AN EXPERIMENTAL STUDY OF COLOUR-HARMONY

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INTRODUCTION

Previous experiments[1] by the author yielded some very promising results concerning pleasing relationships of colours and forms suggesting the need for a more thorough investigation of the problem of harmony in different fields of visual perception.

In this paper the problem of Colour-Harmony is examined. The word «harmony» will be taken to include any combination of colours, or of tones, arrangement of forms or other qualities, which induces a pleasurable feeling tone in the observer.

The development of numerous pigments led artists and various thinkers to speculate and to theorize on the nature of these relations, starting as early as Alberti (1472), and Leonardo 1579). Goethe (1872) was probably one of the first to experiment with colours and on their relationships. However, Cohn (1894), working in Wundt's laboratory in Leipzig, can be accepted as the real pioneer of experimentation in this field. At the end of a large series of experiments he concluded that colour combinations tended to be more pleasing as the component colours approached the complementary relation. Following Cohn, psychologiste like Jastrow (1897), Baker (1900), Barker (1907), Chown (1907), Washburn (1921), von Allesch (1925) have all undertaken research in this field. But, unfortunately, owing to the lack of any really adequate system of colour specifications and illuminating conditions in standard terms at that time their results are difficult to evaluate, and an arbitrary comparison of them as to what colours are «good combiners» reveals no substantial agreement. Later, investigators

(1) B. A. BIRAND (TOĞROL), «The Problem of Suitability in Visual Perception», **Istanbul Studies in Experimental Psychology**, 1958, II, pp. 62-83.

like Moon and Spencer (1944), and Granger (1955), and recently Guilford (1959) have made fresh attempts to introduce some sort of a quantitative and objective approach into the field of colour harmony.

Since every colour sensation unites three distinct qualities, defined as Hue, Value and Saturation recent investigators in their research programs have carefully followed the obvious course, i.e. first to try to determine the pleasantness along one variable, and then to repeat it with the others. All of these researches yield some statistically significant results within the framework of their design, but still, fail to give a workable answer to a simple question as, for instance, why a certain «purple» does not go well with a certain «red», whereas the same «purple» looks quite all right with another «red». The balance between colours is certainly a complicated one. It is tridimensional to start with, and a unilateral approach can not answer any of its basic problems.

The existence of a «general law» covering harmonious-colour-combinations was suggested to the author through her familarity with colours, and by the encouraging results of some preliminary experiments conducted by her in a different country. A law a more fundamental character, independent of the affective values of the particular colours, as well as the individual «tastes», would include some sort of tridimensional balance including all three qualities between the members of the combining colours.

To test these assumptions under well controlled conditions with a set of Ss who were aesthetically unbiassed was the aim of these experiments.

EXPERIMENT

DESIGN.

Following points were considered in the design of these experiments:

1. The influence of Hue, Brightness and Saturation relationships of colours in colour combinations, where all these qualities could be easily handled without being realized by the Ss.

2. The size of the materials was the next point. It was thought to be essential to use larger pieces of paper in these experiments than has customarily been used by previous investigators, size was determined

by considering fovea as equal to the angle subtended by a penny held at arm's length.

3. The influence of neutrals in the colour combinations. These were introduced with all the other colours as they exist in the environment.

4. Presenting certain instructions to cope with the influence of area and background to some extent since these variables could not otherwise be introduced into these experiments.

5. To encourage the Ss into an active and creative mood by letting them to construct atrangements, rather than to have them rank or compare prearranged pairs.

METHOD.

1. Colour Specification.

Throughout the research Munsell System of colour notation was used. It is essentially a scientific concept for describing and analyzing colour in terms of three attributes, identified as Hue, Value and Chroma. This system arranges the three attributes of colour into orderly scales of equal visual steps, so that the attributes become dimensions by which colour may be analyzed and described accurately under standard conditions of illumination. It seems, for the time being, to be the most suitable for work with surface colours as fulfilling the requirements of the psychological colour-solid.

Chromatic colours in the Munsell System of colour notation are divided into five principal classes which are given the Hue names of red, yellow, green, blue and purple. A further division yields the five intermediate Hue names of yellow-red, green-yellow, bule-green, purple-blue, and-purple, these being combinations of the five principal Hues. Hence the Hue notation of any colour indicates its relation to the five principal and intermediate Hues or any other of their subdivisions.

The Value notation indicates the degree of lightness or darkness of a colour in relation to a neutral grey scale, which extends from a theoretically pure black symbolized as 0/ to a theoretically pure white symbolized as 10/ . A grey or a chromatic colour that appears visually half way in lightness between pure black and pure white has a Value notation of 5/ . Lighter colours are indicated by the numbers ranging above 5, while darker ones are indicated by numbers below 5.

The Chroma notation of a colour indicates the strength (saturation) or degree of departure of a particular Hue from a neutral grey of the same Value. The scales of Chroma extend from /0 for a neutral grey out to /10, /12, /14, or further, depending upon the strength or saturation of the individual colour. A colour classified popularly as "vermilion" might have a Chroma as strong as /12, while another colour of the same Hue and Value classifield popularly as "rose" might have a Chroma as weak as /4.

A complete Munsell notation for any chromatic colour is written Hue Value/Chroma, or symbolically H V/C. A particular sample of "vermilion" might then have a Munsell notation of 5R 5/12, while a particular sample of "rose" might have a notation of 5R 5/4.

2. Colour Material.

The coloured materials consisted of rectangular standard Munsell papers of 2.5 inches by 3 inches in size, such as are supplied by the Munsell Colour Company. Ten major hues from the number 5 series including all the five primaries and the five intermediates were selected to represent the Hue variable.

N i c k e r s o n's suggestion as to the proportion of the visual steps of value to saturation being 1/2 was kept in mind while choosing the Value and Chroma steps. In the initial plan, intervals 2/, 4/, 6/ and 8/ were chosen for the Value, and intervals /4, /8 and /12 for the Chroma scales. Every single hue thus was to be represented 12 times, providing a sample of 120 colours. (4V/3C $\times$ 10H = 120)

Owing to the irregular shape of the different hue pages of the Munsell Book of Colour due to the inavailability of some pigments at present in some higher saturation levels, this sample could not exactly be provided in this initial form. Instead, some adjustment had to be made, such as shifting the chromas of some of the shorter-wave colours towards the less saturated end, adding some different value steps in some odd cases, and leaving some out altogether. In the end, a sample of 71 chromatic papers, fulfilling the requirements of the initial plan as nearly as possible formed the experimental set.

An additional group of achromatic colours starting from black (0/), going in equal visual steps to white (10/) was included in this set, increasing the final number of the experimental materials to 81 surface colours.

