İKİ - RENKLİ KARIŞIMLARLA İLGİLİ BİR ARAŞTIRMA

AN EXPERIMENTAL STUDY OF TWO-COLOUR COMBINATIONS *

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Renk karışımlarında mevcut objektif kaideleri araştırmak üzere tecrübeler yapılmıştır. İki - renkli karışımlarla yapılan üç seri incelemenin, birinci ve ikinci kısımlarında renk çiftlerinin uygunluğuna tesir eden faktörler araştırılmıştır. Üçüncü seri araştırmada ise kısa süreli gözlemlerde renk - çiftlerinin tefrikine ne gibi faktörlerin tesir ettiği incelenmiştir. Tecrübî neticeler, renk - çiftlerinin uyuşmasına tesir eden, doğrudan doğruya objektif tembih özelliklerine bağlı bir takım temel faktörlerin mevcudiyetine işaret etmektedir.

Experiments were carried out to test the possibility of an objective law governing combinations independent of the affective values of the particular colours forming them. Three sets of experiments with two-colour combinations were conducted, two of them to determine the factors contributing to the pleasantness or unpleasantness of the pairs the third to investigate the conditions influencing discriminations of pairs at very short durations of exposure. Experimental evidence renders it quite plausible to predict the presence of a fundamental factor, dependent on objective stimulus properties in the appreciation of colour combinations.

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INTRODUCTION

Aesthetic appreciation is generaly believed to be governed by subjective criteria. This belief is held by laymen and scientists alike. Yet, a great number of behavioural aspects of human beings such as learning, thinking, remembering, etc., are known to be lawful. They are accepted to depend on his properties as an organism, on his capacities for response to stimulation, and the structure of his nervous system. To accept the aesthetically oriented behaviours as subjective and unlawful is not compatible with this overall trend. That such behaviours contain many interacting variables enabling a well controlled scientific investigation very difficult, is true. But so is his many other behavioural aspects. Yet, through rigidly controlled scientific experimentation it was possible to probe into many human activities in the laboratories the world-over.

Previous attempts by the author to investigate basic and objective principles underlying preferences of simple colour combinations and form combinations strongly indicated the possibility of the existence of some objectively definable principles governing such combinations (Togrol, 1958). A more thorough investigation of this problem was made possible during her tenure as a Research Fellow of Newnham College at Cambridge University. A series of experiments conducted with various sorts of colour combinations yielded some quantitatively definable relationships as existing between the members of these combinations (Togrol, 1961, 1964). The experiments with 2-colour combinations from this first group of investigations, along with two recent additional groups of experiments of 2-colour combinations will be reported in this paper. It was the hypothesis of these experiments that: (1) Prefences of colour combinations are governed by objective principles dependent on stimulus properties, and (2) These prefences are likely to be dependent on physiological properties of the human visual mechanism.

Munsell System of Colour Notation was chosen for work with surface colours as it fulfills the requirements of the psychological colour solid. Thus, the three dimensions of chromatic colour sensation, namely Hue, Brightness (Value), and Saturation (Chroma), and their relative effects and interactions in colour combinations could be investigated. As it is a well known system, it is only sufficient here to remind that a complete Munsell notation for any chromatic colour is written as Hue Value/Chroma, or symbolically H V/C. A particular sample of vermilion might then have a Munsell Notation of 5R 5/12.

Standard Munsell papers 2.5×3 inches in size were used as materials throughout the experiments. This size would be sufficient when held at arm's length to subtend an angle equalling the size of the fovea.

GENERAL PLAN OF EXPERIMENTS

It has been decided to report the experiments seperately since the problems considered at each phase were somewhat different, and the results of preceding phases were directly relevant to the design of the succeeding phases.

EXPERIMENT I

The problem of this series of experiments was, (a) to determine what sort of interval differences would be employed along the Hue, Value and Chroma dimensions in different sorts of colour combinations when the subjects were free to compose their own combinations, and (b) the influences of preferred individual colours on such combinations.

Subjects : The 20 Ss were men, students of Cambridge University without any particular training or interest in arts. Consideration influencing selection was that all Ss should be of normal colour vision. The Ishihara Test of Colour Blindness (9th Edition) was used for screeing purposes.

