

A Theory of Colors in Combination—A Descriptive Model Related to the NCS Color-Order System

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Abstract: Colors rarely appear alone, they usually appear together. Since the number of colors is very large, the number of color combinations is almost infinite. Consequently, it is difficult to investigate how people perceive and evaluate color constellations in various contexts. It seems pointless to study arbitrarily chosen combinations. To bring order into the large number of possible color combinations, a structure is needed. The following article presents such a theoretical model—a theory of colors in combination. The article is based on the Natural Color System for the ordering of singular colors, which is in turn the practical extension of Hering's phenomenologically based Opponent Color Theory. Thus, the model is descriptive, i.e., the variables carry immediate meaning regarding the actual color appearance. Since the model is purely descriptive, it contains no information per se of whether colors are beautiful together or not. However, the model can be used as a reference structure to investigate the attributes and connotations of the experience of a given color combination (some examples of this are given). The most relevant attributes, or dimensions, of color combinations are categorized into three main groups, each with three subfactors: The Color Interval, with the subvariables Distinctness of Border, Interval Kind, and Interval Size, is the perceptual phenomenon that occurs in the transition from one color percept to another. The Color Chord, with subvariables Complexity, Chord Category, and Chord Type, expresses the character of the combination, how the colors “sound” together, i.e., the totality of the Color Gestalt. The Color Tuning, with subvariables Surface Relations, Color Relations, and Order Rhythm, refers to some of the different ways color combinations can be varied. The present color combination model

should be seen as a theoretical, albeit empirically based, starting point for further studies of people's perception of color constellations, a scientific area that still, probably because of its complexity, seems to be uncharted territory.

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Key words: color combinations; color order systems; complementary colors; color harmony; color interval; color contrast; color chord; tuning; visual texture; distinctness of border; color phenomenology; color percepts; color space; opponent colors; natural color system

INTRODUCTION

Many researchers have been interested in what people associate with colors and how they evaluate them. Most studies aiming at investigating these questions, however, have been performed in laboratories and with single colors, isolated from any natural environment. In connection with our own earlier studies of color associations,¹ we found, among other things, that one reason why studies of isolated colors were of limited value was that people rarely experience color percepts one at the time. Colors usually appear together—a fact that makes the concept of “unrelated colors” in the CIE vocabulary somewhat strange.

The question underlying the present work is whether it is possible, on the basis of a phenomenological analysis, to design a descriptive model for color combinations. Such a model would certainly be helpful, both in research and for color design, to identify and describe various color constellations—in the same way as the NCS system denotes single colors.

Regarding the development of the NCS, the task was to organize, by means of phenomenological analyses and psychophysical experiments, individual color percepts in relation to each other, and assign them descriptive notations

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corresponding to their characteristically qualitative color attributes.² This provided a color system that facilitates communication between different professionals involved in environmental color design and it can also serve as a reference for scientific studies of how people perceive and evaluate colors, color differences, and color combinations.³

In the mid-1930s in Sweden, Ewald Hering's phenomenologically based theory on "Das natürliche Farbensystem" was introduced by Trygve Johansson, who considered Hering's theory an appropriate basis for a general color composition theory—in analogy with a music theory.⁴ He formulated the criteria for such a color system as follows:

"In order to serve as a basis for aesthetic studies of color, a color system must only consider attributes of the color sensation as such (= the color percept, authors' remark), i.e., those which can be perceived and assessed solely by means of the innate color sense. All concepts referring to color material or light stimuli must strictly be excluded."

Hering's Natural Color System did, according to Johansson, fulfill these criteria.

In Hering's writing⁵ we can already see the early stages of the "formal-aesthetic" analysis of color combinations that Trygve Johansson, with a somewhat different terminology, later used. "Opposite colors" (Gegenfarben) is the term that Hering gives to the chromatic elementary color pairs yellow-blue and red-green, whose two color attributes, respectively, cannot simultaneously be seen in one and the same color—they are mutually exclusive. This is the crucial observation behind Hering's construct that also provided the name "opponent color theory." Hering points out that the concept Gegenfarben should be used to explain the visual appearance of the colors without any attempt of physical or physiological explanation of the phenomenon, i.e., an example of phenomenological analysis. In the same section, we also find the following lines, dealing with colors together:

"Two intermediate hues that belong to two opposite quadrants of the color circle, such as the red-yellow and the green-blue are opponent in two respects [red against green and yellow against blue (authors' remark)]; but if they belong to two adjacent quadrants, such as the red-yellow and the green-yellow, then they are opponent in only one respect". [red against green with yellowness in common, authors' remark] (Ref. 5, p. 50).*

The ideas and the inspiration for the Color Combination Theory presented in this article came from Hering, from Trygve Johansson and his co-workers,⁶ as well as from Sven Hesselgren's introduction to his Color Atlas.⁷ With the

final form of the NCS system, we had the ability to identify characteristic similarities and relations between colors. We could now also refer the myriad of colors in the color space to a limited number of characteristically different Color Categories and we could also, by quantitative measures, assess the pattern-creating phenomenon "Distinctness of Border."

COLOR COMBINATIONS

Thought Model

Goethe, Fechner, Chevreul, Ostwald, Munsell, Pope, Itten, Kandinsky, Moon, and Spencer were among those who have formulated theories for color harmony—and many others were convinced that they had found the truth about what is beautiful and ugly in the world of colors. The more recent French work with "the Planetary Color System" by Michel Albert-Vanel should also be mentioned for its implicit structuring of color combinations. We have tried to relate some of their findings and claims in combination with phenomenological analysis to the NCS structure, and we have particularly studied what nonfigurative artists have created. This analytical work led up to a thought model that intends to describe various phenomena inherent in color combinations, i.e., attributes of a Color Gestalt that might serve as parameters, or dimensions, of a descriptive model of color combinations. (Outlines of such a model have been published earlier,⁸ and more recently also in this journal⁹).

An assumption was that the model should describe analytically only what can be seen in a color constellation and that it should not make any attempt to provide recipes for good or bad combinations. On the other hand, the model should provide a reference structure for experiments studying perception and evaluation of color combinations—in different cultures, in different contexts, and in different times.

Further, the Color Combination Theory should have a high degree of generality. This can be obtained, if it is entirely and solely based on the human color sense—with its abilities and restrictions—unaffected by the artistic evaluations, stylistic trends, and doctrines of taste formed in various human cultures.

Aesthetic evaluations of how colors can be combined, valid as they may be in certain cultures or during certain periods of time, should not be part of the basis of a formal theory of color combinations. On the other hand, however, such a theory might be useful when studying how the evaluation of color constellations has changed in the past, and how it varies between cultures and over geographical space. It can also be useful as a reference structure when studying such variations and for investigations of whether there are any specific relations between colors that carry universal connotations.

A strictly formalistic color combination theory thus explores and describes the variations of color expressions—within the boundaries defined by the human color sense. Such formal descriptions of color combinations can conse-

* Hering's phenomenological analysis of these Gegenfarben then constituted the basis for his Opponent Color Theory for the physiology of color vision.

quently be assumed to be general over individuals as well as over time and space—irrespective of the perceivers' emotional and evaluative reactions to the combinations.

It is very difficult to make systematic investigations into the world of color combinations. One of the main reasons why so few attempts at such studies have been done is probably that there are so many possible color combinations. Without some kind of theoretically based model for the various possibilities of color constellations, it is difficult to study and map out how people appreciate different color combinations. This was drastically demonstrated when we, as an example, calculated how many different four-color compositions it is possible to design with the limited number of samples (about 1700) in the NCS atlas. The number is "astronomical" and, if all the constellations were to be materialized and shown one at a time for one second each, day and night, it would take hundreds of thousands of years to see them all.

On the other hand, all these color combinations can be brought together into a comprehensible number of groups or categories. Within each category, a large number of combinations are just variations of one and the same color combination theme.

In studying color as a language (some prefer to call it a system of signs) and means of expression, one can see the single colors analogous to the words of a language, and the Color Combination Theory as parallel to its grammar.

Terminology

To communicate comprehensibly within a specific domain of knowledge, we need terms for the relevant phenomena, attributes, variables, quantities, etc. In addition to the phenomenological analysis of colors, color differences, and color combinations, we have, therefore, encountered and dealt with several related linguistic problems. When the phenomena and attributes have been identified, the task becomes to find words for them, which should be as descriptive and unambiguous as possible. Sometimes there was an appropriate and general accepted term at hand, but in other cases we were forced to decide upon a "least bad word" and hope that we, or others, would find a better one later on. During the R&D-work of the NCS, such changes (we hope to the better) have been made, changes that, unfortunately, have annoyed some people. Changes of terms are by no means unique for the area of color; it is common and often necessary in all sciences along with altered ways of thinking and new information. On the other hand, it is practical to establish, at certain times, some standard terminology (as, e.g., is done by the national standard organizations, the international ISO, and regarding matters of color and light, the CIE). The vocabulary should be seen not only as examples of how terms are used today, but also as normative suggestions of how to use the words.

When we started the investigations into problems of color combinations, we found that there were very few generally accepted terms. Therefore, as an initial step in our own work, we felt a need for a list of words that could describe

both the totality and the parts of a color constellation percept. Through the phenomenological analysis of color combinations, we found a number of color combination phenomena, which in the following outline of a terminology are called basic elements. See Fig. 1, in which they are also shown as graphical symbols.

Figures 1(a)–(h) illustrate some symbols and terms for visual basic elements that influence the character of a color constellation.

A color theory deals, of course, with questions concerning how a change of colors of objects can alter their perceived form and also the perceived distance between them. This Color Combination Theory, however, exclusively deals with phenomena concerning the interrelations among visually perceived Color Elements, and how their perceived colors influence the overall form and color character of the Color Gestalt.

Questions regarding the experience and evaluations of single forms or overall Form Character belong, according to Hering, to the realm of form and space, while the experience of colors and color combinations should be referred to the domain of light and color. This he formulated in 1906 in the introduction to a chapter on Von Wesen der Farben, here in translation in Ref. 5, page 1:

"COLORS AS THE SUBSTANCE OF THE SEEN OBJECT. When we open our eyes in an illuminated room, we see a manifold of spatially extended forms that are differentiated or separated from one another through differences in their colors. The word *color* is used in its broadest sense, and thus it also includes black, gray, white, and, in general, anything that is dark or light. Colors are what fill in the outlines of these forms, they are the stuff out of which visual phenomena are built up; our visual world consists solely of differently formed colors; and objects, from the point of view of seeing them, that is, seen objects, are nothing other than colors of different kinds and forms." . . . "The forms in which colors appear to us in visual space, and thus the spatial properties of colors, are treated in the theory of the space sense of the eye; but the colors themselves as different qualities of the content or stuff of seen objects are treated in the theory of the light sense. The latter will occupy us here."

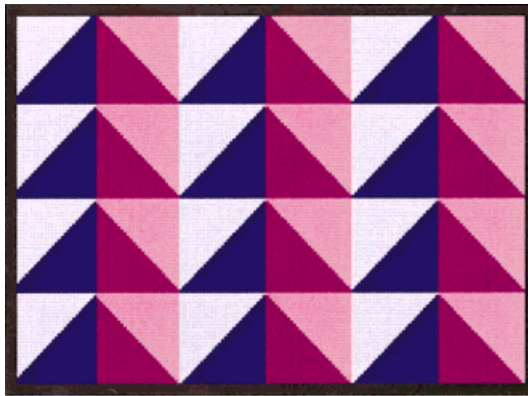
Descriptive Model of Color Combinatorics

Departing from a broad phenomenological analysis of the above-outlined basic elements of the Color Gestalt, a descriptive color combinatoric model has been worked out. The purpose was to identify and describe a number of factors or variables that influence our perception of a Color Gestalt. Some of these are possible to quantify experimentally by psychometric methods; for others we must, for the time being, be content with verbal descriptions. In addition to drawing attention to these Color Gestalt phenomena, the model can serve as a point of departure for further experimental studies of how people experience, evaluate, and

react to various color combinations, which by means of the model now, more adequately than before, can be identified and described. It can also be used in color education in empirical tests of coloristic hypotheses regarding its parameters. This would broaden and deepen the consciousness of what influences the evaluative and emotional reactions, both on the individual and general level. Perhaps this also could help color designers to increase their knowledge of what

guides their own and other users' experience, behavior, and judgments as regards beauty, harmony, and meaning—to the extent this can be related to the formal attributes of color perception. The model shall provide means to describe the formal character of various color combinations and how they are evaluated, but the model as such does not say anything about which combinations are pleasing to everybody or which colors are ugly together during certain epochs.

