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MINOR STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF THE UNIVERSITY OF NEBRASKA

X. Factors Determining the Affective Values of Color Combinations

By Elysbeth C. Allen and J. P. Guilford

In a previous study,[1] the senior author proposed a quantitative law of affective combination by which the affective value of a combination of two colors can be predicted from the affective values of the two components. This law was later found to apply to combinations of odors as well as colors.[2] In both cases, however, the predictions were not perfect, indicating that there are other factors determining the value of the combination. A search of the literature on color harmony finds many suggestions to account for 'good' and 'poor' color combinations. In fact this literature presents a veritable mine of hypotheses which are capable of direct scientific verification or refutation. Only a few of them will be tested in this study.

Many writers on the subject of color combinations have been concerned with such factors as differences in hue, tint, and chroma of the two colors, in one way or another.[3] Cohn[4] was one of the first to urge that contrasting hues and tints make the most agreeable combinations; he presented experimental results to support his contention. Other investigators, particularly Baker[5] and Metcalf,[6] have obtained results which contradict this general rule. Yet many 'authorities' who have written on the subject stress the importance of using complementaries or near complementaries in getting artistic effects. As a second choice, hues that are very close together on the color circle rather than those with a medium amount of difference are recommended. Neighboring hues are said to require a strong brightness-difference to be pleasant, and contrasting hues require a small brightness-difference.[7] Medium differences in hue are said to be worse if there is a brightness-difference.[8] There are other rules of good color combinations, but our data seem inadequate to the

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[1] J. P. Guilford, The prediction of affective values, this Journal, 43, 1931, 469-478.

[2] W. Spence and J. P. Guilford, The affective value of combinations of odors, this Journal, 45, 1933, 495-501.

[3] For a bibliography of the work on color preferences see A. R. Chandler, A bibliography of experimental aesthetics, 1865-1932, *Ohio State Univ. Stud., Bur. Educ. Res. Mimeo.,* 1933 (no. 1), 1-25. For a summary and critical discussion, see J. G. Beebe-Center, *The Psychology of Pleasantness and Unpleasantness,* 1932, 1-427.

[4] J. Cohn, Experimentelle Untersuchungen über die Gefühlsbetonung der Farben, Helligkeiten, und ihrer Combinationen, *Phil. Stud.,* 10, 1894, 562-602.

[5] E. S. Baker, Experiments on the aesthetics of light and color: I. On combinations of two colors, *Univ. of Toronto Stud., Psychol. Ser.,* 1, 1900, 201-249; II. Spectrally pure colors in binary combinations, *ibid.,* 2, 1907, 27-43.

[6] J. T. Metcalf, The pleasantness of brightness combinations, this Journal, 38, 1927, 607-623. This study deals exclusively with colorless stimuli.

[7] M. E. Chevreul, *The Principles of Harmony and Contrast of Colours,* 1890, 69 ff. Also W. von Bezold, *The Theory of Color,* 1896, 175 ff.

[8] Von Bezold, *op. cit.,* 185.

task of testing them. Our data can be used to indicate validity of the rules that have been listed in this paragraph only.

Method and Procedure

Selection of the color combinations. Forty-five pairs of colors were selected from the 90 colors of the Milton-Bradley series in the following manner. The 90 colors were given some preliminary ratings for hue, tint, and chroma, using the Munsell *Book of Color.* Eight pairs were chosen in which the two colors were practically equal for tint and for chroma but the hue differed from 2 to 9 steps on the Munsell scale. Six pairs were chosen with hue and tint constant but the differences in chroma varied 3 to 9 points on the scale. Eight pairs had hue and chroma relatively constant but tints differing from 2 to 5 steps. Six pairs had almost identical hues but differences in both tint and chroma. Six pairs were almost equal in tint but varied in both hue and chroma. Five more were equated for chroma with differences in hue and tint. The remaining 6 varied simultaneously in all three attributes of color, making a total of 45 color-pairs. The result was 18 pairs differing in hue by less than one step, the remaining 27 differing from 1 to 9.6 steps, 10 steps difference being exactly complementary. There were 19 pairs with less than one step of difference in tint, the remaining 26 differing from 1 to 5.3 steps. There were 20 pairs with less than two steps difference in chroma the remaining ones differing from 2 to 9.5 units. After the judgments for affective value had all been obtained, each *O* was asked to rate the colors according to the Munsell scales on two different days. The means of the 20 ratings were used as the final evaluations of hue, tint, and chroma of the colors used.