Material : Ten Munsell major hues from No. 5 series were selected to represent the Hue variable in these experiments. Nickerson's (1936) suggestion as to the proportion of visual steps of value to saturation being 1/2 was kept in mind while choosing the Value and Chroma steps. Intervals 2/ , 4/ , 6/ , and 8/ were chosen for Value intervals and /4 , /8, and /12 for the Chroma scales. However, owing to the inavailability of some pigments at some higher saturation levels, adjustments had to be made and a sample of 71 colours with additional 10 neutrals were selected.

Procedure : The experiments were conducted in a dark room, illumination being provided by using "Siemens - Ediswan Industrial Colour Matching Unit", providing a suitable source of artificial daylight with colour temperature of about 6500°K, approximating in energy distribution to C.I.E. Illuminant C.

Ss were tested one at a time. They were seated at the table where the experimental material was randomly laid out. There was sufficient space left for Ss to place their own compositions. They were first instructed to compose three different 2-colour combinations by choosing only two colours from the table that they thought would go well together. They were free to use same colours repeatedly in their different compositions. But they were not allowed to change the size of the colours by superimposing them. The experimenter noted the code number of the colours and replaced them before S started to compose his next combination. The S's next task was to make three combinations by choosing any two colours that they thought would look unpleasant together. They were lastly asked to indicate their most preferred rive colours in their rank order. There was no time limit.

Treatment of Data: The differences between the H V/C dimensions of colours were calculated providing certain interval-differences along all three dimensions of the pairs. The interval differences determined for the Hue variable were between 0 and 5, in accordance with the placement of different colours on the Colour Circle. Brightness differences were between 0 and 5+, and Saturation differences were between 0 and 10+. To give an example; if two colours used by a S in one of his combinations had the following notations,

R 6/10 , Y 4/6

then, this combination would yield the following interval differences :

HUE = 2, VALUE = 2, CHROMA = 4.

Following the determination of the frequencies of interval differences for H, V and C, the chi-square (x^2) test was given. Owing to the invariability of some of the pigments, all three dimensions were not equally represented in the experimental set. For this reason, the expected probability of occurance for each interval difference along the the different dimensions had to be calculated individually.

Results :

(1) Pleasant-Colour-Combinations. x^2 analysis for Hue, Value and Chroma interval-differences gave the following results:

Hue	: $x^2 = 2.5$	$P > .10$
Value	: $x^2 = 891.8$	$P < .001$
Chroma	: $x^2 = 5.2$	$P > .10$

These results indicate a marked influence of the Value Interval Differences (VID) on two colour combinations. In Fig. 1 it is seen that the distribution for VID had 3-ID as its peak point.

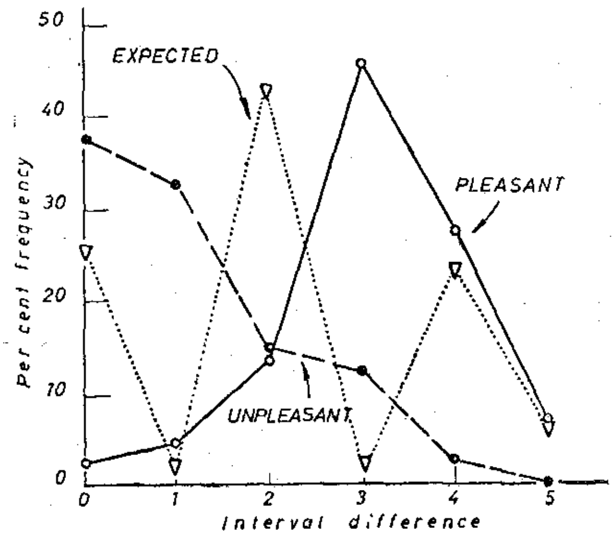

Fig. 1: Distributions of interval differences of value for two colour combinations.