3. Subjects.

The Ss who took part in the experiments were 20 undergraduate men from Cambridge University without any particular training or interest in arts, reading natural sciences, psychology, mathematics, languages or English. Their ages ranged from 19 to 24 years.

Women were not included in this group since they are popularly known to be less naive as far as colour education is concerned. An important consideration influencing selection was that all Ss should be of normal colour vision. The I s h i h a r a Test of Colour Blindness (9th Edition) was used for screening purposes.

4. Experimental Procedure.

Illumination was provided by using the principle of the «Siemens-Ediswan Industrial Colour Matching Unit» which consists of the use of fluorescent lamps with tungsten lamps providing a suitable source of artificial daylight, with colour temperature of about 6500 °K, approximating in energy distribution C I.E. Illuminant C.

Considering the size of the space illuminated which was a 52 ins. by 29 ins. table top in a room of 6×10×12 feet in size, with walls of essex-board attached to handiangle steel bars with no windows, providing relative darkness; this arrangement of one unit consisting of two fluorescents and two tungstens was multiplied by four providing enough light of the best colour quality artificially available in this country.

The light canopy of 8 fluorescents and 8 tungstens was fixed on plywood as large as the table top, and was placed directly on top of the table at a distance of 31 inches away from it.

The Ss were taken into the room individually, and they were seated at the table with a neutral grey top (Munsell N5) where the experimental material was laid out along the edge away from the S with sufficient space left for the S in front to place their own combinations. There was no time limit, the experiments on the avarage taking for about 50 minutes with each subject.

5. General Instructions.

Actual procedure is best understood by referring to the instructions given to the Ss, which were as follows:

These are experiments on colour combinations. There are 81 colours on this table and it is possible to make many combinations with these colours. You are going to be asked to make certain combinations with them according to instructions. You do not have to use every single colour on this table. You may use the same colour in your different combinations, if you like. There is no time limit. Have you any questions?
Will you now make,
I. Three different combinations by choosing any two colours that you think would go well together.

The experimenter noted the code number the colours used in each combination, replacing them before the S started to compose his next combination. She then asked him,

II. To choose three different blouse and skirt combinations for girls.
III. Three different blouse and skirt combinations one for each of the following: for a blond, for a brunette, and for a dark girl.
IV. A blouse and a skirt combination one for each of these: for a short and plump girl, for a short and slim one, for a tall and heavy built, and for a tall and slim girl.
V. Three different combinations by choosing any three colours that you think would go well together.
VI. Three blouse, skirt, scarf combinations for girls.
VII. A blouse, skirt, scarf combination one for each of the following: for a blond, for a brunette, and for a dark girl.
VIII. A blouse and skirt and scarf combination one for each of these: for a short and plump girl, for a short and slim one, for a tall and heavy built girl, and for a tall and slim girl.
IX. Three different combinations by choosing any four colours that you think would go well together.
X. Three different combinations by choosing any five colours that you think would go well together.
XI. What are your favourite colours?
XII. Choose five colours which you prefer from the table and rank them.
XIII. Make two different combinations by choosing any two colours that you think would look unpleasant together.

XIV. Two different combinations by choosing any three colours that you think would look unpleasant together.

6. Treatment of Data.

The relations between the individual colours in the combinations composed by the Ss were analysed by a consideration of the existing «interval-differences» along the three dimensions of colour. Since the Hue, Value and Chroma notations of every colour of the experimental material were predetermined according to the Munsell System, it was easy to calculate the differences between their «interval-steps»

The arrangement of Hue follows a circular pattern in this system, as in most others, and since 10 major hues were included in the experimental material, starting from any hue the departure of the second from this could be easily resolved by counting the interval-differences between them; the highest possible interval-difference being 5, a perfect hue contrast (K 1). Four steps was also accepted as a contrasting relation designated by (K 2). A difference of 1 step was judged to be a slight gradation with symbol (G 1), and 2 steps a somewhat higher gradation (G 2). Difference of 3 steps was high gradation and low constrast designated by (K 3).

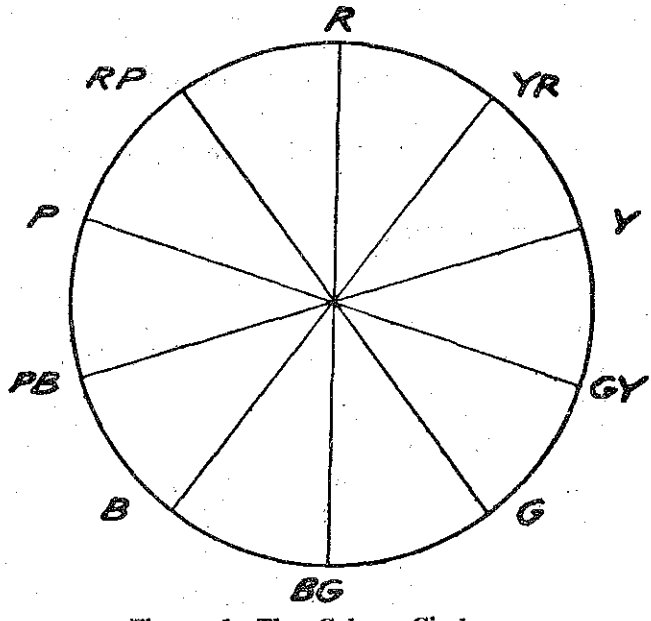


Figure 1. The Colour Circle.

Looking at the colour circle and starting from R, the difference between R and YR was 1 step, the symbol (G 1) would be given for their hue difference if any such colours were placed side by side. In case of R and Y the symbol would be (G 2) and so on, with R and BG having (K 1) with an interval difference of 5 steps. Again, at the anti-clockwise direction R would be (G 1) and with P (G 2) and so on.

The differences between the values and chromas of the colours were also similarly studied, with the difference that these variables followed vertical and horizontal linear courses, respectively. But in case of chroma smallest difference between any two colours had to have an interval of 2 steps to be (G 1) and all the others had similarly to be doubled since N i c k e r s o n 's suggestion of value to chroma as being ½ was accepted in the selection of the materials. On Table 1 these different symbols and their corresponding «step-interval-differences» for Hue, Value, and Chroma variables of colours is shown.

T A B L E 1.

	G 1	G 2	K 3	K 2	K 1
HUE	1	2	3	4	5
VALUE	1	2	3	4	5+
CHROMA	2	4	6	8	10+

Interval Differences and Their Corresponding Symbols.