The colored papers were cut into rectangles 2 in. x 4 in. and the pairs were glued adjacent to each other in 4 in. squares on photo-mount cards having a neutral gray surface which rated exactly 5.0 points on the Munsell scale. In order to find the affective values of the single colors, they were cut into 4 in. squares and glued similarly on the neutral gray backgrounds. Both the single colors, numbering 40, and the combinations were presented to *O* for his judgments within the same hour of observation.

Procedure. Ten *O*s including 5 men and 5 women, 2 of them being instructors in psychology, 4 graduate students, and 4 undergraduates, served in the experiments. None had had any technical training in the fine arts. Each *O* judged the colors and the combinations 5 different times on 5 different days, using a rating scale of the numerical type, with values ranging from 1 to 9, and with an indifference point at 5. The stimuli were presented under artificial 'daylight' illumination for 5 sec., against a large neutral gray background. *O,* having his head fixed in a head-rest, looked into a small chamber whose walls were of the same gray material as that upon which the colors were glued. The stimuli were exposed in a small window at the rear. The order of presentation of stimuli was arranged so as to avoid adaptation and contrast effects. From the experiments we have the affective value of the 45 combinations as based upon the means of 5 judgments for every *O,* and the pooled ratings for 5 men and 5 women. We also have similar ratings for the affective values of the components of all the pairs, and the evaluations of hue, tint, and chroma for all the color components.

Results

The law of affective combination. We first present Table I to show how well the affective value (AV) of a combination can be predicted from the affective values of the separate components. Linear functions were assumed because that is what were found in the previous studies. The multiple coefficients of correlation appear in column (1) and the partial standard regression coefficients (Beta coefficients) for the more pleasing component (P) appear in column (2), and the Beta coefficients for the less pleasing component (U) appear in column (3), for the *O*s separately and for the pools of judgments of women and men. On the whole, the predictions can be made more accurately for the women than for the men. The coefficients of multiple correlation (R) are smaller than those previously found when predicting from P or U, but all the multiple coefficients, save one, are very

TABLE I

Coefficients of Multiple Correlation and Standard Regression Coefficients for the Prediction of Affective Values of Color Combinations from the Values of the Components and from the Differences in Tint and Chroma

		(1)	(2)	(3)	(4)	(5)	(6)
	O	$R_{AV.PU}$	$\beta_{AVP.U}$	$\beta_{AVU.P}$	$R_{AV.TC}$	$\beta_{AVT.C}$	$\beta_{AVC.T}$
Women	A	.47	.20	.31	.38	.29	−.21
	B	.72	.12	.65	.26	.06	−.24
	C	.61	.22	.44	.32	−.22	−.27
	D	.70	−.11	.75	.10	.11	−.14
	E	.60	−.02	.61	.49	.45	−.13
	Mean	.64	.09	.57	.28	.21	−.17
Men	G	.15	.04	.13	.62	.61	−.07
	H	.70	.57	.22	.38	.38	−.06
	I	.55	.09	.52	.68	.68	.05
	J	.69	.21	.55	.53	.52	−.07
	K	.65	.28	.50	.29	−.30	−.04
	Mean	.58	.38	.25	.66	.65	−.04

significant.[9] The Beta coefficients give a fair idea of the relative importance of the two variables P and U in predicting the AV of the combination. For the women the less pleasing component, U, is decidedly the stronger factor but for the men there is disagreement as to which is the stronger factor.

It has been suggested before that perhaps the distinction between P and U variables is a rather artificial one.[10] A different type of distinction was tried with these data. We classified the component colors as stronger (S) or weaker (W), according as their affective values were farther from the indifference point or nearer to it. That is possible when a rating scale method is used and the indifference point has been established. As it happened with our particular selection of colors, however, the S-W distinction almost coincided with the P-U distinction because a majority of the single colors are above the indifference point, that is pleasant rather than

[9] Any R in this problem that is greater than 0.363 would be regarded as significant, and any R greater than 0.442 very significant, according to R. A. Fisher's table of significance as presented by H. R. Wallace and G. W. Snedecor, Correlation and machine calculation, *Iowa State Col. Pub.*, 1931, 62.

