red line) and y_{9b} (blue line) functions (8) and (9), respectively.

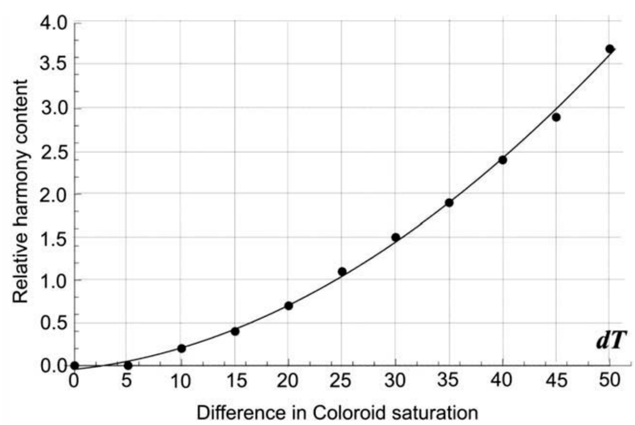

FIG. 10. Graph, showing the difference between the two experiments, carried out with eyes adapted to light and dark.

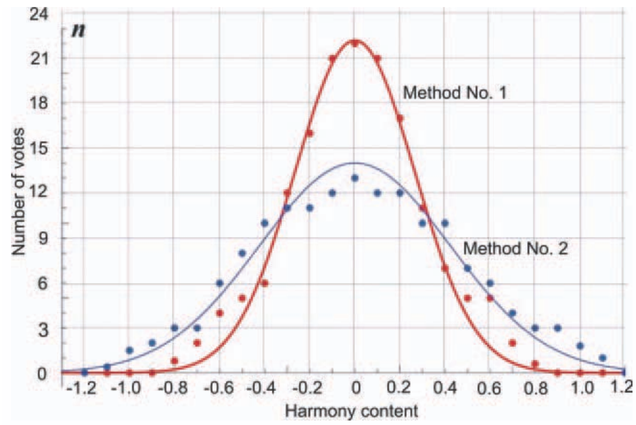

FIG. 11. Distribution functions representing the experimental results of the test carried out on harmony contents at different saturation levels. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

$$y_{9r} = 24.09 - 0.00039x + 0.0011x^2 \tag{8}$$

$$y_{9b} = 24.13 - 0.013x - 0.00014x^2 \tag{9}$$

The difference between the two results in graphical form is shown in Fig. 10 and its mathematical formulation is given in Eq. (10).

$$y_{9\Delta} = -0.0426 + 0.0126x + 0.00125x^2 \tag{10}$$

The maximum spread for the difference in the votes, in the first method (light adaptation) was two harmony contents, whereas with the second method (dark adaptation), it was 2.5 harmony contents. For the 95% of the votes, however, this figure was within 1.2 and 1.6, respectively.

The distribution curves for both methods are shown in Fig. 11 and the corresponding functions, y_{11r} (red line) and y_{11b} (blue line), are given in Eqs. (11) and (12), respectively.

$$y_{11r} = 22.2 \exp\left(-\left(\frac{x-13}{3.75}\right)^2\right) \tag{11}$$

$$y_{11b} = 14 \exp\left(-\left(\frac{x-13}{6}\right)^2\right) \tag{12}$$

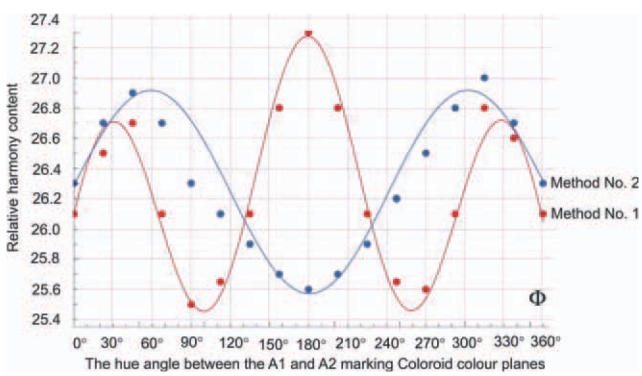

FIG. 12. Judgments on the harmony content with differing hues. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