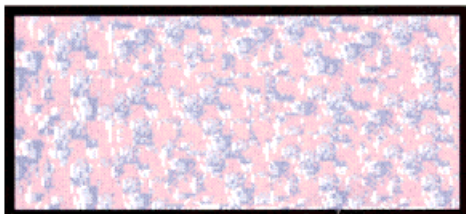
To describe a single color unambiguously, three mutually independent dimensions are sufficient. Regarding the NCS-



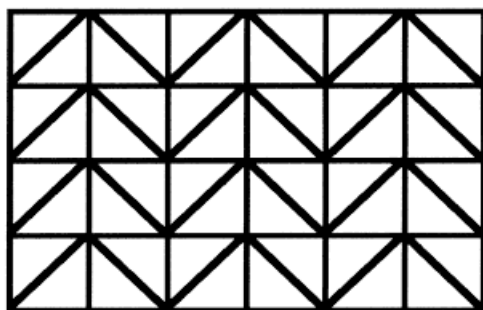
(a)



(b)



(c)



(d)

FIG. 1a-d

FIG. 1. (a) Color Gestalt: The visual entirety that is perceived to “take place” within the confined area that the observer chooses to focus on in a given moment. This means, for example in an art gallery, that the Color Gestalt in one moment consists of what is within the frame of a picture, in the next moment it includes parts of the wall and other pictures, and in the next only a fraction of the picture. It also means that a single Color Element can constitute the Color Gestalt, which, after all, makes it meaningful to study people's experience of single object colors.

FIG. 1. (b) Color Element: A single Color Element is defined by its particular form and also by (as Hering says) the color that fills in the outlines of this form. The Color Elements are the building blocks of which the Color Gestalt is made.

FIG. 1. (c) Texture Element: A Color Element that is so small that, in a given moment, one cannot visually decide with certainty either form or color. The Texture Elements constitute the perception of the Visual Texture Gestalt.

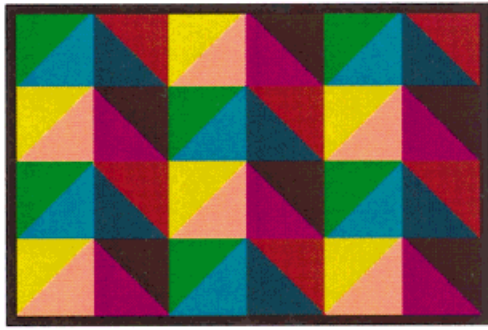
FIG. 1. (d) Contour Line Network: The structure formed by the borderlines that seem to demarcate the different Color Elements from each other, i.e., the line pattern that, within the frame of the Color Gestalt, emerges, if the contours of the Color Elements are marked by a pencil line and the colors are excluded.

FIG. 1. (e) (see next page) Form Character: The overall pattern that emerges when Color Elements perceptually fuse together in one direction and are demarcated in another. It is generally the “Distinctness of Borders” that determines what kind of pattern is experienced, but characteristic color resemblances between the colors can also be influential. The Form Character of the Color Gestalt is not unambiguously determined; it is dependent on what the observer in the given situation pays attention to. In a similar way, Texture Elements may form overall gestalts, as, for example, the veining in a pinewood board.

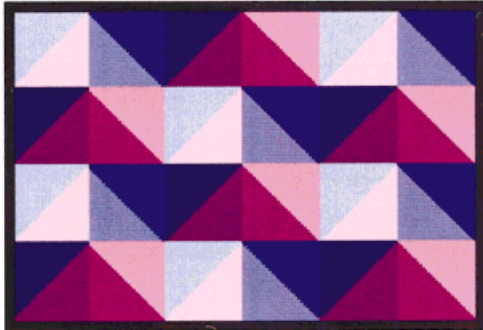
FIG. 1. (f) Color Character: The particular color content that characterizes the whole Color Gestalt—independent of the Form Character. The Color Character is dependent on the way the colors interact and how large a part of the visual field they occupy. If the colors of the elements are changed, but with preserved Distinctness of Borders between them, the Color Character of the gestalt changes, but the Form Character is unchanged.

FIG. 1. (g) Tuning: An ordering or balancing of the Color Elements regarding size, formal color resemblance, and spatial distance between elements. Another appropriate word would be harmonizing or harmony in its descriptive meaning, but as this word also carries a connotation of evaluation, we have chosen not to use it here. Many authors who have set up laws of color harmony seem to have had in mind the concept Tuning in the sense we use it.

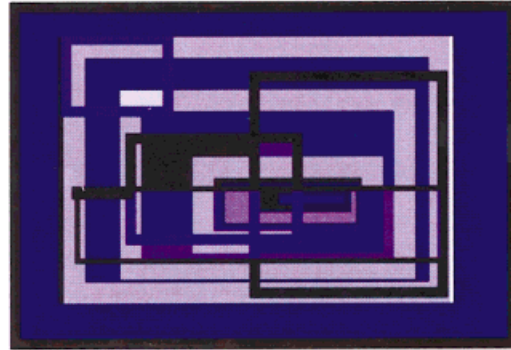
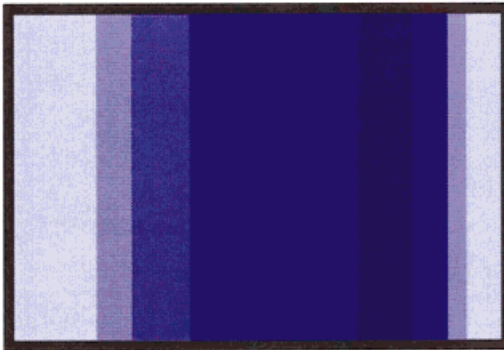
FIG. 1. (h) Visual Environment: The fact that two identical Color Gestalts can be differently perceived and evaluated, depending on the visual context in which they appear.



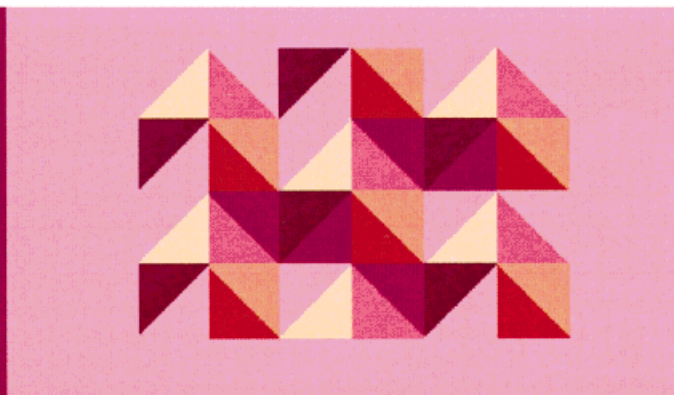
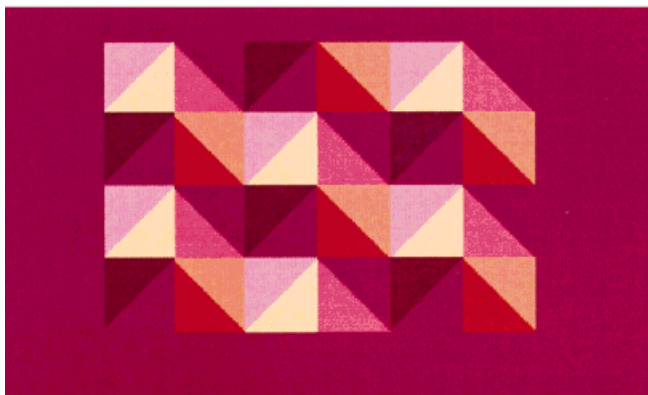
(e)



(f)



(g)



(h)

FIG. 1 (continued) e-h

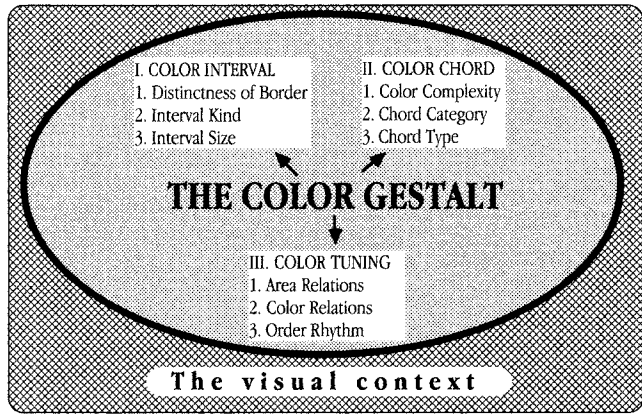


FIG. 2. Dimensions of the color combinatoric model.

space, it has been shown that within its three chosen independent dimensions some additional perceptual dimensions can also be identified. These are, however, not independent of those originally chosen, but could have constituted alternatives for an NCS-space, which then would have looked differently.

We have identified more descriptive attributes or variables for color combinations than for single colors. They could be meaningfully divided into three main groups, each with three subfactors. Even if these 3×3 “dimensions” sometimes are referred to as “a color combination space,” this should not be taken too literally. It doesn’t seem possible to select a number of these “dimensions” in such a way that they are independent and can form a color combination space in which a specific Color Gestalt can be represented by a point—and where a point always represents a specific Color Gestalt. So from this point of view, there is no analogy with the NCS color space.

The model has developed gradually in stages as a result of many years’ interaction between research and practice. Its theoretical basis consists of the same phenomenological analysis and psychometric assessments that led up to the NCS system, concerning the characterizing and discriminating attributes of colors. The terms chosen for the various dimensions or variables are shown in Fig. 2 and are described below.

COLOR INTERVAL

The word interval stems from the Latin *intervallum* referring to the space between two objects. By Color Interval is meant the perceptual phenomenon created in the encounter of two Color Elements, both when juxtaposed and when a spatial distance is between them. The Color Interval describes what is visually perceived in the transition from one color percept to another. As a perceptual phenomenon, the Color Interval is thus something more and beyond what can be described by the difference in the color notations of two color percepts, as, for example, in NCS terms. An alternative concept for Color Interval could have been contrast in its original meaning “stand against” from Latin *contra*

stare, an expression for the qualitative—and bipolar—state of opposition that is always present between two colors. In the contrast between, for example, two grays of different lightness, the color attributes whiteness and blackness “stand against” each other.

The word contrast is, however, most often used in the restrictive quantitative and unidimensional meaning of “large difference,” as, for example, “light contrast” on a TV screen and in photographs, when it does not necessarily imply any reference to oppositeness of colors.

The concept of Color Interval contains *per se* three analyzable perceptual variables, which influence the perception of the transition or “space” between two Color Elements.

Distinctness of Border, GT

When two different Color Elements border on each other the contour they have in common is perceived as a line (From Sw. GränsTydlighet).¹⁰ This line-percept we call borderline, and it is perceived to be variously distinct depending on the difference between the color attributes of the Color Elements. As described in texts regarding the development of the NCS (Ref. 2 and 3) the value of *GT* can be calculated, if we know the NCS notations of the colors. When no border at all could be seen, the *GT* was given the value 0, and the most distinct borderline that could be imagined in a given situation was assigned the value 10. Operationally, the *GT* is calculated as the sum of the differences of the following NCS attributes, with different weight constants:

- The difference in the blackness-whiteness dimension, expressed as the correlated blackness-difference Δs_v , derived from the lightness difference Δv , and with the weight 1.0.
- The difference in chromaticness Δc , with the weight 0.2.
- The difference in hue $\Delta \phi$, with the weight 0.3 multiplied with a reduction factor referring to the chromaticness.
- The sum of these differences raised to the power of 0.4 according to the formula:

$$GT = 1.5\{[\Delta s_v - 0.3] + 0.2[\Delta c - 0.5] + 0.3[\Delta \phi(c1 + c2)/200 - 0.3]\}^{0.4}. \quad (1)$$

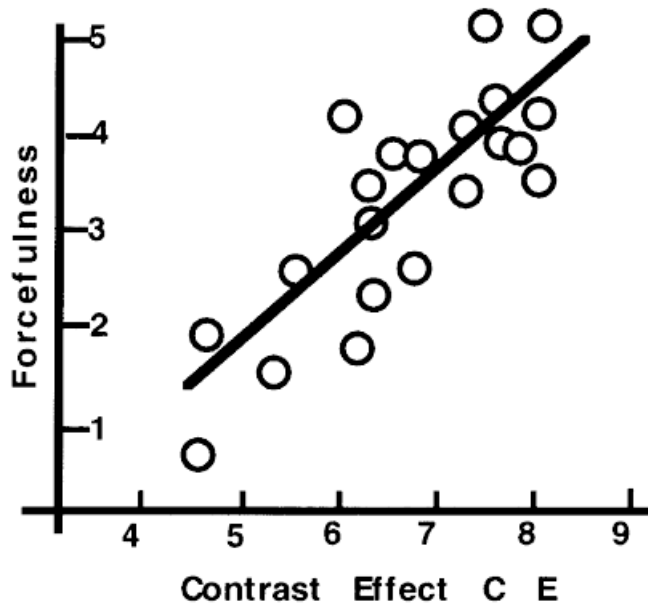
The numbers 0.3 and 0.5 within the brackets represent the threshold values, i.e., the smallest difference in the actual attribute that is required, if a borderline is perceived at all.