The data obtained as a result of these experiments is summarized below :

COLOUR PREFERENCES

For each **S** :

Instructions	**N of Colours Selected**
XII	5
Performed with 20 Ss.	$(5 \times 20 = 100)$

PLESANT-COLOUR-COMBINATIONS

For each S :

Instructions	Number of Combinations	N of Colours in Each Combination	Overall N of Colours Used
I — IV	13	2	26
V — VIII	13	3	39
IX	3	4	12
X	3	5	15
TOTAL	32		92

Performed with 20 Ss. (92×20=1840)

UNPLEASANT-COLOUR-COMBINATIONS

For each S :

Instructions	Number of Combinations	N of Colours in Each Combination	Overall N of Colours Used
XII	2	2	4
XIV	2	3	6
TOTAL	4		10

Performed with 20 Ss. (10×20=200)

RESULTS

The results of these experiments were worked out in percent frequencies and whenever necessarry their levels of significance are given. The tables thus prepared and the curves drawn reveal very interesting tendencies operating in the field of colour combinations.

It might here be useful to define certain terms used in these tables. Neutral colours, that is, white and greys are referred as achromatic colours following the psychological nomenclature, the rest being called chromatic colours. Chromatic colours in their turn are divided into two groups :

a) Warm colours: These were the generally accepted long-wave colours, P, RP, R, YR, Y, in the experimental materials.

b) Cool colours: Short-wave colors, GY, G, BG, B, PB.

In selecting suitable colour material with equal number of warm and cool chromatic colours and achromatic colours had a drawback since the existing series of Munsell Colours is not yet represented in pigment terms at all levels. There were briefly, 44.5% Warm chromatic colours, 43.1% Cool chromatic colours, 12.4% Achromatic colours.

1. The function of individual colours in the combinations.

a. Colour preferences.

The following distribution was observed in the preferences of the Ss: 39 % Warm chromatic colours, 49 % Cool chromatic colours, 12 % Achromatic colours.

The proportion of the preferred chromatics to the achromatics was almost the same as that of experimental material. However, there seems to be a considerable tendency towards preference of cool colours as opposed to warim ones within the chromatic series, the level of significance of their differences reaching to less than 5 % in these experiments.

This result reflecting higher preference of short wave colours to the long wave ones was in accordance with the findings of other psychologists like G r a n g e r, G u i l f o r d and some other previous experimenters, as well as with the findings of the author in experiments conducted in another country of a different cultural background three years ago.

b. The use of colours in pleasant-colour-combinations.

The inspection of the use of colours selected by the Ss as their favourite ones from the experimental material showed a considerably less employment of these particular colours in the construction of their P.C.C. On the average the colours given the first rank were used up to 4% in their combinations, those of the second ranking 4.4% and the third ranking 3.3%, etc.

Another point to be considered was how these colours were actually used in the construction of these combinations? When the combinations were studied carefully, it was seen that these colours were employed as

the «first-picks» of the Ss while composing; their favourite colours, when used, constituted 40% of the «first-picks» in the P.C.C., and even 20% in the un-P.C.C.

These facts point to the importance of some other factors as being operative in colour combinations than the affective tone of the particular colours-forming them. It is more likely that, the S instinctively reaches first to one of his favourite colours when confronted with a colour problem. But having picked that colour, instead of using his next favourite one to complete the combination, selects an entirely different one, obviously weighing some other odds in this bargain.

The preferred colours used in the P.C.C. showed the following frequency distribution of warm and cool chromatics and achromatics : 36.6% Warm chromatic colours, 43.3% Cool chromatic colours, 20.0% Achromatic colours. When compared with the percentage distribution of the chromatics and achromatics in experimental material, there seems to be a marked increase in the employment of the achromatics.

The frequency distribution of the cool and warm chromatics and achromatics in the P.C.C. was as follows: 41.7% Warm chromatic colours, 40.8% Cool chromatic colours, 17.5% Achromatics. Again a tendency towards a more frequent use of achromatics can be observed from this distribution. A point of interest is the decrease in the use of cool chromatics in this overall distribution. This is somewhat unexpected since they are the most frequent selected kinds among the favourites. But it should be remembered that favourites are selected irrespective of any context.

c. The use of colours in unpleasant-colour-combinations.

An interesting result in the analysis of the use of colours in the un-P.C.C. is the employment of the favourite colours by the subjects to some extent in these combinations. The tendency is not as high as in the P.C.C. (about 2% in un-P.C.C. as opposed to 4% in P.C.C.) but still it exists. And 27% also constituted the «firts-picks» in the construction of these combinations. It is important that there is such a tendency as to reach towards a favourite colour first within a display, and then to match this with others accordingly trying to fulfill the given task, be it a pleasant or an unpleasant one.

The percent frequencies of the warm and cool chromatics and achro-

matics in the un-P.C.C. reveal the following distribution: 72% Warm chromatic colours, 25.5% Cool Chromatic colours, 2.5% Achromatic colours. This shows a completely different tendency in the use of chromatics and achromatics from the one observed in the P.C.C., in that the avoidance of achromatics is to a marked extent, with a great deal of increase in the employement of warm chromatics to a considerable decrease of cool ones.

d. Colours with maximum frequencies

Another very interesting phenomena is the repeated occurrence of colours with maximum frequencies in the un-P.C.C. as well. A mutual point in all these colours is their relatively high chroma notations, both in the long wave and in the short wave range.

To summarize:

(1) Individual colour preferences favour cool chromatics (short-wave colours.)

(2) Achromatics are more frequently used in P.C.C.

(3) Warm colours are more frequently used in un-P.C.C. with almost complete avoidance of achromatics.

(4) Preferred colours are employed mostly as the «first-picks» by Ss both in P.C.C. and in un-P.C.C.

(5) Colours with maximum frequency are the same both for P.C.C. and un-P.C.C.

(6) Colours with maximum frequency have high chroma notations.

Table 2. Hue Relationship of Colours in Pleasant - Colour - Combinations

Interval Difference	5	4	3	2	1	0	%
Interval - D Symbol	K1	K2	K3	G2	G1	0	
Frequency (%)	4.5	15.0	22.7	25.0	21.4	10.5	100

Table 3. Value Relationships of Colours in P. C. C.

I - D	5 +	4	3	2	1	0	%
I - D. Symbol	K1	K2	K3	G2	G1	0	
F (%)	6.8	27.3	45.5	13.6	4.5	2.3	100

Table 4. Chroma Relationships of Colours in P. C. C.

I - D	10 +	8	6	4	2	0	%
I - D. Symbol	K 1	K2	K3	G2	G1	0	
F (%)	4.5	9.1	19.2	24.7	29.6	12.9	100

Table 5. Hue Relationships of Colours in Unpleasant Colour - Combinations.

Interval Difference	5	4	3	2	1	0	%
Interval - D Symbol	K1	K2	K3	G2	G1	0	
Frequency (%)	10.0	22.5	17.5	22.5	20.5	7.5	100

Table 6. Value Relationships of Colours in Unp. C. C.