[10] Guilford, *op. cit.*, this Journal, 43, 1931, 476.

unpleasant, so that in most cases a color that is P is also S, and one that is U is usually W. Only in a few cases was the less pleasing color farther from the indifference point and hence stronger than was the more pleasing one. As a matter of interest, we computed the multiple coefficients of correlation predicting the AV of the combination from S and W. There were small changes in R for different individual *O*s, but the Rs for the pooled ratings were almost identical with those in Table I, being 0.640 for the women and 0.589 for the men. Nothing is apparently gained from the practical standpoint of accurate prediction by using the S-W distinction, but logically it would seem to be much more significant than the P-U distinction. If our AVs for the components had been distributed equidistant above and below the indifference point, an increase in the Rs might have resulted.

Influence of differences in hue, tint, and chroma. Since earlier writers have urged that both small and large differences in hue are favorable for pleasing combinations, before attempting to correlate those differences with the AV of the combination we have attempted to see whether the supposed non-linear relationship holds. On account of the very wide scatter of the data when AV is plotted against difference

TABLE II

RELATION OF THE AFFECTIVE VALUES TO DIFFERENCES IN HUE

	Difference				
	0–.9	1–1.9	2–4.9	5–7.9	8–9.9
Women	.733	−.470	−1.74	−.072	.270
Men	−.062	.055	−.125	−.021	.192
N	10	10	8	11	6

in hue, very little notion could be gained concerning the type of relationship. We therefore eliminated the influence of other known factors in the following manner. We obtained regression equations for predicting AV from the two components, and from differences in tint and chroma. The Beta regression coefficients may be found in Table IV. We predicted the AVs of the combinations from the 4 variables, found the discrepancies between the predicted AVs and the observed AVs, and used these discrepancies to find the relationship between AV and differences in hue. Table II shows the mean discrepancies for various degrees of difference in hue. A negative average in Table II means that the effect of that particular difference in hue is to lower the AV of the combination and a positive mean indicates an enhancing effect.

The limited data of Table II are merely suggestive that there is some truth in the hypothesis that both very similar and contrasting pairs are pleasant. The women's results suggest this much more strongly than do the men's. Certainly, the data fail to show any continuous linear relationship between differences in hue and the AV of the combinations, and since the type of functional relationship is as yet unknown, no correlation between these two variables will be attempted.

When the AVs of the combinations are plotted against the differences in tint, the scatter diagram is apparently a linear distribution with a positive slope. The scatter diagram for the AVs plotted against the differences in chroma is likewise linear with a very slight negative slope. These facts being true, we felt justified in correlating the AV of the combinations with difference in tint (T) and with difference in chroma (C) and in finding a multiple R and the Beta coefficients. These results are given in Table I, columns (4), (5), and (6). There is little doubt from the results that the men are decidedly more responsive to these two variables than are the women. The two multiple Rs are 0.66 and 0.28, respectively. With the exception of two *O*s, the greater the difference in tint the more pleasing the combination. All the *O*s, with one very doubtful exception, are slightly inclined to prefer their two components near together for chroma rather than far apart. The women are almost as responsive to homogeneity of chroma as they are to difference in tint, although not very responsive to either factor. Men are decidedly responsive to contrasting tints, but are practically unresponsive to the factor of homogeneous chroma. It is not to be overlooked that the responsiveness to either of these factors is contingent upon a concomitant discrepancy in hue, as some writers have pointed out. If a difference in hue were held constant the influences of T and C might be significantly enhanced. As it is, the men as a group are more influenced by differences in tint and in chroma than they are by the AVs of the two components. The two total Rs are 0.66 and 0.58, respectively.

We can also predict the AV of the combinations from all 4 independent factors, S, W, T, and C, simultaneously. The results appear in Table III. Only the two

TABLE III

Multiple Correlations and Beta Coefficients for Predictions of Affective Value from S, W, T, and C