The term $(c1 + c2)/200$ represents the chromaticness factor, expressing that the *GT* caused by a nominal hue-difference decreases with decreasing chromaticness.

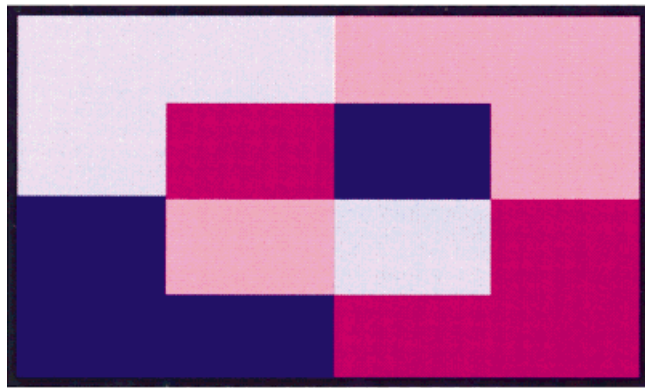
The correlated blackness-difference Δs_v is calculated from the difference in NCS lightness value Δv with the formula:

$$\Delta s_v = 100\Delta v(1 - kf_\phi \times c/100), \quad (2)$$

where kf_ϕ is a convergence factor accounting for the fact that the lines for constant NCS lightness in the NCS triangle converge with increasing chromaticness, implying that Δs_v



(a)



(b)

FIG. 3. (a) Relationship between calculated contrast effect (CE) according to Eq. (3) and judged forcefulness for twenty-two 4-color compositions of a design as in 3(b).

for a certain lightness difference decreases with increasing chromaticness. The size of kf_ϕ is different for different hues (see Ref. 2, p. 194). For most practical applications it can, however, be approximated to an average value of 0.45. The c -value in Eq. (2) is the chromaticness for the least chromatic color of the pair.

The border distinctness, GT , is the most important of the interval variables as concerns the legibility of a Color Element against its background and for the perception of the Form Character, i.e., the overall pattern formation of a Color Gestalt and a Texture Gestalt. To create an equally distinct borderline by means of hue, at chromaticness $c \approx 50$ ($\Delta\phi_{50}$), a 7-times larger difference is required, and by means of chromaticness (Δc) is needed a 5-times larger difference—compared with a certain difference in the blackness-whiteness dimension (Δs_v).

The Border Distinctness GT is exclusively an interval phenomenon occurring between two Color Elements that

border on each other. In a complex Color Gestalt, there are many such borderlines and the overall effect of contrast of the composition seems to be some average GT between the Color Elements. In an experiment,¹¹ where the subjects (among other things) estimated how strongly they experienced the forcefulness in a number of 4-color combinations, it was hypothesized that this experience would be related to the overall contrast effect, as discussed above. In this study, we tested an operational definition of contrast effect, CE , with the assumption that perceived CE could be calculated as an average GT for the 50% most distinct borderlines in the actual color composition, according to:

$$CE = \sum GT_{50\%}/n. \quad (3)$$

The contrast effect, CE , was calculated for each of the 22 color compositions in the experiment and was related to the judgments of forcefulness. The result is shown in Fig. 3, which also depicts the form of the test pictures. In this design, each of the four colors is bordering on the other three, both by surrounding and being surrounded by them. The number of different intervals is six. The three most distinct borders for the colors in the figure were $GT = 7.1$, 7.3, and 8.4 giving a CE of 7.6.

As shown in the diagram, there was a clear relationship between the contrast effect, CE , calculated as described, and the experienced forcefulness of the color combinations. The correlation coefficient, $r_{jc} = 0.81$ indicates that about 65% of the variance can be explained by the formal CE value, while the rest must be sought for in other causes.

Interval Kind (IK)

This variable refers to the interval characteristic that depends on which two elementary attributes constitute the

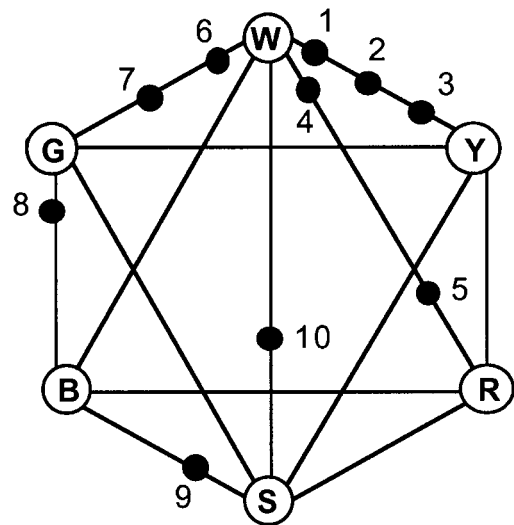


FIG. 4. NCS Color Hexagon, where the 10 colors from Table II are symbolized by points along the elementary scales, can be used to illustrate how the Interval Kind and its size is determined. (For the sake of simplicity, color 8 has been marked on the G-B-scale, although it has 20% whiteness.)

TABLE I. Interval Kinds for color pairs according to Fig. 4.

	1	2	3	4	5	6	7	8	9	10
1	a	(w-y) a	(w-y)	(y-r)	(w-r)	(y-g)	(w-g)	(w-g)	(w-s)	(w-s)
2			(w-y) a	(y-r)	(w-r)	(y-g)	(w-g)	(w-g)	(w-s)	(w-s)
3				(w-y) a	(y-r)	(w-y)	(y-g)	(y-g)	(y-s)	(y-s)
4					(w-r) a	(r-g)	(w-g)	(w-g)	(w-s)	(w-s)
5						(w-r) a	(r-g)	(r-g)	(r-s)	(r-s)
6							(w-g) a	(w-g)	(w-s)	(w-s)
7								(w-b) a	(g-s)	(g-s)
8									(g-s) a	(g-s)
9										(w-b) a
10										

^a If the colors in these cases have different secondary attributes of second order (SA_{II}), these determine the Interval Kind.

state of opposition. IK is the qualitative aspect of the perception of a contrast, in the transition from one Color Element to another. For the assessment of Interval Kind it is not necessary that the Color Elements be juxtaposed, as is the case with the phenomenon of border distinctness, *GT*.

If the NCS notations for the two color percepts are known, the Interval Kind can be determined in the following general way:

1. If the two Color Elements have different Main Attributes (*MA*) (see Ref. 3, p. 213 about Color Categories), these two elementary attributes form the primary kind of oppositeness determining the Interval Kind. It is denoted by the lowercase letter symbols for these two *MA*:s. For a color pair with the two colors marked 1 and 3 in the color Hexagon (Fig. 4), the Interval Kind is white-yellow (*w-y*) as the Main Attribute (*MA*) in color 1 is whiteness ($w > y$), and in color 3 the *MA* is yellowness ($y > w$).
2. If the two Color Elements have the same *MA*, but different Secondary Attributes of the first order (SA_I), the Interval Kind is determined by the two Secondary Attributes. For the color pair 1 and 6 in Fig. 4, the Interval Kind is yellow-green (*y-g*) as both colors have whiteness as Main Attribute, color 1 has yellowness as SA_I ($w > y$), and color 6 has greenness as SA_I ($w > g$).
3. If both the two colors have both the same *MA* and the same SA_I , the Interval Kind is determined by these two elementary attributes only. The Interval Kind for the color pair 1 and 2 in Fig. 4 is white-yellow (*w-y*) as

both have whiteness as *MA* and yellowness as SA_I ($w > y$).

4. If the *MA* and SA_I happen to be the same and of identical size in the two colors, the Interval Kind is correspondingly determined by the colors' Secondary Attributes of the second-order *SA*, etc.

In Table I are listed the Interval Kinds for all the 45 color pairs that can be formed by the 10 colors in Figure 4.

To show how the Interval Kind is denoted for different color pairs according to the principles described above, the example colors (see Table II), for the sake of simplicity, have been chosen so that they can be marked along the elementary scales, as illustrated by the NCS Color Hexagon in Fig. 4.

Interval Size (IS)

This variable is the third characterizing variable of a Color Interval. As the term itself indicates, the Interval Size expresses how big the difference is between the two color attributes that determine the Interval Kind, i.e., the size of the specific color contrast. An expression as a percentage for the relative Interval Size is obtained by calculating, from the NCS notations, the mean differences of the two elementary attributes that constitute the interval in relation to the double scale value 100.

From the NCS notation, the values of the elementary attributes are calculated as follows, exemplified with color 8 in Table II and Fig. 4: $sc = \phi_{bg} = 00\ 80 - B70G$; $s = 00$; w

TABLE II. Values for elementary attributes and NCS lightness for the colors referred to in Fig. 4.

Color	NCS	s	w	y	r	b	g	Σ	$v =$ NCS lightness
1	0010-Y	0	90	10	0	0	0	100	0.994
2	0040-Y	0	60	40	0	0	0	100	0.974
3	0080-Y	0	20	80	0	0	0	100	0.933
4	0015-R	0	85	0	15	0	0	100	0.939
5	0070-R	0	30	0	70	0	0	100	0.606
6	0015-G	0	85	0	0	0	15	100	0.963
7	0060-G	0	40	0	0	0	60	100	0.800
8	0080-B70G	0	20	0	0	24	56	100	0.663
9	7030-B	70	0	0	0	30	0	100	0.073
10	6500	65	35	0	0	0	0	100	0.350

TABLE III. Interval Kind (*IK*), Interval Size (*IS*), and Distinctness of Border (*GT*) for the color pairs referred to in Fig. 4.

Color pair	<i>IK</i> Interval Kind	<i>IS</i> Interval Size	<i>GT</i> -Distinctness of Border
1-2	white-yellow [w-y]	0.300	3.6
1-3	white-yellow [w-y]	0.700	4.9
2-3	white-yellow [w-y]	0.400	3.7
1-4	yellow-red [y-r]	0.125	5.0
1-5	white-red [w-r]	0.650	7.6
3-5	yellow-red [y-r]	0.750	6.9
1-6	yellow-green [y-g]	0.125	3.3
3-7	yellow-green [y-g]	0.700	6.1
3-8	yellow-green [y-g]	0.680	6.5
5-8	red-green [r-g]	0.630	5.7
4-8	white-green [w-g]	0.605	7.3
1-10	white-black [w-s]	0.600	8.0
5-10	black-red [s-r]	0.675	6.4

$$= 100 - (s + c) = 100 - 80 = 20; g = c \cdot \phi_{bg}/100 = 80 \cdot 70/100 = 56; b = c - g = 80 - 56 = 24.$$

In Table II are listed the elementary attribute values of the colors in Fig. 4, calculated as above, as well as the NCS lightness values v .

Interval Kind and Interval Size are determined as shown in the following example for the color pair 3-4.

The two colors have different Main Attributes (*MA*), namely whiteness (color 4) and yellowness (color 3) and thus the Interval Kind is whiteness-yellowness (*w-y*).

The differences in the various elementary attributes are:

$$\Delta s = 0; \Delta w = 65; \Delta y = 80; \Delta r = 15; \Delta b = 0; \Delta g = 0.$$

The Interval Size is calculated as the mean of the sum of the two largest elementary attribute differences divided by $2 \cdot 100$:

$$IS = (\Delta w + \Delta y)/(2 \cdot 100) = (65 + 80)/200 = 0.725.$$

In Table III is found the Interval Size and also the calculated *GT* values [from Eq. (1)] for some of the color pairs in Fig. 4.

Some of these Color Intervals are also illustrated in Fig. 5.

For Texture Elements, only the Border Distinctness (*GT*) is analytically meaningful regarding the Color Gestalt dimension we call interval. In our definition of visual Texture Element is implied that it is not possible to decide with any certainty either its form or its color. This also means that it is not possible to determine visually whether two Texture Elements are qualitative opposites. This means that neither Interval Kind nor Interval Size can be determined between two Texture Elements. Not even the Distinctness of Border, *GT*, can be assessed with any certainty, but this interval phenomenon still accounts for the overall pattern of a Texture Gestalt formed by the Texture Elements.

The perceptual phenomenon appearing in the transition between two Color Elements we call Color Interval, and it is this percept that to a great extent accounts for the perceived Form Character (see Fig. 1). A Color Interval is

characterized by (1) perceived Distinctness of Border (*GT*), provided the Color Elements border on each other, (2) Interval Kind (*IK*), and (3) Interval Size (*IS*).

But also the spatial distance perceived between Color Elements is, naturally, a part of the total interval experience—as well as distances in time in, for example, mobile Color Gestalts. It should be pointed out, however, that the total experience of a Color Gestalt in that case is determined exclusively by the perceived distances and not by the physically determined distances between the objects that constitute the distal stimuli of the color percepts. The reason why we have refrained from treating the spatial- and time-related intervals in this color combination model is that so far we have been able to analyze only fragmentarily whether and how the perception of interval in space and time is related to the perceptual color space.