(2) **Unpleasant-colour-Combinations.** The results of x^2 tests for this set of combinations were as follows:

Hue	: $x^2 = .7$	$P > .10$
Value	: $x^2 = 281.6$	$P < .001$
Chroma	: $x^2 = 4.6$	$P > .10$

Value seems to be as significant a factor for unpleasant colour combinations as for the pleasant ones. However, the distribution of interval differences for this variable follows an entirely different trend from the previous one. In Fig. 1 it is seen that the curve for such combinations is of a descending type with zero-ID as its modal point.

(3) **Colour-Preferences.** On the whole Ss' preferences seemed to pool towards cool-chromatics: 49 % (Short-wave colours; as blues and greens) followed by warm chromatics: 39 % (Long-wave colours; as reds and yellows) and neutrals: 12 %. Maximum frequencies were for saturated colours in both the cool and the warm series. The differences between these preferences were significant at the .05 level of confidence.

An interesting point was the avoidance of preferred colours by the Ss in the construction of their combinations. Only about 4 % were employed in pleasant colour combinations, and 2 % in unpleasant colour combinations. That most of these preferred colours used in the combinations constituted the "first-picks" of the Ss was an additional interesting point.

EXPERIMENT II.

The purpose of this group of experiments was to verify the findings of the first series of experiments with a different national group of subjects within a new experimental design.

Subjects: 10 men were used as Ss. They were students of Istanbul University and their colour vision was normal.

Materials: Two sets of 16 pairs of Munsell Colours were used. These colour pairs were mounted on white cardboard side by side. The first set was prepared to represent four interval differences along all three dimensions of colour. A 4×4 Greaeco-Latin Square arrangement was employed in the randomization of different variables. In the second set Chroma difference was held constant at zero interval difference, and Hue and Value differences were changed.

Procedure: Ss were tested one a time in a quiet room with ample north lighting. The colour pairs were presented to the Ss four at a time on a white background in random order. The Ss were instructed to pick the most pleasant pair among the 4 pairs presented, and to hand it over to Experimenter. He was then asked to select the most unpleasant pair of the remaining 3. His next task was to score these two pairs indivudually on a six-point-scale with 5 as the highest score and 0 the lowest. There was no time limit.

Results:

(1) Pleasant-Colour-Pairs. Analysis of the data yielded significant influences of Value and Hue differences of the combining pairs on preferences. F-ratios were significant at $P < .01$ level of confidence both

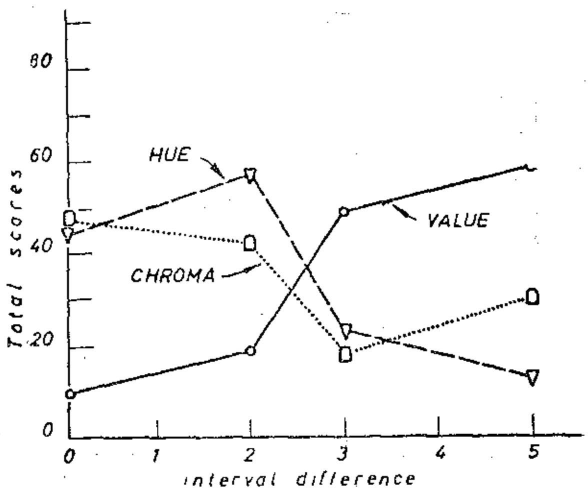

Fig. 2: Distributions of interval differences of hue, value and chroma dimensions for pleasant pairs.

for Value and Hue differences as shown in Table 1. Fig. 2 presents distributions of various interval differences of H V C dimensions of preferred pairs. From this figure it is indicated that larger V but smaller H and C interval differences may be contributors for preferences of colour pairs.

When the Chroma Interval Differences were held constant at zero and H and V differences varied in the colour pairs, Value Differences again stand out as a most significant factor for preferences as can clearly be seen in Table 2 and Fig. 3.

