in other animal phyla. Preliminary results indicate that the same technique can be used to distinguish stocks of the same species belonging to populations geographically separated.

On the basis of the results obtained, it appears that this technique will become a useful tool in taxonomic and population-genetical studies, and that it may perhaps also be used for an understanding of phylogenetic relationships in biochemical terms. More complete accounts will be published elsewhere.

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Area Balance in Color Harmony: An Experimental Study

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The importance of area in color design is generally recognized both by aestheticians and practicing artists. In fact, one recent authority on composition maintains that ". . . the choice of quantity is more important than the choice of colour" (*1*). From the practice of artists an empirical "rule" has developed concerning the proper balance of areas in a design. The accepted principle is that a large area of color at a low degree of saturation will balance a small area of highly saturated color; the principle is sometimes extended to lightness—balancing of the darks against the lights. When stated in quantitative terms, this "rule" is of particular interest to experimental aesthetics, and the object of the present preliminary investigation is to examine two quantitative hypotheses that have been proposed, with a view to testing their predictive value. The first hypothesis was suggested by A. H. Munsell (*2*), a practicing artist who developed the Munsell Color System, and the second was put forward more recently by Moon and Spencer (*3*).

Munsell gives the following quantitative "rule" for areas:

> The stronger the color . . . the smaller must be its area; while the larger the area, the grayer the Chroma. Thus, R 7/6[2] balances R 3/3 in the proportion of nine parts of the lighter red to forty-two parts of the darker red. In other words, these symbols will balance colors inversely as the product of their factors. This opens up a great field of area (*2*).

Cleland, in his "Practical Description of the Munsell Color System" (*4*), has stated the same principle in the following terms:

> We . . . have to take the Value into account in determining the amount of area of these two colors to be used if we are to arrive at a perfectly balanced color design; and this is done by the simple process of multiplying the Chroma by the Value of each of the colors.

[1] The author is grateful to H. J. Eysenck for his helpful comments and suggestions.

[2] That is, in terms of the usual Munsell notation: Hue Value/Chroma.

Moon and Spencer (*3*) also claim that relative area is a function of both value and chroma. They consider that a pleasing balance is obtained when the product of each area and its distance from the "adaptation point" are the same, in color-space. (The "adaptation point" is simply the general level to which the eye is adapted when viewing the color patches.) The color-space to which Moon and Spencer refer is a metric-space that they have developed by making a mathematical transformation of the C.I.E. color-space (*5*). The reason for constructing this particular space was to provide a suitable system for the geometrical formulation of color harmony; the ordinary C.I.E. space was considered unsuitable because it is an affine color-space, "where angles in general do not have any meaning and where distances in different directions cannot be compared" (*5*). It is not necessary, for the present purpose, to discuss the nature of this metric-space in detail, for it is correlated with the Munsell system, and Moon and Spencer's hypothesis may be translated in terms of Munsell notation. But it is necessary to consider their system very briefly, for it is in terms of the metric-space that they have put forward their basic postulate. This postulate is stated as follows: "A pleasing balance among n color patches is obtained when the scalar moments about the adaptation point in ω-space are equal, for all the patches" (*3*). This postulate will become obvious from Fig. 1, which shows both the rectangular and cylindrical coordinates of Moon and Spencer's system.[3]

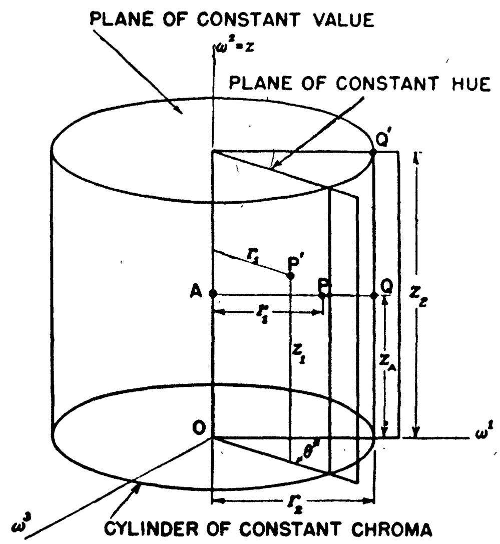

FIG. 1. Moon and Spencer's metric color-space, showing the Cartesian coordinate system (ω^1, ω^2, ω^3) and the cylindrical coordinate system (r, θ, z).