I - D	5 +	4	3	2	1	0	%
I - D. Symbol	K1	K2	K3	G2	G1	0	
F (%)	0.0	2.5	12.5	15.0	32.5	37.5	100

Table 7. Chroma Relationships of Colours in Unp. C. C.

I - D	10 +	8	6	4	2	0	%
I - D. Symbol	K1	K2	K3	G2	G1	0	
F (%)	2.5	7.0	13.0	17.5	27.5	32.5	100

2. Two colour combinations.

The analysis of the two colour combinations made by the Ss showed that while a large number of them were done by using two chromatic colours side by side, some of them were composed by combining a chromatic colour with an achromatic one.

a. Combinations with the chromatic colours.

These were studied according to the interval differences of two colours along their Hue, Value and Chroma dimensions.

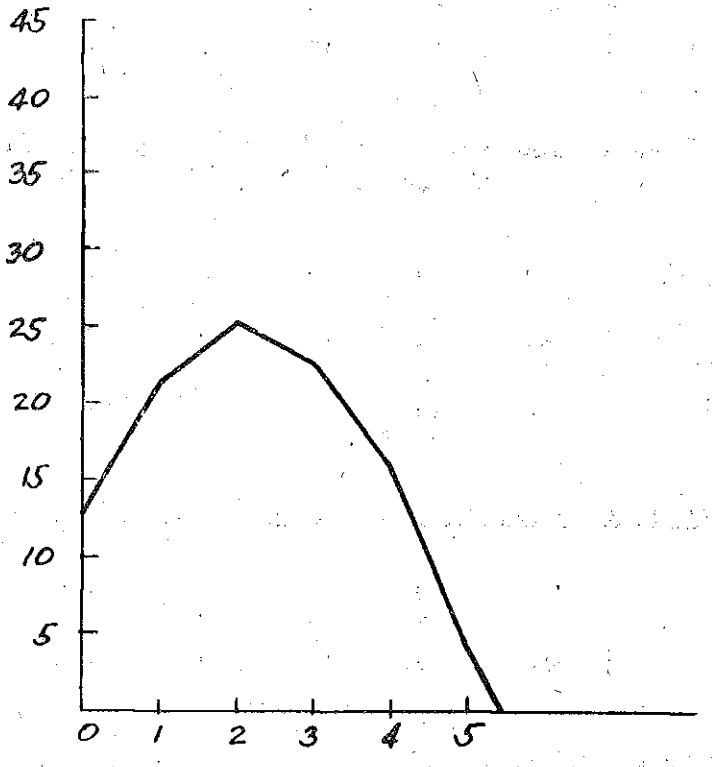


Figure 2. Hue Curve in P.C.C.

I. Hue relationships. From Table 2 it can be seen that the hue relationships of the two colours in P. C.C. follow a somewhat normal distribution starting from zero interval to five, having 2 as its peak. Figure 2 shows the percent frequency curve where a marked preference for interval 2 followed by 3 is clearly observed.

Also from Table 5 and Figure 5 it is seen that the curve for the unpleasant colour combinations is a bimodal one with peaks at intervals 2 and 4.

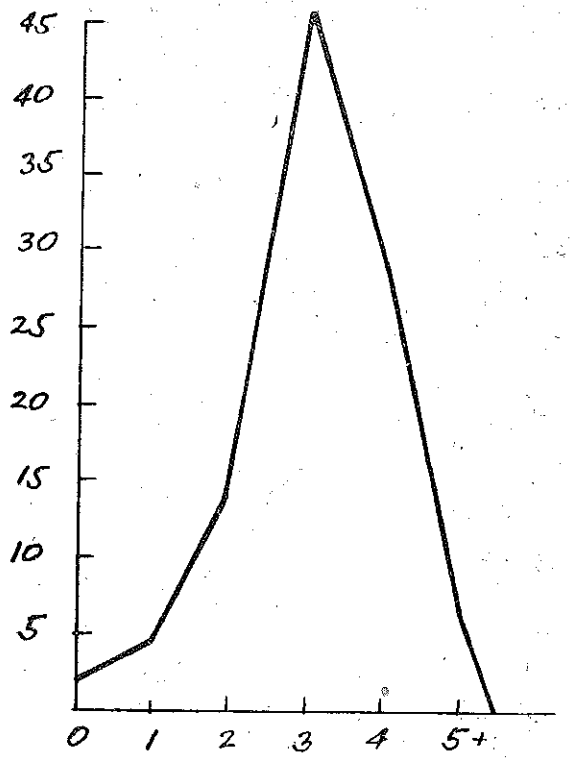


Figure 3. Value Curve in P.C.C.

II. Value relationships. The distribution of the value intervals in P.C.C. is normal having 3 step interval as the maximum.

The curve is completely changed for the un-P.C.C. The maximum frequency happens at 0 interval, the curve descending steadily with increasing intervals. The interval 5 which is the last point on abscissa has no frequnency at all.

III. Chroma relationships. The chroma distribution of the P.C.C. again follows a normal curve with 2 (G 1) as its maximum point. It has a slight skewness to the right.

The chroma curve for the un-P.C.C. is very similar to the value curve for the un-P.C.C., showing, however, a steadier descent.

IV. Suggested formulae. These results show very interesting tendencies in the relationships in terms of step-interval-differences between combined colours along three dimensions. The curves drawn as a result of experiments show certain similarities that might well indicate an

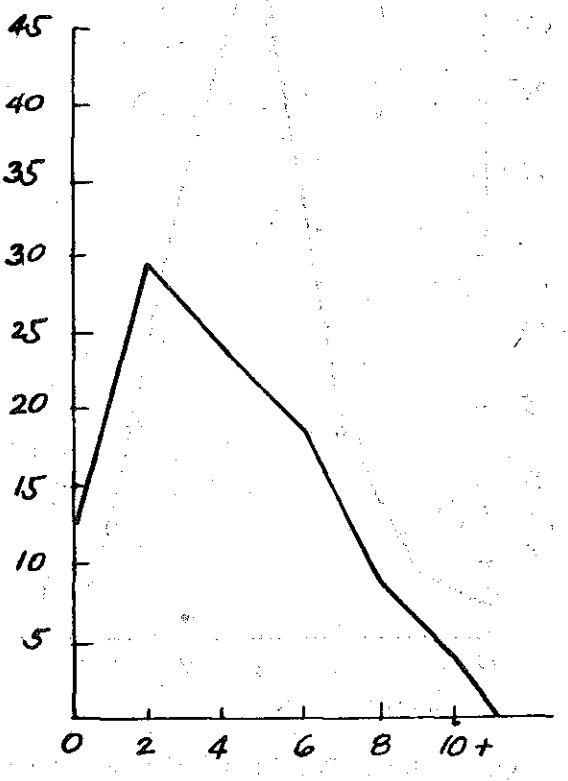


Figure 4. Chroma Curve in P.C.C.

overall pattern which applies to each of these cases. Limiting ourselves to the extreme points, which, as a matter of fact, indicate more pronounced generalities, we can deduct some workable formulae describing this tridimensionality.