TABLE 1. Analysis of Variance for Effects of H, V, C interval Differences on Pleasant Colour Combinations (4×4 Graeco-Latin Square)

SOURCE OF VARIATION	SUM OF SQUARES	d.f.	MEAN SQUARE	F	
Value difference	413	3	134	67	P <.01
Hue difference	298	3	99	49	P <.01
Hue	7	3	4		
Chroma difference	126	3	42	21	
Error	90	3	30	15	
Total	934	15			

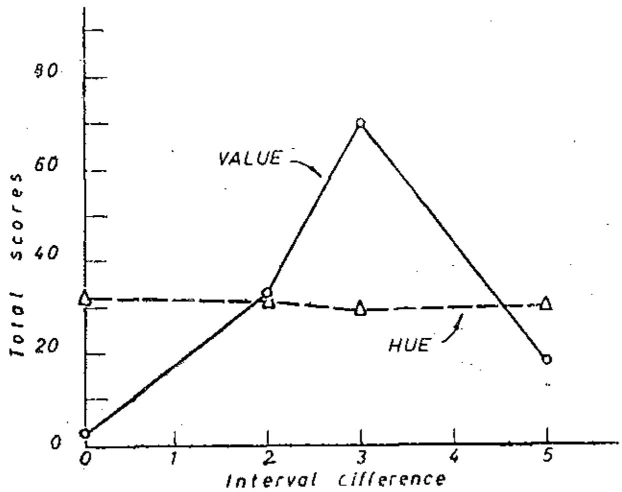

Fig. 3: Distributions of interval differences of hue and value dimensions for pleasant pairs when chroma differences was held constant at zero

TABLE 2. Analysis of Variance for effects of H and V Interval Differences on Pleasant-Colour-Pairs (Chroma Difference = 0)

SOURCE OF VARIATION	SUM OF SQUARES	d.f.	MEAN SQUARE	F	
Hue difference	3	3	1		
Value difference	620	3	207	207	P <.001
Error	506	9	56		
Total	1129	15			

(2) **Unpleasant-Colour-Pairs.** Table 3 presents the F ratios for effects of interval differences along the three dimensions for unpleasant combinations. In this set of experiments Hue differences yielded very significant results for this task ($P<.01$). Distributions of interval differences along H V C dimensions indicate larger H and C but smaller V differences as contributors for choice in this situation (Fig. 4). Holding Chroma differences constant at 0 level again pushes Value differences as the most important factor (Table 4). In Fig. 5 it is indicated that when Chroma difference is kept at 0, when Value difference reaches a 0 level, the colour pairs are most often judged as unpleasant.

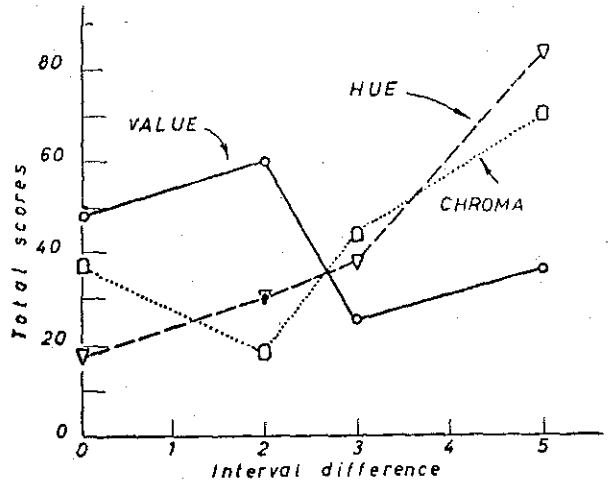

Fig. 4 : Distributions of interval differences of hue value and chroma dimensions for unpleasant pairs