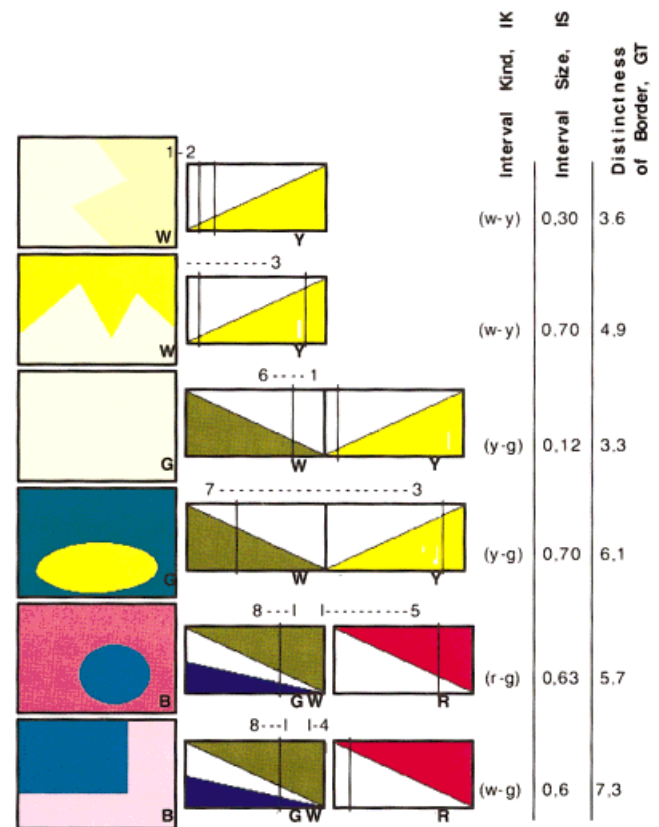


FIG. 5. Of the two white-yellow (*w-y*) intervals, that are of the same kind, 1-3 is larger than 1-2, which is indicated by different distances of the two lines symbolizing the two colors in the bipolar W-Y-scale. In a similar way, the distances between the color symbols in the two connected bipolar diagrams G-W-Y show that the yellow-green interval (*y-g*) is smaller between the colors 1-6 than between 3-7. For the red-green interval (*r-g*) between the colors 5-8 and the white-green interval (*w-g*) between 4-8, the Interval Size must be illustrated as the sum of two distances in the two scales, B-G and W-R, that cannot be connected. Interval Sizes for different Interval Kinds are comparable with each other only as relative quantities. The values for *GT*, on the other hand, represent absolute quantities and, therefore, comparison can be made between color pairs of different Interval Kinds. The numbers refer to the colors in Table II.

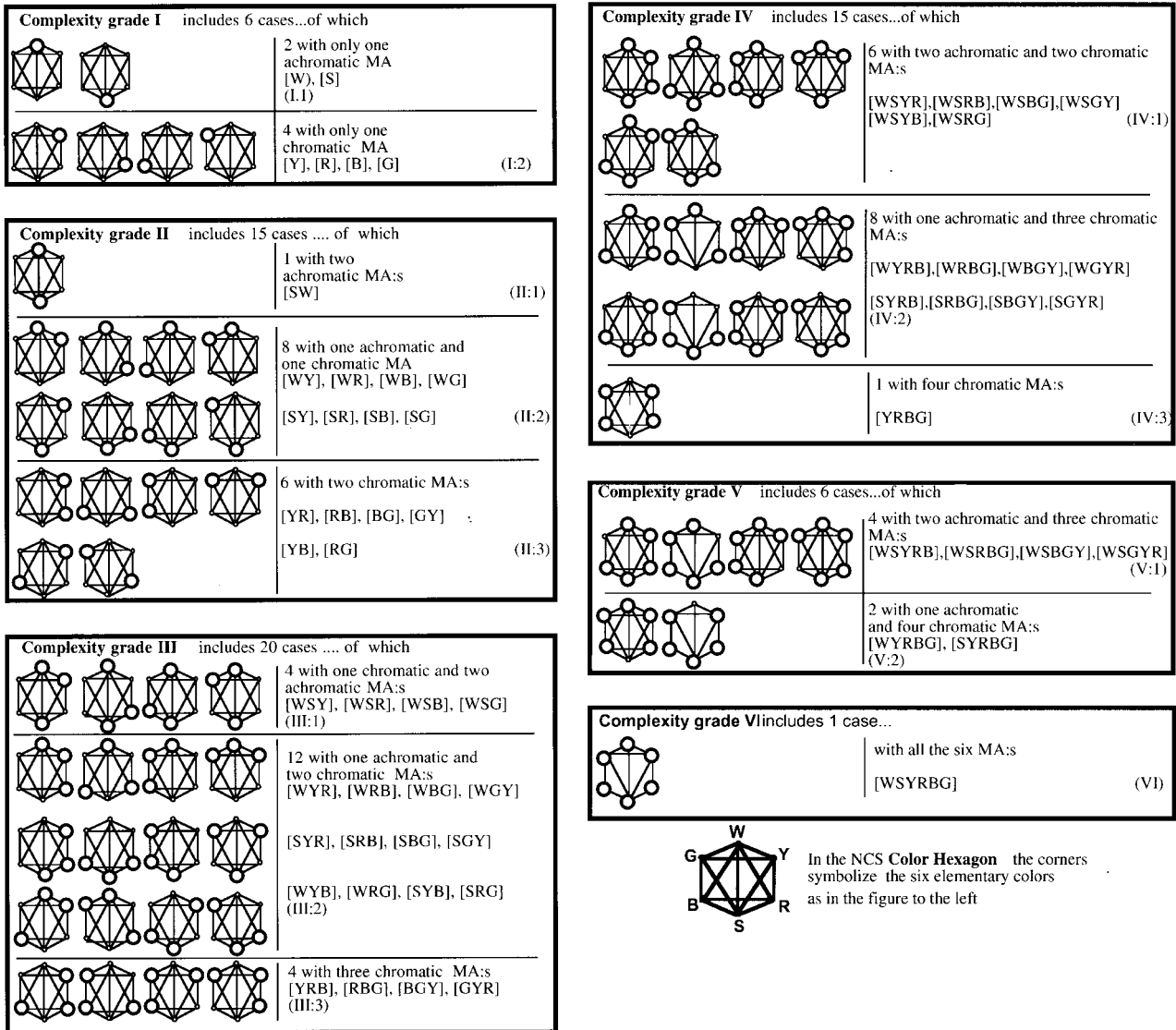


FIG. 6. The 6 grades of Chord Complexity and 63 cases of different constellations, depending on which Main Attributes (MA) are included and marked in the NCS Color Hexagon symbol as well as by letter notations. Indicated in the bottom Hexagon are the elementary colors that are symbolized by the six corners.

COLOR CHORD

This term refers to the specific Color Character of the total Color Gestalt. The perceptual phenomenon Color Chord is characterized by:

- The total number of Elementary Attributes present.
- Which of these Elementary Attributes are present.
- The way these Elementary Attributes, as Main and/or Secondary Attributes, interact and relate to each other.

The Color Chord describes the complexity and concordance among the colors, how they visually “sound together,” in analogy with musical chord.

In Trygve Johansson’s earlier attempts to characterize interactions between colors on the basis of the natural color system,⁴ the word interval was used for “the kind of accord (Sw. samklang) between the colors,” while the term chord

(Sw. ackord) was reserved for “constellation of different hues.” In our Color Combination Theory, we have considered it to be more correct and also more fruitful to keep a more basic meaning of “space between” for interval and “combination of tones/elements sounding together” for Chord (actually a contraction of accord). The interval describes the perceptual phenomenon occurring in the encounter between two color percepts and it depends on, but is not necessarily the same as, the describable difference between the two color percepts. The Chord, on the other hand, describes the complexity and the accord between all the color percepts in a Color Gestalt. In a Color Gestalt that contains only two colors, there is both an interval phenomenon and a chord phenomenon, and each of them can be described in its own way.

In the phenomenological analysis of the factor Chord, we have identified three subdimensions of importance for the

coloristic character of the Color Gestalt, which are possible to describe in formal terms. They refer to the complexity, category (earlier named content), and type of the Chord and are possible to describe formally.

Complexity

The formal Complexity of a Color Chord is exclusively a question of how many of the elementary attributes one can perceive in the Color Gestalt. First of all the Complexity is dependent upon how many of the six elementary Color Elements that, all together, appear as Main Attributes (*MA*, which means that the elementary attribute is dominating in a Color Element by >50%). The number of Secondary Attributes (*SA*) also influences the experience of Complexity, but to a lesser extent.

Depending on the number of Main Attributes, we have six different grades of Complexity, with altogether 63 different cases regarding which of the Main Attributes are represented in the Color Gestalt. These can be symbolically marked in the NCS Hexagon as in Fig. 6 and some examples can be seen in color in Fig. 8.

It is almost a matter of course that a Color Gestalt with the Complexity grade VI (all 6 elementary attributes present as Main Attributes) is perceived as more complex than a Color Gestalt of the Complexity grade I with the same number of Color Elements but all with the same Main Attribute. The phenomenological analysis in addition to a series of preliminary experiments showed, however, that Secondary Attributes of the first order (*SA_I*), in some cases, also had a decisive influence on the perceived Complexity of the Color Gestalt. This is particularly evident for Color Chords of Complexity grade I, if the number of second attributes, in addition to the Main Attribute, is larger than three. Such a Color Gestalt can be perceived as more complex than one of Complexity grade II.

The classification of Color Chords in different Complexity grades is thus of a perceptually formal kind and does not self-evidently predict the experience of complexity. In an experiment¹¹ earlier mentioned in connection with Distinctness of Border (*GT*), the subjects also had to assess the color combinations along the semantic scale complicated. For each of the 22 four-color pictures was calculated a Complexity factor, *CF*, with the following tentative formula:

$$CF = MA + 0.1 SA_I(6 - MA), \quad (4)$$

where *MA* means the total number of Main Attributes in the Color Gestalt and *SA* the number of Secondary Attributes in addition to those that are Main Attributes.

The Complexity factor calculated in this way was compared with the means from the subjects' assessments of how complicated they found the pictures. The relationship is shown in Fig. 7, as is the co-variation between the Complexity factor, *CF*, and the mean values of the semantic scale cultured.

The diagram indicates clearly that the perceived complexity judged has a co-variation with the Complexity factor

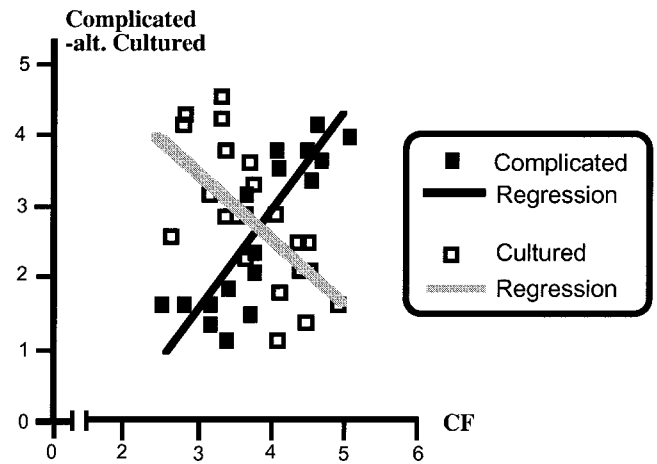


FIG. 7. Relationship between calculated Complexity factor (*CF*) according to Eq. (4) and judged mean values from the semantic scales Complicated and Cultured for 22 four-color compositions.

(*CF*) calculated according to Eq. (4)—the correlation coefficient was $r_{cj} = 0.87$. The formal *CF* value in this case thus explained about 75% of the variance, while 25% had other causes.

The diagram in Fig. 7 also shows that the higher the calculated Complexity factor, the less cultured the color combination was judged to be. This negative correlation coefficient was $r_{cj} = -0.63$, which explains only 40% of the variance.

In Table IV, we see how the value of the calculated Complexity factor, *CF*, according to Eq. (4), varies with Complexity grades and the number of Secondary Attributes, *SA_I*.

The total number of Color Elements in a Color Gestalt does not, according to this definition, influence the formal Complexity of a Color Chord, but it most probably influences how varied the Color Gestalt is experienced as a whole.