Following symbolic Munsell notation of H V/C, and placing the most frequent interval values from the Hue, Value and Chroma curves of the P.C.C. correspondingly we could write;

$$\text{H V/C} = 2\ 3/2 = \text{G2 K3/G1}.$$

The values next to the maximums; 3 4/4 = K3 K2/G2.

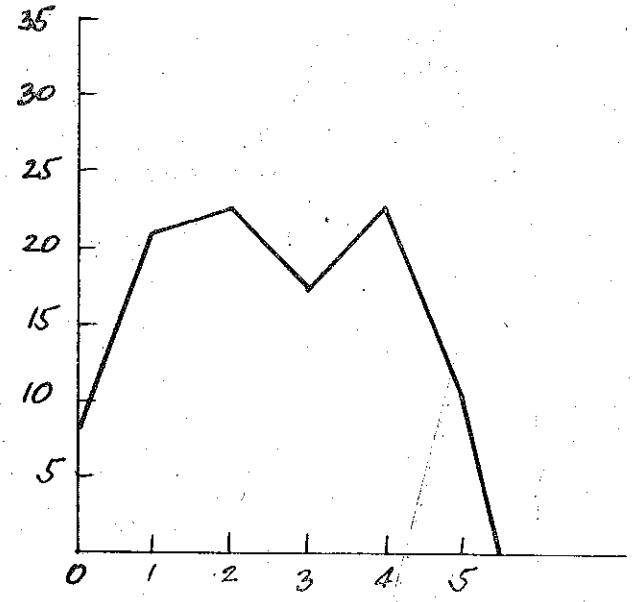


Figure 5. Hue Curve in Unp. C.C.

These two cases can fit into a more general formula. If we consider the numerical value of H, r in the formula, the numerical value of V will be r+1 and the numerical value of C will be r—1. So, the relationships of hues, values and chromas in P.C.C. combinations when the interval differences between the component colours along every dimension are considered, thus, gives the following formula :

r r+1/r—1.

For the un-P.C.C. hue differences do not seem to be a crucial relationship. Its curve has two peaks and not much of a variation, it may fit a horizontal line with further experiments and some mathematical acrobacy. The very important point, however, is the 0 difference as being the maximum point both along the V and along the C dimensions hinting towards a relationship of 0/0 between the interval steps of values and chromas, or Gl/Gl as the next alternative. Thus, the formula for un-P.C.C. becomess : H 0/0.

b. Combination with a chromatic and an achromatic colour.

Value being the only common variable of these compositions their relationships could only be investigated along this scale. Among the

P.C.C. group 26.6% of the compositions is of this kind. The most frequent interval difference is 5, followed by 4; the curve ascending. The interesting point is the complete avoidance by the Ss of such a usage in their un-P.C.C. Another interesting point is the high employment of these compositions in applied problems such as the different kinds of skirt and

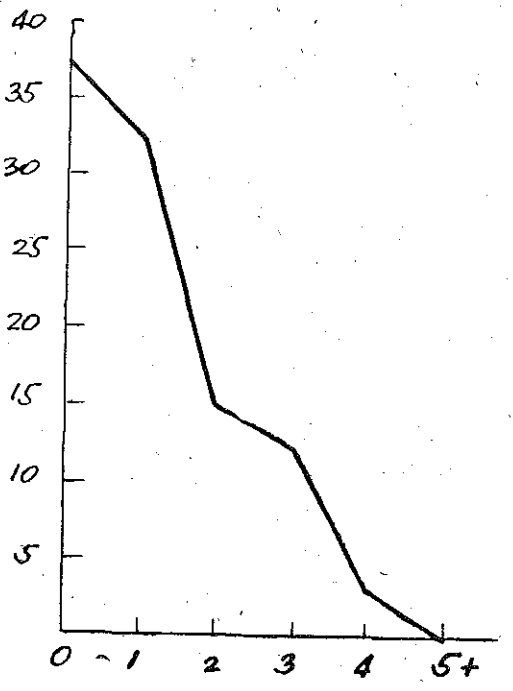


Figure 6. Value Curve in Unp. C.C.

blouse combinations. These results show the importance of value relationships in the tridimensional balance of colour combinations.

c. Skirt and Blouse Combinations.

The experiments were extended to the investigation of possible variations, in colour combinations by the addition of certain situational factors to the verbal instructions. One of the tasks consisted of composing first simple skirt and blouse combinations for girls and then complicating the matter a little further by adding the variable of different complexions, or of different physiques of wearers to be considered in the combinations. Since the distributions of interval differences along

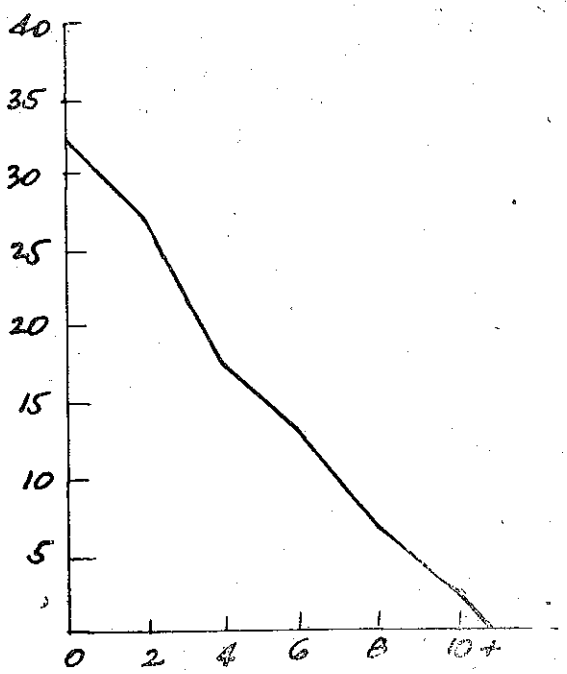


Figure 7. Chroma Curve in Unp. C.C.

the Hue, Value and Chroma variables followed a more or less normal course as in the P. C. C., maximum points are indicated as the more pronounced characteristics. The use of achromatics in these combinations is very much higher than in simple colour combinations. The average use of «chromatic+achromatic» for the eight different types of these blouse and skirt combinations is over 35%, in some cases reaching 50% or even higher. Where two chromatics are employed for the simple skirt+blouse combinations the most frequent interval differences are: H2 (G2), V2 (G2), C2 (G1). 65% of these combinations are made by using chromatics with achromatics. The highest frequency is at 5 followed by 4, the curve being an ascending one. For combinations made considering the complexion of the wearer the most frequent interval differences for Hue, Value and Chroma are as follows :

	H	V	C
Blond	4 (K2)	2 (G2)	8 (K2)
Brunette	2 (G2)	2 (G2)	6 (K3)
Dark	4 (K2)	3 (K3)	8 (K2)

The contrasting relations of chroma in all these cases is the most prominent feature, followed by hue contrast in the two extreme cases. 45% of the compositions for «blonds», 10% for «brunettes» and 50% for «dark girls» are made by the use of «2 chromatics+1 achromatic». The most frequent interval difference is 5 for «darks», 4 for «blonds», showing the same trend of seeking value contrasts.