The judgments on the relative harmony contents for different Coloroid hues are shown in Fig. 12. This represents again the results of 95% of the judgments made on the compositions. The data of the graphs were calculated by mathematical averaging of the votes. Our conclusion, based on experimental results, is that when the difference is smaller than 30° then the judgments on the harmony content of the compositions were nearly the same, irrespective of the adaptation of the subject's eyes. When however the difference was greater than 30°, the judgments differed considerably. The most significant difference was when the eyes were adapted to light. The compositions, made of complementing colors, judged with maximal harmony content and with eyes adapted to dark, they were judged having minimal harmony. The functions, y_{12r} (red line) and y_{12b} (blue line), fitting the curves in Fig. 12 are given below in Eqs. (13) and (14), respectively.

$$y_{12r} = 8.25 \sin\left(\frac{4.7}{360}x + 0.5\right) + 7.5 \sin\left(\frac{\pi}{360}x\right) + 14 \tag{13}$$

$$y_{12b} = 6.6 \sin\left(\frac{3}{360}x + 0.01\right) + 0.48 \sin\left(\frac{\pi}{360}x\right) + 3.3 \tag{14}$$

The mathematical difference y_{12_Δ} in the results of the two methods is depicted in Fig. 13 with the describing mathematical formula in Eq. (15).

$$y_{12\Delta} = 1.22 \sin(0.0235x + 0.35) - 1.2 \sin(0.0412x + 0.55) - 0.6 \sin(0.0088x) + 0.55 \tag{15}$$

CONCLUSIONS

Before we are drawing any conclusions, we feel compelled to make the following remarks. With light adapted eyes, the judgments of the experimental subjects were very similar to the judgments made at natural lights, pub-

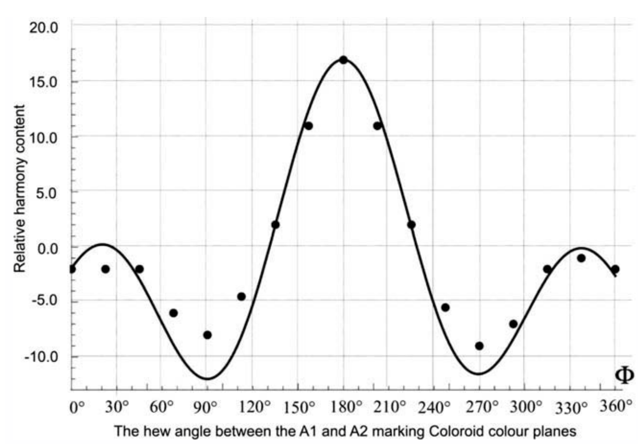

FIG. 13. A graph showing the difference between the two experiments carried out with eyes adapted to light and dark.

lished.[7–17] Likewise, when the subject's eyes were adapted to dark their judgments were like those research results, obtained in dark room, performed using monitors as described in the literature.[18–22]

We have drawn the following conclusions from the experiment.

1. The experimental subjects took less time to make their decisions when their eyes adapted to light. Likewise with eyes adapted to dark, they took longer to decide. As a result, in the first case, the spread on the judgments were smaller than in the second case.
2. The subjects, with their eyes adapted to light, judged lightness difference, smaller than $dV35$ having larger harmony content. In case it was bigger than $dV35$, the judgment vent toward the smaller harmony content. These results were the opposite, when the eyes were adapted to dark. We have found the biggest difference between the two methods at $dV15$. Here, the magnitude of this difference approached the unity harmony content.
3. When the eyes of the subjects were adapted to light, with increasing saturation difference, according to their judgments, the harmony content has increased as well. When their eyes were adapted to dark, they voted for decreased harmony content. The maximum difference between the results of the two methods was at $dT50$. The magnitude of the difference exceeded 3.5 units on the harmony content scale.
4. With light adapted eyes, the subjects judged color pairs with maximum harmony content, when hue angle was 30°, 180°, or 330° between the two members of the pair. These angles changed to 60° and 300°, when the eyes were adapted to dark. The same subjects judged the 180° hue angular difference the minimum harmony content. According to their judgment, with light adapted eyes, the harmony content was minimal when the angle between the two color planes of the color pairs was 85° and 265°.

This conclusion shows, beyond any doubt, that the results of the two methods are not identical. The first set of rules, resulting from the first experiment, refers to the daylight color relations, which have been regarded as the "color harmony rules" for centuries. The second set relates to color harmony of colors, displayed on monitors. The two sets differ substantially from one another; therefore, we have to find a different expression to discriminate between the two sets of rules.

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