	$R_{AV.SWTC}$	$\bar{R}_{AV.SWTC}$	$R^2_{AV.SWTC}$	$\beta_{AVS.WTC}$	$\beta_{AVW.STC}$	$\beta_{AVT.SWC}$	$\beta_{AVC.SWT}$
Women	.707	.674	.454	.304	.492	.207	−.166
Men	.881	.868	.753	.516	.375	.649	−.039

pools of data are represented. $R_{AV.SWTC}$ is the raw multiple R, uncorrected for the number of variables. $\bar{R}_{AV.SWTC}$ is the corresponding R after the correction.[11] $\bar{R}^2_{AV.SWTC}$ is known as the 'coefficient of multiple determination' and it estimates the proportion of the determination of the dependent variable that may be attributed to the combined influence of the several independent variables. Thus the AVs of the combinations for these 5 women are determined by the factors S, W, T, and C to the extent of about 45%. The AVs of the men are determined about 75% by those same factors.[11] We shall have to look elsewhere for the remaining causal factors. A comparison of the Beta coefficients suggests that for women the weaker of the two components has the greatest potency in determining the AV of the combination, and the difference in chroma has the least effect. For the men the stronger component has more effect than the weaker, as we should rather expect, but stronger than either is the factor of difference in tint. Difference in chroma has practically no effect for the typical man in this group.

Influence of differences in hue and tint. What now of the rules that neighboring hues require a large difference in tint to be pleasant, whereas medium or large differences in tint are better with small brightness differences? The strong correlation between brightness difference and AV, especially in the case of the men's data, argues in favor of a large brightness difference, no matter what the difference in hue may be. To test the question further, we have fractionated our data into 3 sets, separating out the small, medium, and large differences in hue. Small differences were those less than 2 units of the Munsell scale; medium differences were greater than 1 but less than 8; large differences were greater than 6. There is thus some overlapping, but this is in order not to restrict the numbers of cases within each category too much. Within each one of the 3 groups the combinations were sub-

[11] M. Ezekiel, *Methods of Correlation Analysis,* 1930, 177.

divided into large and small differences in tint. Small differences were those less than 2 units on the Munsell scale, and large differences those greater than 2 units. Table IV shows the resulting differences in AVs under the different groupings.

The numbers of cases are very small indeed, and we have accordingly used (N-2) instead of N in computing the standard deviations of the means when N is 10 or above and we used (N-3) when N was less than 10.[12] This gives a conservative estimate of the sigma of a difference and also of the critical ratios. In spite of the limited data the critical ratios for the men at least are significant. The negative differences indicate that the rules of the 'authorities' are wrong. In every one of the 3 sets of data, a large difference in tint is on the whole preferred to a small difference. Regardless of what the difference in hue is, then, the same relationship of brightness-differences to affective value holds. The law is upheld almost with statistical assurance in the case of the men's data and not for the women's data, just as the correlation coefficients would lead us to expect. We can be reasonably sure that the lower multiple Rs for the women in column (4) of Table I are

TABLE IV

DIFFERENCES IN MEAN AFFECTIVE VALUES OF COMBINATIONS HAVING LARGE OR SMALL DIFFERENCES IN TINT WHEN THE SIMULTANEOUS DIFFERENCES IN HUE ARE LARGE, MEDIUM, AND SMALL

	Contrasting hues ($H>6$)			Medium hue diff. ($1<H<8$)			Neighboring hues ($H>2$)		
	Women	Men	N	Women	Men	N	Women	Men	N
Tints nearly the same	4.76	4.41	8	4.17	3.83	6	4.79	4.47	10
Tints differing	5.06	6.00	6	4.54	5.18	8	5.55	5.32	12
Diff. in AV	−.30	−1.59		−.37	−1.35		.86	.85	
CR_σ	−.45	−3.70		−.36	−2.50		1.73	2.80	

not due to any contaminating effect of differences in hue. We say "reasonably sure" here because what little evidence there is in Table IV is in favor of large brightness-differences as opposed to small, and it is consistently so for all degrees of difference in hue.

SUMMARY AND CONCLUSIONS

Forty-five color combinations were carefully selected as to differences in hue, tint and chroma. Ten *O*s, 5 men and 5 women, judged the affective values of the combinations using a rating scale method. The following conclusions are indicated by the results.

(1) The law of affective combination was fully verified; the affective value of a combination is highly dependent upon the affective values of the components.

(2) There is some evidence that either very small or very large differences in hue give more pleasing results than do medium differences. This tendency is much stronger for women than for men.

(3) The affective value of a combination is positively correlated with the amount of contrast in tint, regardless of whether the difference in hue is great, medium, or small. This correlation is much stronger for the men than for the women.

(4) There is a slight preference for combinations with small differences in chroma rather than large differences. This is a negligible factor in the case of the men.

[12] J. W. Dunlap and A. K. Kurtz, *Statistical Nomographs, Tables and Formulas*, 1932, 103.