When the physique of the wearers are placed for consideration the maximum interval differences show the following ditribution :

	H	V	C
Short + Fat:	1 (G1)	1 (G1)	8 (K2)
Short + Slim:	3 (K3)	2 (G2)	6 (K3)
Tall + Fat:	2 (G2)	5 (K1)	8 (K2)
Tall + Slim:	1 (G1)	3 (K3)	6 (K3).

Contrast of chroma is again used in all these compositions, with Value contrast employed for cases that fall into the «tall» group. On the other-hand, hue relationships in all these cases, is more or less of the grading type. «Chromatic + Achromatic» usage in these combinations is rather high. 45% of combinations for Short+Fat, 15 for Short+Slim, 30% for Tall+Fat, 25% for Tall+Slim are «Chromatic+Achromatic» type of compositions. Interval difference 5 is the most frequent in these three groups, with 3 being the most frequent difference for «Tall+Slim» cases.

Achievement of a tridimensional balance, as was observed in abstract colour cobinations definitely persists for applied problems too. However, the degree of interval differences in different cases show slight variations. The use of higher chroma and hue contrasts in different types of «skirt+blouse» combinations and more frequent use of chromatics with achromatics in some of these combinations, indicate the influence of certain situational factors in such compositions.

3. **Three colour combinations.**

As in the previous part of the experiments the Ss were requested to place, side by side, horizontally, the three colours that they chose according to the instructions.

The possible different compositions by using chromatic and/or achromatic colours in the three colour combinations were as follows :

	f	%
C C C ...	1	12.5
C C A ...	0	0
A C C ...	0	0
C A C ...	3	37.5
C A A ...	0	0
A A C ...	0	0
A C A ...	3	37.5
A A A ...	1	12.5
	8	100.0

Each combination was analysed accordingly along the three variables, Hue, Value and Chroma, by studying the relations of colours 1 and 2; 2 and 3; 3 and 1 respectively in each combination. Before dealing with these analyses it might be interesting to look at the frequencies in different possible chromatic and achromatic compositions where some obvious tendencies can easily be observed.

a. The frequency of different types of possible chromatic and/or achromatic compositions in three colour combinations.

In the P.C.C. «three chromatics» had the highest frequency followed by «two chromatic + one achromatic» group.

In the un-P.C.C. 90% of the combinations were of «three chromatics» group, the remaining being of «two chromatics + one achromatic».

In the rest of the experiments where compositions were of the applied sort Ss were asked to make «skirt, blouse and scarf» compositions and the use of the «three chromatics» was on the average 50% of the time. In all these eight different sorts of «skirt, blouse and scarf» cobinations, the use of two chromatics with one achromatic, providing the achromatic placed in the middle, was the next highest, in frequency.

The very low employment of achromatics in the construction of unpleasant colour combinations again occurs in this part of experiments. In contrast to that the highly frequent use of achromatics for applied cases still persists. All these point to the important role of value relationships in the pleasingly balanced organizations of colours.

When we study the compositions more closely, we see that all these apparent possibilities are used in a very subtle way, to achieve a certain form of distinct balance in this new task of 3-C-C as they did in the previous, 2-C-C.

b. Combinations with three chromatic colours.

I. Hue relationships. The Hue relationships of the three colours in P.C.C. follow a normal course with a slight skewness to the left. The maximum frequency is at 4 interval difference between colours 1 and 2; 2 and 3; 3 and 1. The highest interval difference between 1 and 2 is at 3; between 2 and 3 is at 4; between 3 and 1 is at 3.

The Hue curve of the un-P.C.C. also follow a more or less normal course with a skewness to the right, the most frequent interval difference for the total being at 1. Between colours 1 and 2 it is at 1; between 2 and 3 is at 2 and 4; between 3 and 1 is at 1 again.

II. Value relationships. In the pleasant colour combinations the distribution of the value interval differences is normal, 3 being the maximum of the total as well as of the different columns.

The unpleasant colour combinations curve is a descending one and the maximum frequency is at 0 interval difference.

III. Chroma relationships. The chroma distribution of the pleasant colour combinations again follows a more or less normal curve with the interval difference of 2(G1) as its maximum point. Between colours 1 and 2 the peak is at 4(G2).

For the unpleasant colour combinations the distribution is again a descending one from 0 interval difference onwards, between all parts of colours.

IV. Skirt & Blouse & Scarf combinations. Faced with the simple task of finding suitable skirt, blouse and scarf combinations for girls the Ss employed three chromatics in about half of their combinations. The Hue, Value and Chroma curves, in such compositions with three chromatics, follow a more or less normal course with maximum frequencies at interval differences 4 for Hue, 2 for Value and 2(G1) for Chroma. This shows a tridimensional variation very much like the one seen in abstract pleasant colour combinations.

When the complexion of the wearer is considered the maximum interval difference for «blonds» is 1 for H; 2 for V; and 2(G1) for Chroma. For «brunettes» it is 4H; 2V; 4(G2) for C. For «dark girls» it is 2H; 2V; 2(G1) for Chroma.

The factor of variation along the 3 variables is still operating. However, there are some slight differences between diffent groups. For «brunettes» the relationships are very much like those of P.C.C. and simple «Skirt & Blouse & Scarf» combinations, whereas of «dark girls» and especially for «blonds» the variations between the three variables is a bit lower, thus hinting even at this stage at some probable influence of the background colouring for the choice of combinations.

When the physique of the wearer was put forward as an additional problem for the choice of skirt & blouse & scarf combinations the maximum total interval differenees show the following distribution :

For	short	and	fat	girls	:	H	:	1 , 4	;	V	:	4	;	C ; 2 , 4.
»	»	»	slim	»	:	H	:	1	;	V	:	2	;	C ; 0 , 2.
»	tall	»	fat	»	:	H	:	2	;	V	:	0	;	C : 4. 2.
»	»	»	slim	»	:	H	:	1	;	V	:	2	;	C ; 0 , 4.