Chord Category

This term refers to which ones of the Elementary Color Attributes that constitute the Color Gestalt as Main and Secondary Attributes and by these give the Color Chord its specific character. Let us, as an example, take two Color Gestalts, both with Complexity grade II and with the same border distinctness (*GT*) between the Color Elements so that the Form Character is the same. In one of the gestalts, some of the Color Elements have the Main Attribute yellowness and the others have blueness [II:3; YB] (see Fig. 6). In the other gestalt, some of the elements have whiteness and the rest blackness as Main Attribute [II:1; SW]. Obviously, these two Color Gestalts are perceived as characteristically different and we say that they belong to two different Chord Categories.

Depending on constellations of Main Attributes, there are 63 Main Categories, i.e., the same as those described in Fig. 6 about the 6 Complexity grades. The Chord Category can

TABLE IV. Complexity factor (*CF*) for different Complexity grades and varying numbers of Secondary Attributes (*SA*).

	Complexity grade						
	0*	I	II	III	IV	V	VI
SA							
0	—	1.0	2.0	3.0	4.0	5.0	6.0
1	—	1.5	2.4	3.3	4.2	5.1	
2	1.2	2.0	2.8	3.6	4.4		
3	1.8	2.5	3.2	3.9			
4	2.4	3.0	3.6				
5	3.0	3.5					
6	3.6						

be symbolized either in the NCS color Hexagon or by letters indicating the Main Attributes, e.g., [YB] [SW] [WG], etc.

In Fig. 8, examples are given of some of the Main Categories of the Color Chord, their Complexity grade, and Complexity factor, *CF*.

A more detailed categorization of the Color Chords in Main and Secondary Categories can be done with respect also to the Secondary Attributes of first order [SA₁]. This can be shown symbolically by noting in the NCS Color Chord Category matrix (See Fig. 9) the categories present in the actual Color Gestalts. This NCS color Category diagram is identical with the one used for single color percepts.² In the matrix in Fig. 9, squares (□□□) show how Color Categories of the Chord can be indicated. Colors of elementary hues, or with nuances where the Secondary Attributes are equal, as well as colors that lack dominating Main Attribute, can, of course, be marked on the lines in the Chord matrix, as shown by circles in Fig. 9.

By marking all Color Categories in a matrix—or in a simplified matrix of smaller format, which we can call Color Chord Scheme (Fig. 10), we have a symbolic “picture” of which category a certain Color Gestalt belongs to. The Color Chord Schemes of the Color Gestalts in Fig. 8 are shown in Fig. 10.

Chord Type

This subdimension tells about the relations between the Main and Secondary Color Attributes of a Color Gestalt, irrespective of which elementary attributes. One example is illustrated in Fig. 11 in the NCS color Hexagons. In the four Hexagons, four two-color constellations (of Complexity grade II:3), which are all of the same Type, are marked: the Main Color Attribute of the one color is the Secondary Attribute of the other color and vice versa. The fifth Hexagon in Fig. 11, within the square and without notations for elementary colors, is a generalized symbol for this Chord Type.

The idea to make Type assessments of Color Chords partly came from Trygve Johansson’s partition of the color circle. In our Color Combination Theory, however, this classification of Chords is based on a partition of the NCS color space in all three dimensions. By doing so, all characteristically different Color Chords can be assessed with respect to both Hue- and Nuance-Type.

If, in a color constellation, all the colors have the same Main and Secondary Attribute regarding hue, e.g., *Y*, and *r*, respectively, the colors belong to one and the same Hue Category (II in Fig. 9) and such a Hue-Chord we call a Hue-Monad. A Hue Chord with colors from two Hue Cat-

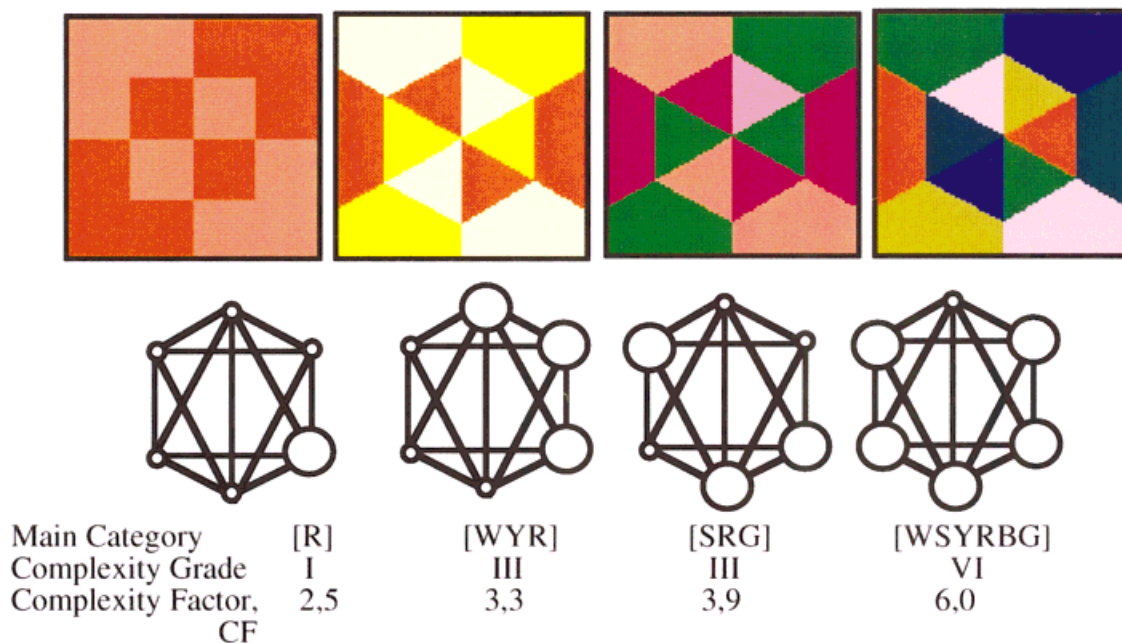


FIG. 8. Examples of main Chord categories, their symbolic notations, Complexity grades and calculated Complexity factor *CF*. NCS-notations of the colors: [S 1070-Y90R; S 1060-Y70R]; [S 1020-Y30R; S 1080-Y10R; S 1080-Y80R]; [S 1070-G20Y; S 2070-Y80R; S 6030-R10B]; [S 1030-R30B; S 3060-Y10R; S 1070-R20B; S 7020-G70Y; S 3060-B10G; S 0080-G30Y].

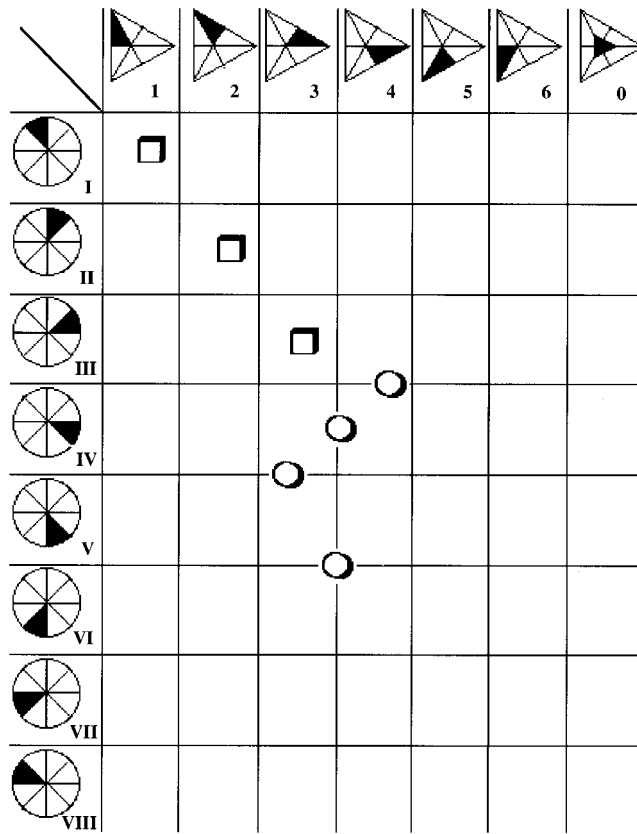


FIG. 9. By marking the colors of the Color Gestalt in the NCS Color Category Matrix, this can also be used as a scheme for categorization of the Color Chord.

egories is called a Hue-Dyad and the following -Triad, -Tetrad, -Pentad, -Hexad, -Septad, and -Octad. In a corresponding way, a Nuance-Chord containing colors from only one Nuance Category is called a Nuance-Monad, from two Nuance Categories a Nuance-Dyad, and so on up to Nuance-Hexad.

The Hue Chords are divided into five Main Types (I, IIA, IIB, III, and IV) and the Nuance Chords into three Main Types (1, 2, and 3), depending on the number of Color Categories that are represented in the Chord and the manner that they are related to each other. Within each Main Type, there are several subtypes depending on the interrelations of the categories regarding Main and Secondary Attributes [see Fig. 12(a) and (b)].

For this categorization, a specification of the categories is not important. Therefore, the letter notations for elementary colors in the Color Circles and Triangles are not given when a Chord-Type is symbolized in the scheme. The symbols comprehend all the categorical possibilities of a Type that can arise through twisting and/or inverting of the symbols. In Fig. 13 is shown, as an example, all the specific Chord categories included in the Hue-Dyad IIA:b and the Nuance-Dyad 2:b.

In all, there are 38 Hue-Chord Types distributed over five main types, and there are 15 Nuance-Chord Types of three main types. In combining Hue and Nuance types, we get a

total of 570 different Chord Types distributed over 15 main types.

As shown in Fig. 12, the typing of Color Chords is based on how the Main and Secondary color attributes of the Color Elements are related to each other, i.e., in which category areas of the NCS symbols Color Circle and Color Triangle the colors have their markings. In the Hue-Dyad IIA:b in Fig. 13, some of the colors of the gestalt have the Secondary Attribute (SA) that is Main Attribute (MA) in the other colors—redness in the first example, blueness in the second, etc.—while the Secondary Attribute in the other colors of the Gestalt is the opposite of the first colors' Main Attribute—blueness and yellowness, respectively, in the first example, greenness and redness, respectively, in the second.

In the NCS Color Circle, the Main Chord-type IIA, with the subtypes a, b, and c, implies that the colors of the gestalt are always symbolized by markings in two quadrants that are bordering on each other—while type IIB has colors in quadrants opposite to each other. In type I, all the colors of the Chord come from one and the same quadrant, in type III they come from three, and in type IV they come from all four quadrants [see Fig. 12(a)].

As regards the Nuance Chords, the colors in type 1 come from colors symbolized by markings in only one of the triangle sectors [see Fig. 12(b)], in type 2 in two, and in type 3 in all three of the sectors. In Figs. 12(a) and (b), this principle is indicated to the left by a shading of the circle quadrants and triangle sectors.

In Fig. 14 is shown by examples how a certain combined Triad-Chord of the type IIB-2:a in the Chord-schemes are represented by certain graphic patterns. The examples A-C exhibit the same patterns, parallelly displaced, because the

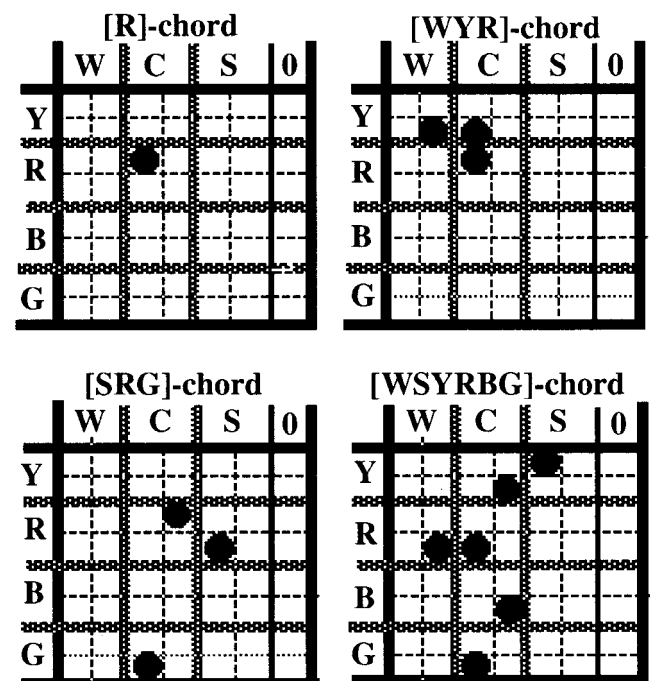


FIG. 10. Color Chord Schemes for the Color Chords shown in Fig. 8.

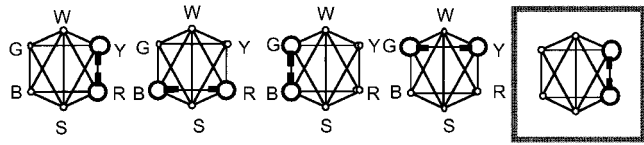


FIG. 11. Four cases of the same Chord Type, with two chromatic Main Attributes (MA) and two chromatic Secondary Attributes (SA). The Type is determined from the circumstance that the MA of the one color is SA in the other color, and vice versa. The general symbol for this Type is shown in the Hexagon to the far right, without letter notations, indicating only the mutual relationship between any neighboring pair of the four chromatic elementary colors.

combination of Hue- and Nuance categories for the three colors follow the same principle of order, which in the NCS symbols implies the same “direction of rotation” for the Category areas. In D–F, the graphic patterns look different as the order between the Hue- and Nuance categories of the colors is varied.