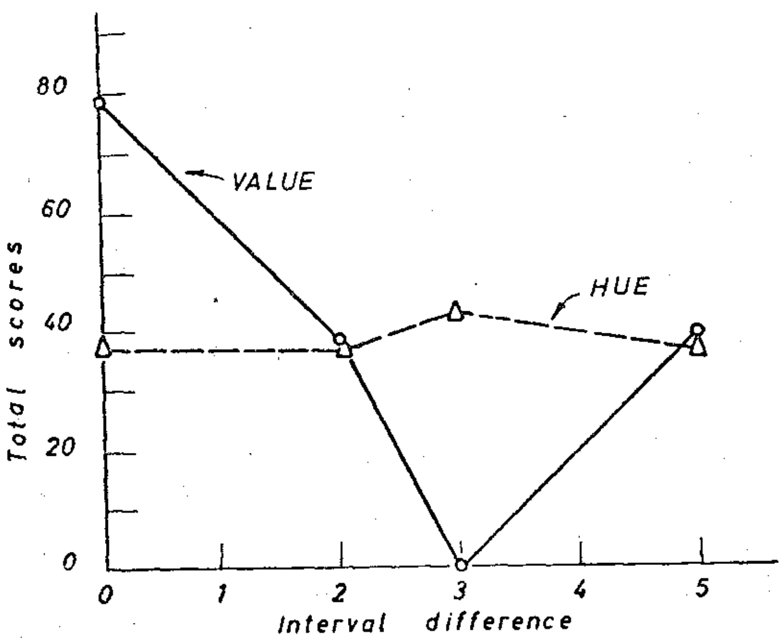

Fig. 5: Distributions of interval differences of hue and value dimensions for unpleasant pairs when chroma difference was held constant at zero.

TABLE 3. Analysis of Variance for Effects of H. V. C Interval Differences on Unpleasant Colour Combinations (4×4 Graeco-Latin Square).

SOURCE OF VARIANCE	SUM OF SQUARES	d.f.	MEAN SQUARE	F	
Value difference	171	3	57	14	
Hue difference	604		201	50	P <.01
Chroma difference	322	3	107	27	
Hue	13	3	4		
Error	214	3	71	18	
Total	1324	15			

TABLE 4. Analysis of Variance for effects of H, V, C Interval Differences on Unpleasant Colour Combinations (Chroma Difference = 0)

SOURCE OF VARIANCE	SUM OF SQUARES	d.f.	MEAN SQUARE	F	
Hue difference	7	3	2		
Value difference	763	3	254	127	P <.01
Error	1446	9	161		
Total	2216	15			

EXPERIMENT III

The purpose of this phase of experiments was to investigate the conditions contributing to discriminations of colour pairs at very brief durations of exposure.

Subjects: The 10 Ss were women, students of Istanbul University. They all had normal colour vision.

Material: Two sets of 9 pairs of Munsell Colours were used. The first set was prepared with Chroma difference at 0 (zero) level, Hue and Value intervals of the pairs differing at three levels: 0, 2, and 5 ID. In the second set of 9 pairs Value differences were held constant at 0 (zero) varying Hue and Chroma at three levels.

The colour pairs were presented to the Ss with a tachistoscope. Two durations of exposure, 1/100 and 1/50 were used. These were very short durations to obstruct the eyes from changing their fixation points during the exposure.

Procedure: Ss were tested one at a time. They were seated comfortably in front of the apparatus and were instructed to say "whatever they saw" in the apparatus, to the Experimenter's "Ready ... Now" signal. They were not told beforehand that the stimulus material was composed of colour pairs. They all seemed, however, to get the hint soon. Almost no additional instructions were needed. The two sets of 18 pairs were randomly mixed for each repetition with different Ss. 9 pairs were presented at 1/100 sec. first, the remaining 9 pairs were exposed at 1/50 sec. afterwards. Ss responses were scored on an all-or-none basis, any response containing perception of pairs, i.e. discrimination of some sort were scorer "1", the others lacking this quality "0".

Results: Analysis of variance for effects of H and V interval differences on perceptions of colour pairs when C differences were held constant at zero, yielded significant results for Value differences ($P<.01$), Hue differences ($P<.05$) and exposure times ($P<.01$).

When Value differences of colour pairs were held constant (0 level), then exposure times and Chroma differences proved to be highly significant: $P<.01$ and $P<.05$ respectively (Table 6).
cant: $P<.01$ and $P<.05$ respectively (Tablo 6).

Larger differences of the Value gave better discriminations for shorter exposures, whereas medium differences for Value contributed slightly better discriminations at comparatively longer durations. When Value differences were held constant at zero, and Chroma intervals were varred, larger differences yielded better results at both exposures (Tablo 7).

TABLE 5. Analysis of Variance for Effects of H and V Interval Differences (Chroma Difference = 0) on Perceptions of Colour Pairs at Short Durations of Exposure (1/100, 1/50 second).