The planes of constant-hue are arranged at angles θ about an achromatic axis (z). Any color is represented by a point in the 3-space, as for instance P (r, θ, z). The adaptation point A is on the neutral axis. Sup-

[3] The author is grateful to the editor of the *Journal of the Optical Society of America* for permission to reproduce Fig. 1 from Moon and Spencer's article (3, p. 95).

pose there are any two colors, P and Q, of the same hue and of the same lightness as the adaptation point, but of different chromas; then P, Q, and A are on the same horizontal line. If the color patch P has area s_1 and Q has area s_2, then the scalar moments about A are s_1r_1 and s_2r_2, and, according to Moon and Spencer's postulate, a pleasing balance is obtained when the moments are equal; i.e., when $s_1r_1 = s_2r_2$. As the principle is perfectly general, the points P and Q need be neither on the same horizontal line nor in the same plane. They may, for instance, be two points, P' and Q' in which case their moments will be:

$$s_1\{r_1^2 + (z_1 - z_A)^2\}^{\frac{1}{2}} \text{ and } s_2\{r_2^2 + (z_2 - z_A)^2\}^{\frac{1}{2}}$$

and, according to the postulate, there should be a satisfactory balance when these moments are equal. If this principle is to be tested by means of color samples it must be stated in terms of Munsell notation. This is possible because there is an approximate correspondence between r in the metric-space and Munsell chroma, θ and Munsell hue, and z and Munsell value. Chroma is taken as equal to the number of units of r from the neutral axis, and value is taken as $z/8$. (This is in accordance with the work of Bellamy and Newhall [*6*] who have shown relationships between the units in the three Munsell scales.) The scalar moment of any color point about the adaptation point (Munsell N5) becomes, in Munsell terms: $s\{(\text{chroma})^2 + 64\ (\text{value} - 5)^2\}^{\frac{1}{2}}$; i.e., equal to area of the color patch × moment arm.

It is interesting to note that Moon and Spencer's postulate is identical with Munsell's "rule" for the case where the color patches and the adaptation point are all of value 5, for the moment arms are then equal to the chromas of the patches, and the areas required for satisfactory balance are inversely proportional to them. For example, suppose two small color patches, R 5/6 and R 5/8 of areas s_1 and s_2, respectively, are presented against a large background of Munsell neutral grey (N5). In this case the second patch is of higher chroma than the first, and the product of the factors of the two patches are $5 \times 6 = 30$, and $5 \times 8 = 40$. Applying Munsell's rule, the area of the second patch must be adjusted so that it is 3/4 of the area of the first. By Moon and Spencer's method, the moment arm of the first patch is $\{6^2 + 64\ (5-5)^2\}^{\frac{1}{2}} = 6$, and that of the second is $\{8^2 + 64\ (5-5)^2\}^{\frac{1}{2}} = 8$, and a pleasing sense of balance is therefore obtained when the areas are adjusted so that the second is 6/8 of the first. Both hypotheses are stated quite explicitly, so they can be submitted to experimental test.

But before such a test can be undertaken, an assumption underlying the two hypotheses must be examined. This assumption, which is not made explicit by either Munsell or Moon and Spencer, is that a certain amount of agreement exists between individual preferences. Clearly, unless there is some measure of agreement concerning the most desirable ratios for color balance, the need for aesthetic formulas does not arise. This problem is a fundamental one throughout the whole field of experimental aesthetics and must be considered in the present situation; so that, in fact, there are two questions which must be answered: first, is there some measure of general agreement between individual preferences for area-balance and, second, if such agreement exists, to what extent can it be accounted for by the two formulas that have been proposed?

Twenty subjects, representing a fairly wide range of occupations and interests, took part in the experiment; all were of normal color vision as tested by three standard tests, the Ishihara, Rabkin, and Farnsworth-Munsell, and none was familiar with the aesthetic theories under test. The experimental material consisted of 64 Munsell color patches arranged in the form of two sets, each containing 16 pairs of colors. Each pair of color patches was presented against a neutral grey background of Munsell value 5, and illumination was provided by a 500-w tungsten lamp in conjunction with a Macbeth daylight filter. The lamp had previously been calibrated at the National Physical Laboratory, to give a color temperature of 2848°K when operated at a specified voltage. Line voltage was controlled by means of a variac transformer. The color temperature was raised from 2848°K (i.e., C.I.E. standard Illuminant A) to 6500°K, by introducing a Macbeth filter especially designed, when used with Illuminant A, to give a match for color quality and an approximation in energy distribution to Illuminant C (i.e., standard artificial daylight). Subjects were instructed to adjust the areas of the two color patches in each pair to give the most pleasing balance. For each set of colors, the average observed ratios for the 20 subjects were then correlated with the predicted ratios, and the amount of agreement between subjects' preferences was determined by calculating the average intercorrelation coefficient.