An analysis and classification of the Color Chords also should explain the impact of the so-called secondary color categories (gray, orange, purple, etc.). The term secondary refers to the fact that the colors are of the same kind, because they first of all simultaneously resemble two elementary colors. We say that such colors have this “Duo-Attributeness” as Secondary Main Attribute (SMA) as they certainly have an identity of their own.

Particularly when we have put colors together in compositions we have noticed how we sometimes perceive the primary Main Attributes (MA) first, e.g., whiteness and other times we see the secondary Main Attribute (SMA) first, for example the grayness, i.e., the white-blackness. Another example is when some colors are perceived as pregnant yellow, with yellowness as MA, and others are perceived as pregnant yellow-red, i.e., orange, with yellow-redness as SMA. It seems, for such colors, that the Secondary Color Attributes are not made conscious and that they could also be classified as “Main-Attribute Colors” (either MA- or SMA-colors).

Concerning the dimension Color Chord, the constellation of “pure Main Attribute colors” (Elementary Colors) can be regarded as special cases within all the three subfactors Complexity, Chord Category, and Chord Type. A closer analysis of how these special cases may be classified and noted, and how relevant they are for the further studies of the perception of color combinations, must be referred to the list of wanted topics in a continued research.

TUNING

Two Color Gestalts, both representing one and the same Color Chord and having the same Interval between the Color Elements, are perceived to be characteristically different, if the relative size of the Color Elements is different. This is so self-evident that it seems strange that it has so seldom been mentioned by any of those who have tried to formulate laws of color harmony.

A. Hue-chord

Type	Monad	Dyad	Triad	Tetrad	Pentad	Hexad	Septad
I.							
IIA.							
IIB.							
III.							
IV.							

B. Nuance-Chord

Type	Monad	Dyad	Triad	Tetrad	Pentad
1.					
2.					
3.					

FIG. 12. (a) Chord Types: Hue-Chords (the Hue-Octad excluded). FIG. 12. (b) Chord Types: Nuance-Chords (the Nuance-Hexad excluded).

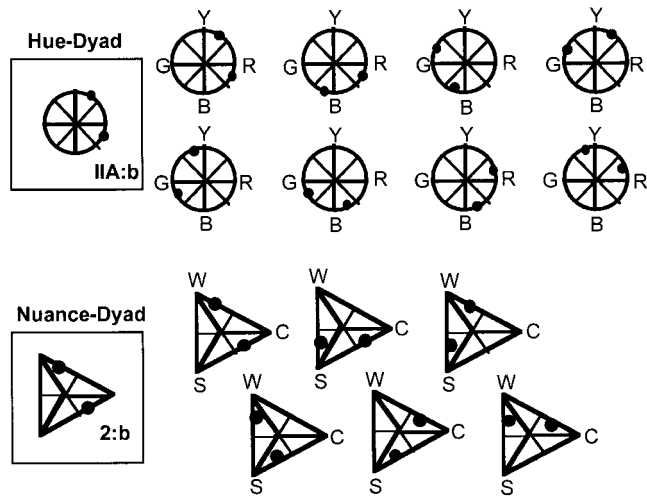


FIG. 13. Here is shown how the symbol for the Chord Type IIA:b (the Hue-Dyad) implies eight different Hue Categories, and that 2:b (the Nuance-Dyad) includes six Nuance Categories.

Because within each color Category a large number of colors are somewhat different, it is possible to create a large number of variants of one and the same Color Chord. But even if the chord classification is the same for all these variations, the overall experience may be different.

Another factor that has an impact on the total experience of a Color Gestalt is the order between the colors, in space and/or in time.

In our combinatoric model, these phenomena have been referred to the subdimension we have named color Tuning. As our intention is that the Model shall be descriptive only—and not evaluating—we have refrained from using the term harmony, which we would actually have liked to use in its meaning of balance, order, and congruity—but the connotation of aesthetic evaluation is too common and this we do not want in this context.

Those who have tried to formulate laws of color harmonies in the evaluating sense have very often taken for granted that such laws can be based on definable relationships among the colors of a composition, such as color similarities and color dissimilarities. It is also common to base color harmony laws on physical or physiological attributes of color stimuli or phenomena of various kinds (e.g., complementary colors).¹²

In our color combinatoric theory, we have taken into account three subfactors within the dimension of Tuning, namely Area Relations, Color Relations, and Order Rhythm. Practically speaking it seems possible to describe in a general way how variations in these Tuning factors influence the characteristic appearance of a Color Gestalt.

The evaluation of these varying appearances, on the other hand, is probably dependent on current ideals of style and doctrines of taste within the many various cultures and subcultures, and it also varies with time, as well as between groups and between individuals. There have been attempts to investigate evaluations of color combinations, but it is in most cases difficult to use the results and make any general conclusions, as the stimuli used have not been comparable. With a descriptive color combination reference model such as the one proposed in this article, however, it is possible to investigate to what extent and for which of the various subdimensions of the model there is consensus regarding evaluations and how these may vary in time, context, between cultures, etc.

Area Relations

This factor refers to the relationships between the area sizes that the various perceived Color Elements have in a Color Gestalt. Examples are given in Fig. 15.

These relationships can be given in numbers representing the relative proportion of each color of the total Color Gestalt perceived. Although we are talking about Area Relations in this context, the concept would also be applicable to the perception of space.

The relative area of a Color Gestalt can be seen as an expression for the importance it has for the Color Character of the gestalt. The larger the area, the more the specific Color Character of this Color Element dominates the total Color Gestalt.

A common belief is that the larger the area a certain color occupies the more chromatic and light it will be perceived. Experiments have shown that this is not generally true, as there are other interacting factors involved in such a change, such as the phenomenon of simultaneous contrast (or contrast reinforcement, which is a more descriptive word) and the luminance situation. But what we can say for sure is that the larger the area of a certain color percept, the more it

FIG. 14. Example of the double Triad-Chord of the type IIB-2:a (Hue-type IIB and Nuance Type 2:a) realized by colors from different Color Categories and with the same (A–C) and different (D–F) combination order between the Hue and the Nuance Categories. NCS notations of the colors in Fig. 14:

- | | | |
|--------------|--------------|--------------|
| A. | C. | E. |
| 1. 1060-Y30R | 1. 1060-R20B | 1. 3060-Y30R |
| 2. 3060-Y70R | 2. 3060-R70B | 2. 1060-Y70R |
| 3. 6030-B90G | 3. 6030-G70Y | 3. 6030-B70G |
| B. | D. | F. |
| 1. 6030-Y30R | 1. 6030-Y30R | 1. 1060-B90G |
| 2. 6010-Y70R | 2. 3060-Y70R | 2. 3060-Y30R |
| 3. 3010-B70G | 3. 1060-B90G | 3. 6030-Y70R |

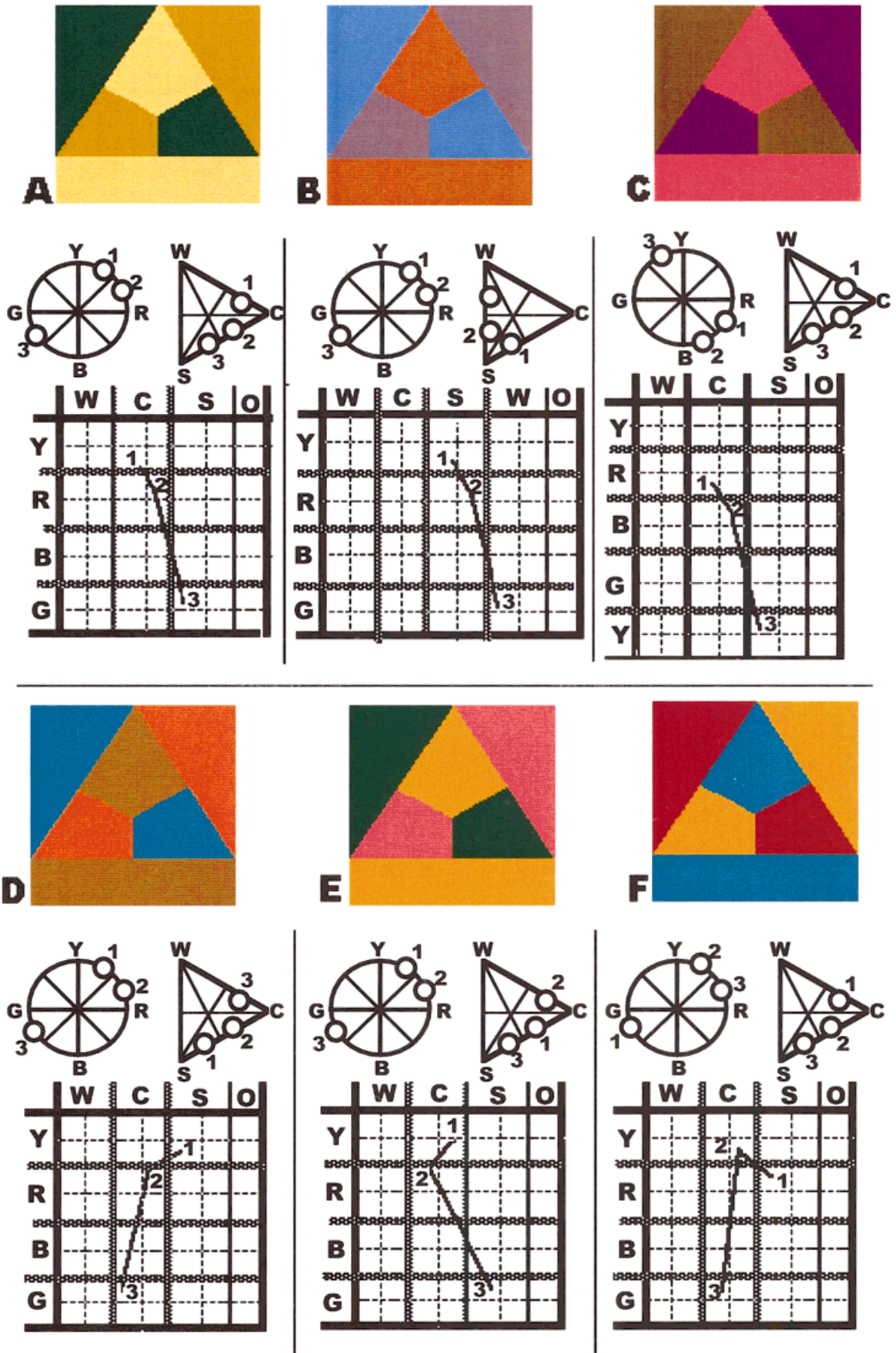
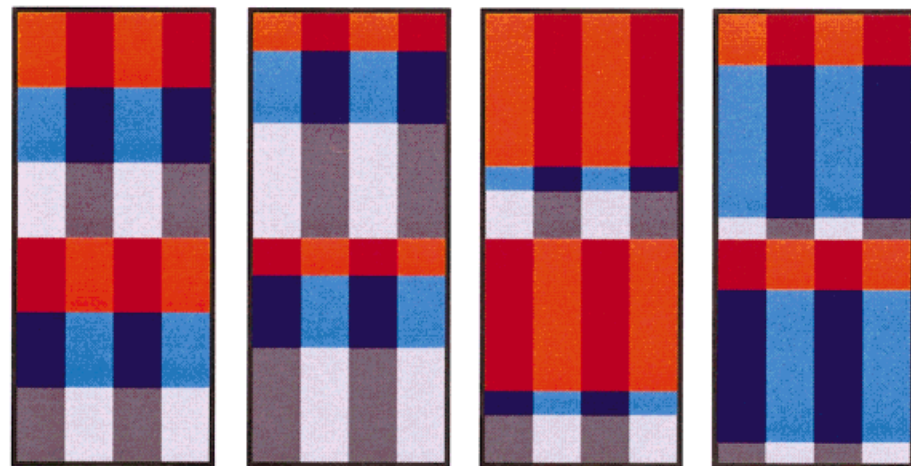


FIG. 14



$(r1+r2):(b1+b2):(gr1+gr2) = 1:1:1$

1:2:3

6:1:2

2:6:1

FIG. 15. Color Gestalts with the same Color Chord and with identical Color Intervals, but with different Area Relations between the colors, look characteristically different. NCS-notations for the colors in the figure: $r1 = S\ 1070\text{-}Y90R$; $r2 = S\ 4050\text{-}R10B$; $b1 = S\ 1030\text{-}B10G$; $b2 = S\ 6030\text{-}R90B$; $gr1 = S\ 2005\text{-}Y20R$; $gr2 = S\ 7005\text{-}R20B$.

dominates the Color Gestalt and the more powerful its particular character is—because there is more of it.