The total interval differences for H & V in all these 4 cases in very much lower than for P.C.C. and simple Skirt&Blouse&Scarf combinations. An interesting fact is the maximum frequency at 0 interval difference for Value in the tall and fat group. And another is the maximum frequency interval at 0 for Chroma in short and slim, tall and slim cases. That the area has an influence on colour relationships along its three dimensions is implied in these results, and needs, further investigation.

When all these skirt, blouse, scarf combinations are considered in general, value variable between the different items seem to have a more grading relation rather than a contrasting one as is seen in P.C.C. when three chromatics were employed in their construction. In some cases an overall contrast of Hue was tried but in general the relationships of the colours in all their aspects was more of a grading tone than a contrasting one.

c. Combinations with «Chromatic and Achromatic» Colours.

About 30% of three-pleasant-colour-combinations were composed by using two chromatics with one achromatic. The Hue, Value and Chroma

relationships of the chromatics employed in these combinations were studied accordingly. For P.C.C. the most frequent interval difference for Hue is at 5; for Value at 2; for Chroma at 2(G1).

There were very few cases of such compositions for the un-P.C.C. As was previously mentioned 90% of the un-P.C.C. were made by using three chromatics.

In all parts of the Skirt & Blonse & Scarf combinations such compositions were frequently used - on the avarage about 40%. The higgest total frequency of Hue is at 3; of Value at 2; of Chroma at 2(G1) interval differences. These maximum frequencies in Hue, Value and Chroma relations for these applied cases of colour combinations again show the same trend of seeking variability along three different dimensions of harmonious colour combinations.

d. Value relations in «Chromatic and Achromatic» Compositions. The most frequent interval difference, considering overall Value relations of such compositions, is at 5 between colours 1 and 2, for P.C.C. and for Skirt & Blouse & Scarf combinations and also for Skirt & Blouse & Scarf combinations when the complexion of the wearer was considered.

For the vast group of combinations where the physique of the wearer was considered the maximum interval difference is lower, being at 2.

Between colours 2 and 3 it was again at 5 for all parts of experiments. Thus, the contrast of value existing between the three colours of P.C.C. seems to have been maintained in applied cases, such as the Skirt & Blouse & Scarf combinations.

The maximum frequency for the combined value of three colours for all parts of the experiment is at 5 interval difference following a more or less ascending course with 0 interval difference as the least frequent.

The employment of achromatics in the unpleasant colour combinations with three colours was rare. When used, two chromatics with one achromatic was employed and the most frequent interval difference was at 1. This, again, indicates the importance of value relationships in harmonious colour combinations. There exists an almost complete avoidance of achromatic colour uses which might lead to easily attained harmonies in un-P.C.C. both with two colours and with three colours.

e. An attempt to classify the different types of balances used between different items of three colour combinations.

Contrasting and grading relationships between the colours along their Hue, Value and Chroma variables yield balances with certain inherent directions that could be summarized into two distinct groups and subgroups.

I. Hand - scale - balance.

A. With three chromatic colours, middle colour acting as the handle of a balance, distinctly contrasting in Hue or in Value from the other two.

B. A chromatic colour placed in the middle with two achromatics on its sides, or an achromatic in the middle with two chromatics on either side. This was a more obvious arrangement where value balances and variations were enhanced even more with the use of chromatics and achromatics together.

II. Linear balance.

A. Three chromatic colours balancing each other along a horizontal direction, mostly three of them grading in hue and value or two of them grading in hue and value and contrasting with the third in hue or value.

(C - C - C)

B. Either two achromatics or two chromatics placed side by side, with a chromatic or an achromatic in the end, respectively. This is a more obvious arrangement where the colours are either grading or contrasting from each other in hue and/or in value.

(A-A-C ; C-C-A)

4. Four Colour Combinations.

The Ss arranged their pleasant four colour combinations in a square form.

1	2
4	3

The interval differences of Hue, Value and Chroma of the individual colours are studied along a circular path between colours 1 & 2; 2 & 3; 3 & 4; 4 & 1; respectively.

a. The frequency of different types of compositions with chromatic and/or achromatic colours.

Of the four different types of apparent arrangements the most frequent one is with four chromatics. 50% of the combinations are made by the use of chromatic colours only. The next in frequency is «3 chromatics and 1 achromatic», 30%.

The rest are constructed by employing «two chromatics with two achromatics».

Table 5. Different frequencies of chromatic and/or achromatic mixtures in 4 Colour Combinations.

	1		2		3		4		%
Arrangement	C	C	N	C	N	N	N	C	
Form	C	C	C	C	C	C	C	N	
F %	53.3		35.0		6.7		5.0		100

When these combinations are analysed, the Hue, Value and Chroma relationships of the colours seem to follow certain definite patterns of arrangement. This is probably above all due to the increase in the number of colours to be combined pleasingly, as well as to the «square-form» of the arrangements.

b. Different patterns of arrangements in four colour combinations.

I. Combinations with four chromatic colours.

Linear patterns : The Hue relationships of this type of compositions are so arranged that the neighbouring colours along the horizontal

direction have either exactly equal interval differences or slightly different ones with the vertical differences in their turn also being equal or almost equal.

Most frequent interval differences of Hue are rather high at 3 (K3) and 4 (K2). Interval differences of Value are rather low, 2 being the most frequent. Chroma differences are also very low, 2 (G1) being the most frequent.

The pattern in this type of arrangements seem to be based on large differences in Hue with Values and Chromas grading among themselves.

Curvilinear patterns. The Hue, Value and Chroma relationships between the colours on the total show rather small differences usually grading along all three dimensions.

II. Combinations with «three chromatics and one achromatic».

In such compositions both Hue, Value and Chroma relations between the three chromatic colours and the value relations between all four colours were studied.

In general the most frequent interval difference for Hue is at 3, followed by 4, for Value at 2 (G2), and for chroma at 2 (GI).

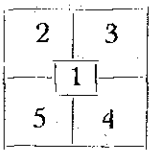
The overall value relations are on the whole of the grading kind; but still there are some contrasts between some of the items of the combinations, as well.

III. Combinations with «two chromatics and two achromatics.»

About 10% of the compositions are of this kind. Value contrasts seem to be the characteristic features of these combinations. The interval differences of chromas between the chromatic colours are also rather high.

5. Five Colour Combinations.

These combinations are arranged in a square form with one of the colours on top of the other four, in the middle. The interval differences of Hue, Value and Chroma of the individual colours are studied in a radial way comparing different items with the middle one; 1 and 2; 1 and 3; 1 and 4; 1 and 5, respectively.



a. The frequency of different types of compositions with chromatic and/or achromatic colours.