SOURCE OF VARIATION	SUM OF SQUARES	d.f.	MEAN SQUARE	F	
Exposure Time	16	1	16	32	$P<.01$
Hue difference	9	2	5	10	$P<.05$
Exp. Time X Hue	0	2	0		
Value difference	37	2	19	38	$P<.01$
Exp. Time X Value	8	2	4	8	
Value X Hue	11	4	3	6	
Exp. Time X Hue X Value	2	4	.5		
Total	83	17			

TABLE 6. Analysis of Variance for Effects of H and C Interval Differences (Value Difference = 0) on Discrimination of Colour Pairs at Short Durations of Exposure (1/100, 1/50 second).

SOURCE OF VARIATION	SUM OF SQUARES	d.f.	MEAN SQUARE	F	
Hue difference	5	2	2.5		
Chroma difference	49	2	24.5	49	$P < .05$
Exposure Time	20	1	20.0	40	$P < .01$
Hue X Exp. Time	1	2	.5		
Chroma X Exp. Time	2	2	1.0		
Hue X Chroma	2	4	.5		
Hue X Chroma X Exp. Time	3	4	.8		
Total	82	17			

TABLE 7. Distribution of Scores for Various Interval Differences (ID) at Two Levels of Exposures.

EXPOSURE	VALUE DIFFERENCE			CHROMA DIFFERANCE		
	0	2	5+	0	4	10+
1/100 sec.	12	22	25	7	16	19
1/50 sec.	21	30	25	15	19	27

CONCLUSIONS

In this paper evidence has been presented that: (1) differences of brightness levels between the members of colour pairs significantly influenced the pleasantness or unpleasantness of their combinations, and (2) perceptions of colour pairs for short durations of exposure were again dependent on the differences of their brightness levels.

Although much more work needs to be done these findings help to indicate towards an existing parallellism between the stimulus factors contributing to our perceptive capacities and to our activities of a rudimentary aesthetic character. Julesz (1965) in his ingenious experiments on visual perception with computer generated random dot patterns has found their perceptive characteristics to be dependent on their adjacent brightness levels. When brightness levels of adjacent dots were nearly similar spontaneous discriminations were impossible, and they were perceived as one, when this was altered they were perceived as two. He suggests that the visual system incorporates a slicer mechanism that seperated adjacent brightness levels into two broad categories: dark and light. And it is impossible to perceive as similar and form clusters by shifting our attention to dots that are not adjacent in brightness. Recent neurophysiological experiments on frogs (Muntz, 1964) and cats (Hubel, 1963) have disclosed that their visual system extracts certain basic features of a scene prior to more complex processing. This early filtering of significant information by retina, in term, makes for efficient utilization of the limited number of optic nerve fibres. What is physiologically determined to be true of frogs and cats, has been perceptualy proved to be true by Julesz's experiments with humans. All this confirms our findings at the perceptual level and provides for speculations for our activities at higher levels, at least within the context of these experiments. We may now say that our appreciations of pleasant 2-colour combinations is dependent on the relative information passed from the adjacent pairs to the central nervous system that provides for simpler and more economic processing of in-put relationships. If the "slicer mechanism" can easily differentiate the stimuli as consisting of two entities then judgements of pleasantness are more readily passed. Opposite is true for in-put relations that obstruct the smoothness of this mechanism.

Any two colours with interval differences of zero or nearly so along the Value and Chroma dimensions are generally judged as unpleasant (Figs. 1, 4 and 5). Using the Munsell Notation, we may now suggest that a general formula indicating the difference levels of dimensions for unpleasant pairs could be written: H 0/0.

To suggest a formula for pleasant pairs is more difficult. A difference of 3 Value intervals has almost consistently occupied the modal point in large number of our results (Figs. 1, 3), with comparatively smaller H and C differences. In Fig. 2 it is 2 ID for Hue and zero ID for Chroma. It could tentatively be suggested that optimum difference level for pleasant pairs may be written as: 2 3/0, or, considering the numerical value of H as r, the optimum relationships along the three dimensions of colour pairs, at least for medium interval differences might be formulated to be :

$$r\ r+1/r-1.$$

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