It was found that the amount of agreement between individual preferences was remarkably high, the average intercorrelation coefficients being .672 and .732 for the two sets of colors. This result is in itself of considerable importance, for it suggests that, in this relatively unexplored part of the field of color aesthetics, there is the same objectivity of preference that has been found in studies of single colors (*7*) and color harmony (*8*). Turning next to the question of the extent to which the two formulas can account for this general agreement, correlations between predicted and observed ratios for the two sets of colors were .18 and .38 for Moon and Spencer's formula, and .73 and .59 for Munsell's empirical "rule." Without undertaking a more refined statistical analysis, these results indicate that Munsell's formula can account to a considerable extent for subjects' preferences: it does, in fact, account for about 35% and 53% of the total variance in the two sets of colors. On the other hand, Moon and Spencer's formula, in its present form, has no satisfactory predictive value.

The results indicate that further research of a more detailed nature on Munsell's formula would be worth while. They also suggest that the more fruitful approach in this field is likely to be along fairly empirical lines rather than by deductive procedures for, whereas Munsell's simple rule was derived from his observations as a practicing artist, Moon and Spencer's formula was derived by more purely deductive arguments. This suggestion does not of course mean that Moon and Spencer's formula should be rejected on the basis of this one small-scale preliminary investigation.

In conclusion, it may fairly be claimed that, here as elsewhere in the field of color aesthetics, preferences show a marked degree of independence of purely personal taste and a dependence on objective stimulus properties, which suggests that they may have a fundamental biological basis in the perceptual system.

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Adrenal Hypertrophy in the White Leghorn Cockerel after Treatment with Thiouracil and Thyroidectomy

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It has been established by previous investigators (*1*) that administration of thiouracil to the rat results in atrophy and degeneration of the adrenal gland. Recently Zarrow and Zarrow (*2*) have correlated this response with a decreased output of adrenocorticotrophic hormone by the pituitary of thiouracil-treated animals. In view of these data it seemed pertinent to report evidence of adrenal hypertrophy in White Leghorn cockerels similarly treated.

The effect of thiouracil was studied in two series of birds. The first series received 0.1% thiouracil in chicken mash from the 11th to the 19th day and was autopsied on the 20th day of age. The second series received a similar thiouracil diet from the 10th to 39th day and was autopsied on the 40th day of age. Control animals used in each case were fed a standard chicken mash.

The effect of thyroidectomy was studied in a series of 26 birds. Thyroidectomy was performed before the birds were 5 days old, and the animals were then placed on a standard chicken mash diet and otherwise treated in the same manner as 23 control birds received on the same day. The birds were autopsied at 40 and 42 days of age, at which time a careful macroscopic examination was made for thyroid tissue in the operated birds. Only those birds in which no thyroid tissue was found were considered to be totally thyroidectomized; those operated birds in which thyroid tissue was present were placed in a subtotally thyroidectomized series for analysis. In no case was the amount of thyroid tissue in the operated birds equal to that in the control animals.

TABLE 1

EFFECT OF THIOURACIL ON ADRENAL WEIGHTS

Treatment	No. birds	Body wt (g)	Adrenal wt (mg)	Relative adrenal wt (mg/100 g body wt)
Birds 20 days old at autopsy				
Control	9	101	23.63	23.4
0.1% thiouracil 11th–19th day	4	93	25.30	27.2
Birds 40 days old at autopsy				
Control	9	398	52.33	13.4
0.1% thiouracil 10th–39th day	8	239	63.10	26.4*

* Difference from control series significant at the 1% level.

It can be seen from Table 1 that after 9 days of thiouracil treatment the adrenals showed no significant change in weight, although the slight hypertrophy even at this early date is perhaps suggestive. After 29 days of treatment, however, a very marked hypertrophy of the adrenal was evident, the relative weight of the adrenals from the treated birds being nearly twice that of the adrenals from the control birds. The effect of thyroidectomy was even more striking (Table 2). A statistically significant increase in relative adrenal weight was induced by both partial and total thyroidectomy with total ablation being the more effective. In terms of absolute weight of the adrenal, however, no significant difference between the experimental and control birds was observed.

TABLE 2

EFFECT OF THYROIDECTOMY ON ADRENAL WEIGHTS*

Treatment	No. birds	Body wt (g)	Adrenal wt (mg)	Relative adrenal wt (mg/100 g body wt)
Control	23	377	55.08	14.6
Subtotal thyroidectomy	21	270	55.89	20.7†
Total thyroidectomy	5	128	52.76	41.2†, ‡

* Operations performed prior to 5 days of age; autopsied at 40 and 42 days of age.
† Difference from control series significant at 1% level.
‡ Difference from subtotal thyroidectomy series significant at 1% level.