The color of a small color chip (in, for example a chart of color samples) against a white background is perceived as considerably more blackish and less chromatic than if the same paint were applied on a large area, for example, as a façade color of a house. This is due to the fact that the oppositeness/contrast between the large white surround and the chromaticness and blackness of the small sample is reinforced. It is also probable that the larger area of the façade is seen under stronger illumination than the samples of the color chart, which makes its luminance higher—and together this makes it look both more chromatic and less blackish than the corresponding small sample.

The concept of Area Relations as being important for the perception of a Color Gestalt is found, for example, in the works by Itten.¹³ Referring to Goethe's lightness values, he claims that there is a harmonic balance between the colors yellow, orange, red, purple, blue, and green, provided that their area sizes have the relationship 3:4:6:9:8:6. These six colors constitute the three pairs of colors that, according to Itten, are the "pigment colors which when mixed give a neutral gray-black tone" and "which we call complementary colors." Further he points out that, if the chromaticness is altered, "one should also change the Area Size to a corresponding degree."

In a similar way, Munsell¹⁴ states that the basis for harmony and beauty is balance and that two opposite colors in his color circle are in balance, as to area size, if they when spun with a Maxwell disc result in a mid-gray color percept. This is, thus, another definition of the concept of complementary colors. In neither of these cases has one started from the appearance attributes of the color percept, but from the physical stimulus attributes of two Color Elements that under certain circumstances of subtractive or additive mixture can give rise to an achromatic color percept (see the

paragraphs about complementary colors in the end of this article).

In our phenomenological analysis of color constellations, we have found that the Area Relation between color percepts is one of the subfactors that influence the character of a Color Gestalt, and which we thus have ranged under the composite dimension Tuning. It is then interesting that two artists, Itten and Munsell, each from their particular experiences, have come to the same conclusion. On the other hand, it is difficult to understand their (partially) contradictory claims about what constitutes a color harmony relationship between two or several chromatic colors in a color composition. One of them (Itten) says that two—of six possible—painted chromatic surfaces of certain size-relationships are harmonious together, if they are painted with those particular pigments that, when they are mixed, would give a paint that will look dark gray. The other one (Munsell) says that two colored areas balance each other, if they are opposite to each other in his color circle and if their Area Relationship is such that, when taken out of context and optically mixed on a spinning Maxwell disc, give a mid-gray color percept. In both cases, one has, by mixing two color stimuli, created a completely new color stimulus. The assumption that the color percepts of two chromatic color stimuli generally would be experienced as harmonious or balanced because of these two reasons does not seem probable, particularly as the stimulus pairs in the two cases are completely different. Another thing is that the artists in question most probably have considered their color pairs balanced and harmonious together, and from their practical experiences of working with colored materials (or objects) they thought that they had found in the physical stimulus attributes a scientific and rational explanation of their judgment. An alternative explanation would have been that the actual colors perhaps have perceptual similarities or relationships which were not made conscious. To start from

physical relationships in this matter of color appearance and psychological evaluation is in our opinion, which we share with Ewald Hering, rather farfetched. A study of color aesthetics should primarily refer to attributes of the percepts per se and not be confused with concepts dealing with color or light stimuli, as we quoted from Trygve Johansson in the beginning of this article.

The two artists' theories concern only a restricted number of strongly chromatic colors, while in our Color Combination Theory it is presumed that the influence of the area factor is in force for all color percepts—this is not to say, however, that the influence is the same for all colors.

For further studies of how the Area Size affects the appearance of a Color Gestalt, it has been shown that the partition of NCS color space into Color Categories is useful. Instead of referring to the Area Relations of all the Color Elements of the gestalt, it is possible to restrict oneself to the Color Categories present. This can be done by notations in a Color Chord scheme, which then contains information of Chord Category and Chord Type as well as Area Relations, as shown in Fig. 16.

To study how the experience of balance, harmony, beauty, or whatever we believe is influenced by Area Relations between, e.g., pairs of Color Elements, we can confine the study to only one color from each of the NCS Color Categories. But even with this humble choice, the number of pairs to be studied exceeds 1500, and with more Color Elements from several categories, the number of combination possibilities increases very rapidly ad infinitum.

Color Relations

The second factor that can by Tuning influence the experience of balance between different Color Elements in a Color Gestalt we have named Color Relations, referring to the perceptual similarities or dissimilarities the color percepts may exhibit with each other. A certain Color Chord can be created by any of the many colors within each of the Color Categories of which the Chord is made up—that is, variations of one and the same color theme. These colors can be tuned as regards similarities in various perceptual color attributes. Again it should be stressed that we refer to such similarities or dissimilarities that can be perceived solely by the human color sense and that do not require any knowledge about physical or physiological causes of the percepts. All possible similarities and dissimilarities can be identified and illustrated by symbols in the geometric NCS models the Color Space, the Color Circle, and the Color Triangle, as shown in Fig. 17.

Some of the perceptual color similarities demonstrated in Fig. 17 are seen spontaneously and are by many considered self-evident, e.g., those under A:a-c that refer to constancy of the “basic” NCS attributes blackness, whiteness, chromaticness.

The same is true for colors of constant nuance (A:d) also called corresponding colors, referring to colors of different hues but with the same whiteness, blackness and chromatic-

	W	C	S	W	O
Y				1	
R		2		1	
B	6		6		
G					

FIG. 16. Chord notation scheme for the Color Gestalts to the right in Fig. 15, with notations of Area Relations for the NCS categories. The Chord is a tetrad-pentad of Chord-type III d:3 according to Fig. 12.

ness. Note, however, that they can have different lightness.

Other similarities may not be equally easy to make conscious, even if they might in fact influence the judgment of whether a Color Gestalt is well tuned, balanced, or harmonious. This may be the case regarding constant resemblance to one of the four chromatic elementary colors. A:e in Fig. 17 shows how this (here constant redness) is symbolized in the Color Circle by curved lines. The same thing can alternatively be illustrated by straight lines in triangles as in figure A:f, which is just another kind of graphical illustration of the conceptual NCS space.

Under B in Fig. 17 are shown examples of constant relationships. Of these, constant hue is probably the most well-known and the one easiest to recognize. Constant saturation is also a concept often used. Here it is important to keep in mind what is meant by “saturation.” In this context we refer to the NCS definition: constant relation between chromaticness and whiteness.

The two following examples of constant relationship we have called delta similarity, referring to colors with constant δ -value [$\delta = c/(c + s)$], and beta similarity referring to colors with constant β -value [$\beta = s/(s + w)$]. To our knowledge these Color Relations have to date not been studied to any extent or even named, either in everyday language or in color theory and color education. Nevertheless, they might be of importance.

Attempts to formulate laws of color harmony often seem to be based on the assumption that certain similarities between colors make the composition pleasing and harmonious, postulates of this kind come from Goethe, Itten, Munsell, Ostwald, and many others. But the similarities thus described often refer to results of certain pigment mixtures or optical mixtures of radiation. It seems likely, however, that what these skilled men have perceived and experienced has later been explained by those physical attributes of stimuli or physiological relationships that closest resemble what they have perceived. If we now, instead, start with the corresponding perceptual similarities and relationships, it would be interesting and valuable to experimentally test whether their harmony hypotheses are general.

Earlier we have mentioned an experiment in which the

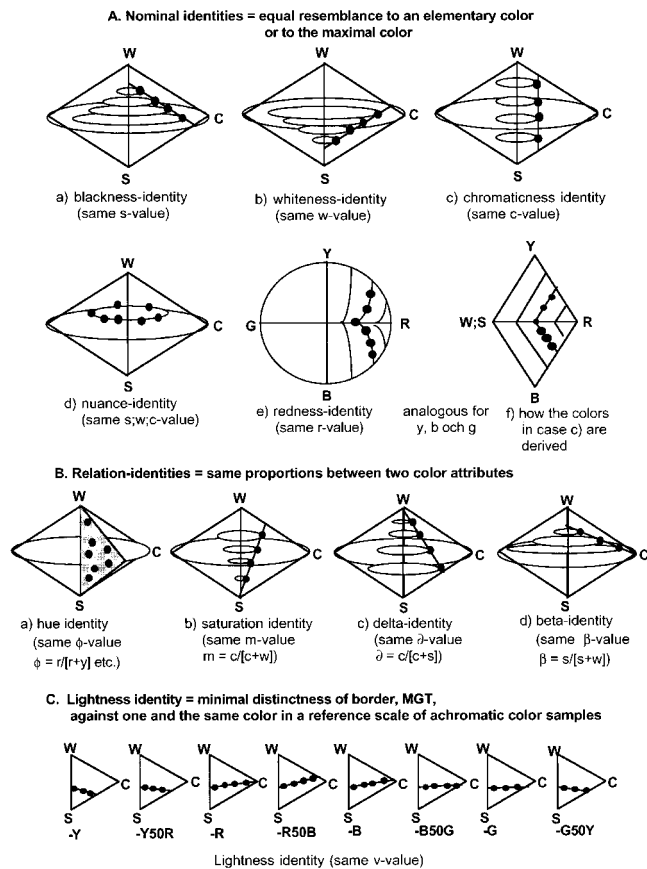


FIG. 17. Similarities between color percepts. For example, redness-identity in A:e means that the colors are equal as regards their degree of resemblance to the elementary color red, in the sense whiteness-identical colors are equal as regards their resemblance to the elementary color white. These similarity relations can be symbolized as straight lines in two triangles with the corners Y, R, B, and [W-S], where the latter signifies an arbitrary achromatic color. The curved lines in the Color Circle are geometrically derived from these straight lines.

test subjects had to judge a number of four-color compositions along different semantic scales,¹¹ of which two were beautiful and cultured. The main purpose of this experiment was to investigate whether there is any consensus on the evaluation of the various combinations or, as some claim, that people are so different that there are no common opinions whatsoever regarding what is beautiful or harmonious in color combinations. The experiments showed, however, beyond any doubt, that the perceptual color similarities that were represented in the test combinations were evaluated in very much the same way by the subjects. The covariation between the mean ratings of the two semantic variables mentioned showed to be very convincing, with a product-moment correlation of 0.94. This also shows that these two concepts, beautiful and cultured (at least for most people in the Swedish culture) are expressions for the same kind of evaluation.

Some of the combination pictures in the experiments were composed by colors that had the same amount of one or more of the color attributes. In other pictures, the colors

had no such similarities. The question was now whether any the pictures would be evaluated as more beautiful or harmonious than others, and, if so, this could be related to certain similarities or identities of color attributes. The mean ratings of beautiful are shown in Fig. 18. Although the results of this pilot study are rather clear they cannot be fully generalized, but they provide motivation for more extensive studies along the same theoretical lines.

In particular the following can be noticed from the results:

- The two pictures in which the colors lacked all formal similarities with each other, “non.sim1” and “non.sim2”, were both judged as less beautiful than any of the pictures that had any similarities between the colors.
- All the pictures where the colors had hue-constancy plus constancy regarding one additional color attribute were judged as more beautiful than those without hue-constancy, e.g., $(s20\phi2) > (s20)$.
- The blueness-constant picture with rather low blueness ($b = 30$) was judged more beautiful than all the pictures that had constancy for one attribute without being simultaneously similar in hue—and the picture with redness $r = 40$ was evaluated about the same as the latter.
- The pictures with the lower degree of blackness, ($s = 20$), the lower chromaticness, ($c = 20$), and the lower saturation, ($m = 0.4$), were judged as more beautiful than the corresponding pictures with higher s , c , and m . And the picture with higher whiteness, ($w = 50$), was more beautiful than the one with lower ($w = 20$).
- The blue picture where all the colors had the same hue, R90B, and the same saturation ($m = 0.4$, $\phi3$) was judged as most beautiful of all the test pictures.

This preliminary study indicates that constancy regarding a certain attribute among color percepts of various kinds can be aesthetically evaluated in various contexts. It would be of interest to test the generality of this assumption in extended experiments and also by analyzing the works of artists and other producers of “Color Gestalts” in various contexts.

Through our extensive experiments for the NCS system, it is well documented that people possess a good ability to judge the degree of resemblance in a color percept to the inner conception of the six elementary colors. These six obviously serve as the built-in reference system of the color sense, in relation to which all color percepts are unconsciously judged. In addition to the attribute- and relation-similarities shown in Fig. 17, it seems, therefore, possible that we perceive some kind of symmetry-similarity (identity), for example, between two different color percepts, which have equal resemblance to an elementary color they have in common, or equal degree of resemblance to two different elementary colors. In the NCS symbols, such colors are marked either on both sides and with equal distance from a common elementary color, or with equal distances from the two closest elementary colors, as shown in Fig. 19.