On table 6 seven different types of arrangements of chromatic + achromatic mixtures is shown. In these combinations the most frequent is the one with 5 chromatics, 53.3%; followed by 4 chromatics and 1 achromatic, 18%.

The analysis of these combinations also yield certain patterns of arrangements as is observed from the earlier results.

Table 6. Different frequencies of chromatic and/or achromatic mixtures in 5 Colour Combinations.

	1	2	3	4	5	6	7	%
Arrange. Form	C C C C C	C C N C C	C N C C C	N C C C N	C N N C N	C N N N C	C N N C C	
F %	53.3	18.4	11.7	5.0	5.0	3.3	3.3	100.0

b. Different patterns of arrangements in five colour combinations.

I. Combination with five chromatic colours.

This type of compositions can be divided into certain groups according to the interval differences along different dimensions. According to the Hue relationships about seven different arrangements can be classified. Another interesting fact is the placement of warm colours in the middle position for combinations dominated with cool colours and a cool colour in the middle of warm ones. Over 50% of these combinations have most saturated colour placed in the middle. If the other four colours are highly saturated, then the colour with the lowest chroma takes the middle position. All these point to the importance of the middle position in the balance of these combinations. Another point is the use of highest saturations in the smallest area in these arrangements.

The total frequencies of interval differences give 3 as the maximum interval difference for H (K3); 2 for Value (G2) and 2 for Chroma (G1).

II. Combinations with «4 chromatic + 1 achromatic» colours.

In these combinations the achromatic colour is either placed in the middle or on one side. When the achromatic colour is in the mid-position the most frequent total hue difference between the chromatic colours is 5 (K1), value 2 (G2), chroma 2 (G1). The value relationships of colours compared with the middle achromatic yield 5 as the most frequent interval difference in the total. With the achromatic placed on one side most frequent interval difference of Hue is 1 (G1), Value 2 (G2), and Chroma 2 (G1). Value relationships in the comparison of chromatics with achromatic give 2 (G2) as the highest frequency.

III. Combinations with «3 chromatic + 1 achromatic» colours.

About 8% of the combinations are of this kind, the maximum frequencies are H 3(K3), V 4(K2), C 2(G1). Maximum interval difference of value is 5 (K1).

IV. Combinations with «2 chromatics + 2 achromatics».

Only 3% of the combinations used this composition. The maximum frequency of interval difference of values is also 5 (K1).

In all these five colour combinations there is a general distribution of value and hue contrasts with rather small differences of saturation.

DISCUSSION.

The results obtained in this investigation lend further support to the theory of a general objective law governing harmonious colour combinations independent of the affective values of the particular colours forming these combinations.

In all parts of colour experiments the emergence of value relationships between colours as a vital factor to achieve harmony point to a possible anology between spatial patterns of darker and lighter areas and patterns of pitch and time as in the world of music; serving to establish identifiable and repeatable patterns, to be more descriptive,

to establish rhythm. Rhythm, perhaps, is thus a common element in the perception of harmonious relationships, be it of sounds, or of colours or may be of forms.

Any pleasing phenomena in our perceptual world may be pleasing perhaps because it satisfies best the functioning of that certain part in our nervous system responsible for that perception, by letting an easy flow of information to the receptors with a high economy in effort. And rhythm may be contributing to the increase of perceptual span by dividing up patterns of material so that larger units can be more readily grasped.

The interruption of rhythms lead to a static experience, devoid of life, highly unpleasant as was observed by the non use of value and saturation intervals when Ss were confronted with the problem of making their own unpleasing combinations with colours.

Further attempts to investigate these points might yield very interesting results in the field of visual perception.

SUMMARY AND CONCLUSIONS.

Ten tests of harmonious colour combinations along with two tests of unharmonious colour combinations were given to 20 Ss of normal colour vision. In addition, their colour preferences were also investigated. All of the combination tests represented variations along each dimension of colour - hue, brightness, and saturation. In each test, Ss were asked to make their own preferred combinations for specific situations.

Combinations were obtained against a backround of neutral grey (Munsell N5). Data for all tests were collected under a source of artificial daylight with colour temperature of about 6500° K, approximating in energy distribution C.I.E., illuminant **C**.

The following conclusions were reached :

1. Individial colour preferences in general favour cool chromatics.

2. Preferred colours are employed as "first picks" by Ss in their combinations.

3. In harmonious two colour combinations the relationships of hue value and chroma yield the formula :

$$r \quad r+1/r-1$$

with r replacing H, $r+1$ replacing V and $r-1$ replacing C in the Munsell System of H V/C.

4. Maximum frequencies for pleasant colour combinations with 2 colours according to the above formula is found to be;

G2 K3/G1 .

5. Maximum frequencies for unpleasant colour combinations yield the relationship of :

H 0/0 .

6. Degree of interval differences in different cases of skirt & blouse combinations again showed a tridimensional balance with slight variations, indicating certain situational factors in such compositions as being operative.

7. In three colour combinations contrasting and grading relationships between the colours along their Hue, Value, and Chroma yielded balances with certain inherent directions that could be summarized into two distinct groups as,

I. Hand — scale — balance,

II. Linear balance.

8. In four colour combinations Hue, Value, and Chroma dimensions followed certain definite patterns of arrangement as in the previous series. Linear and curvilinear patterns were met in combinations where four chromatics were employed. In combinations with 2 chromatics and 2 achromatics contrast seemed to be the characteristic feature.

9. Five colour combinations revealed the same tendency for systematic patternings in the arrangements, as is observed throughout the experiments.

10. Results are interpreted as evidence in favour of an "objective and general law" governing combinations of colours in the field of colour perception. Further experiments should be designed to control these findings.

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REFERENCES

1. BİRAND, B. A. The problem of suitability in visual perception. Tecrübî Psikoloji Çalışmaları, 1958, 2, 11-83.
2. EYSENCK, H. J. The general factor in aesthetic judgments. Brit. J. Psychol., 1940, 31, 94-102.
3. ———; A critical and experimental study of colour preferences. Amer. J. Psychol., 1941, 54, 385-394.
4. GRANGER, G. W. An experimental study of colour preferences. J. Gen. Psychol., 1955, 52, 3-20.
5. ———; An experimental study of colour harmony. J. Gen. Phychol., 1955, 52, 21-35.
6 ISHIHARA, S. Test for Colour Blindness. London: Lewis, 1948.
7. MUNSELL, A. H. A Color Notation. Baltimore : Munsell Color Company, Inc., 1954, 67 pp.
8. VALENTINE, C. W. Experimental Psychology of Beauty. London : Jack, 1913.