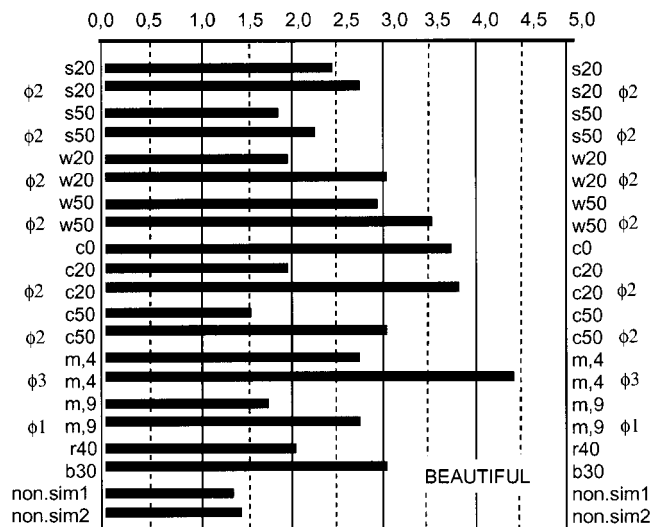


FIG. 18. Mean values for four-color pictures judged by the semantic scale beautiful. The notation s20 signifies a picture where all the colors have the blackness 20, etc., and m4 means constant saturation of 0.4. $\phi 2$ signifies that the colors in addition were of the same hue, in this case R10B. $\phi 3$ was hue R90B, and $\phi 1$ was Y30R. In one picture, all the colors had the same redness of 40, r40, and in one the colors were of constant blueness, b30. In two pictures, there was no similarity at all between the colors, "non.sim1" and "non.sim2".

ON COMPLEMENTARY COLORS

Very few experiments have actually been performed to find out whether symmetry similarities, i.e., equal deviation from elementary colors, have any bearing on the experience of Tuning or balancing of colors in a Color Gestalt. On the other hand, there are many examples in the color literature of statements that so-called complementary colors together would create balance, or harmony, as it is also labeled. Because "complementary colors" may be examples of symmetry similarities, there are reasons to further scrutinize the concept "complementary colors."

In color literature and encyclopedias, the concept "complementary colors" is defined in several different ways. Some of these refer to certain additive mixtures of light stimuli, others to certain subtractive mixtures of pigment materials. Further there are definitions referring to specific physiological functions of the visual sense in specific viewing conditions. As far as we understand, it is not possible to decide whether simultaneously perceived Color Elements are complementary according to any of these definitions unless one has acquired, through specific experimental learning, the knowledge of the particular definition in question.

According to these various operational definitions, "complementarity" does not refer to any spontaneously perceivable similarity or dissimilarity between color percepts, and, therefore, they do not fulfill the criterion of the color combination theory that only deals with relationships and attributes of the color percepts as such.

The word comes from the Latin Complementum meaning

that which fills up or completes. This origin should be kept in mind when we now go through some of the various definitions of what is meant when two colors are said to be complementary. Regarding definitions in scientific color literature, we have found the following definitions:

- "Two spectrally different light stimuli are said to be complementary if they when projected on a white screen give rise to two color percepts of different hues which when they overlap on the screen (so-called additive stimulus mixture) result in a new stimulus that is perceived as achromatic white or gray." This physical definition can be seen as congruent with the original meaning of the word as one stimulus (!) spectrally "fills up," or completes, what is spectrally lacking in the other in order to result in an achromatic stimulus (!).
 - "The hues of differently painted sectors of a Maxwell disc are called complementary, if they, when spun (rotated), result in a new stimulus (!) that looks achromatic gray." This is also a form of additive stimulus mixture.
 - "Two filters perceived to have different hues because they have different spectral transmission properties are said to be of complementary colors, if they, when superimposed, result in a stimulus (!) that is perceived as achromatic gray or black." This is a so-called subtractive mixture. The chromatic light stimulus passing the one filter is extinguished when passing the other. Note that this is the opposite of the meaning of the word complementary.
 - "Two chromatic pigments are said to be complementary, if the visible result when they are mixed . . ." (also this is a form of subtractive mixture) ". . . becomes achromatic gray." It should be noted that the result of such mixtures varies considerably depending on the properties of the pigments, as different brands may have different color modifying power.
- The four definitions above refer to physical phenomena as the energy radiation that hits the retina of the eye, after the "mixing" of the two original stimuli, is a new stimulus (!). And it is not possible to anticipate, by means of the visual sense only, whether or not two simultaneously perceived chromatic stimuli, when mixed, will give a new stimulus that looks achromatic white, gray, or black. With knowledge about the spectral distributions of the two energy radiations, however, a well-informed person in some cases can figure out, or calculate, if the result of their mixture comes up as gray.
- "If one after a while of intensive staring at (fixating) a chromatic color area moves the visual point to a larger achromatic (often white) area, the hue that emerges (is seen) as an after-image phenomenon is said to be the first color's complementary color."

This definition refers to a physiological phenomenon, probably a result of the signal from the retina being weakened for those wavelengths reflected from the white area that are of the same length as those from the chromatic area

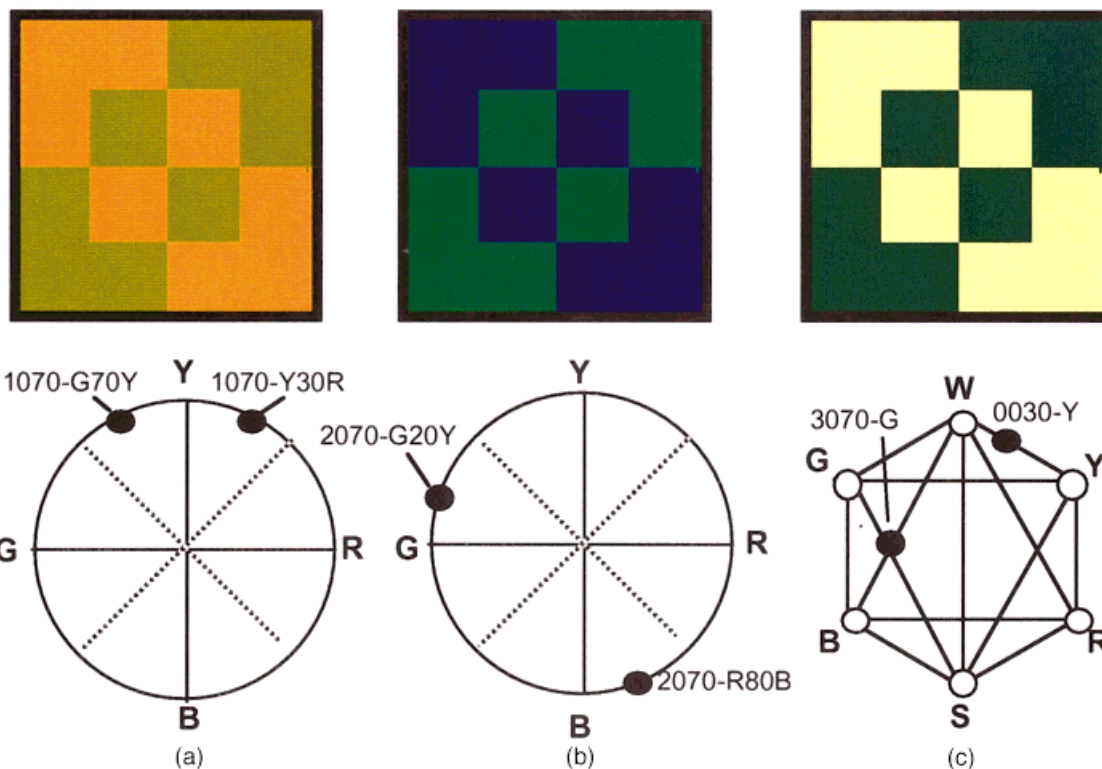


FIG. 19. Examples of symmetry-similarity. (a) The one color deviates regarding hue in redness relatively as much from the elementary yellow as the other color does in greenness, and, therefore, the yellowness is equal in both colors (yellowness-constancy, compare Fig. 17 A:e). (b) The one color deviates regarding hue in yellowness relatively equally from the elementary green, as the other color does in redness from the elementary blue, and the relative greenness is, therefore, as large in the first color as the relative blueness in the second. (c) The relative whiteness in the yellow-white color is as large as the relative greenness in the black-green and the first deviates relatively as much in yellowness from the elementary white as the second deviates in blackness from green.

first viewed. The signals from that part of the white area that corresponds to the retina image of the chromatic area give rise to a color percept with the same hue as that from a complementary color according to case (a). It should be noted that the after-image color of the original color of the area mode appears self luminant, i.e., it is of the luminous color appearance mode.

- f. Another definition of complementary color that probably refers to the same or a similar physiological mechanisms, is the special case of contrast reinforcement also named simultaneous contrast or induction, when an inherent achromatic gray area is placed as inner field against a chromatic surrounding field. The hue that vaguely appears in the gray is said to be complementary to the hue of the surrounding field, which is the hue of “the inducing” color.
- g. A definition, often encountered, is that “complementary colors have opposite positions on the Color Circle.” This definition carries a good share of ignorance, because a color circle is only a graphical model that illustrates the order of hues according to a given (arbitrary) principle. Which hues are opposite to one another is thus depending on which principle the hue circle is based on. If the graphic hue circle is based on one of the complementary

principles in the paragraphs a–f, this definition, of course, holds—but in that case the argument is circular.

The reason why two complementary color stimuli in a Color Gestalt would have a harmonious relationship is often said to be that they together “form a whole—or totality—entirety” or represent the largest possible dissimilarity. Renner,¹⁵ for example, refers to Goethe, who considered harmonious only that color combination in which the totality of the color circle was represented.

The color circle he is referring to is based on the color percept of three chromatic stimuli, that through mixing—physical or physiological—may result in the other hue percepts. This reasoning (argument) presupposes very deep knowledge of physical and/or physiological mixing phenomena and is thus not congruent with the Color Combination Theory, which is based entirely on the attributes of color percepts as such, i.e., what can be perceived and assessed in the actual viewing moment by means of the inborn/congenital color sense.

By phenomenological analysis, one can find that two originally chromatic color percepts by some method of mixing their stimuli can be transformed to an achromatic color percept. In the same way it is easy to see, in induction- and after-image experiments, that (in Josef Albers’ words¹⁶)

one color can become two or two colors can become many. On the other hand, there are, to our knowledge, no documented experiments showing that people can judge whether two colors are complementary according to the common definitions quoted above, unless they have acquired this particular ability through many years of special training.

h. Opposite colors according to the NCS provide an alternative definition of the concept of (chromatic) complementary colors. It refers to the simultaneous presence in a Color Gestalt of all four chromatic elementary attributes: yellowness, redness, blueness, and greenness. If, for example, in a two-color combination, one of the colors contains two of these chromatic Elementary Color Attributes and the other color the other two attributes, then the two colors are each other's perceptual complement in the sense that the Color Gestalt as a whole "is filled up," as all four of the chromatic elementary colors are represented. An example of this could be a combination of an orange color (with yellowness and redness) and a turquoise (with blueness and greenness). Another way to express this is that the one color has what is missing in the other. In the NCS Color Circle, such colors are found in diametrically opposite quadrants: YR-BG, and RB-GY. This perceptual oppositeness is well in accord with the original, etymological meaning of the concept complementary.

The definitions (a), (b) as well as (e) and (f) seem to follow the laws of additive stimulus mixing. In the NCS, it is, of course, possible to mark the perceived hues for any pair of complementary stimuli. If pairs from these definitions (normal lighting and viewing conditions assumed) are marked in the Color Circle by straight lines, it shows that they approximately intersect in a point shown in Fig. 20. From experience, we have noted that the same also holds for mixtures of pigments.

As also shown in Fig. 20 by the shaded parts of the circumference of the NCS Color Circle, the perceptual NCS opposite colors, according to definition (h), are mostly in accordance with the perceived hues for complementary stimuli, i.e., all four chromatic elementary attributes are represented in a combination of these colors.

Stimuli complementary to hues between Y and Y20R, on the other hand, are perceived to have hues between R85B and B. In a constellation of two such color percepts, the attribute greenness is lacking, while it is possible to see redness in them as an attribute in common. Correspondingly, yellowness is lacking when stimuli for color percepts between R and R30B are put in a constellation with stimuli for colors between B65G and G. In addition to the lack of yellowness in such compositions, one can perceive a blueness as an attribute in common.

From extensive experiments with color assessments it is evident and documented that a so-called "naïve" observer, without learning, training, and/or indoctrination by means of innate color sense only, is able to judge which of the chromatic Elementary Color Attributes a color percept con-

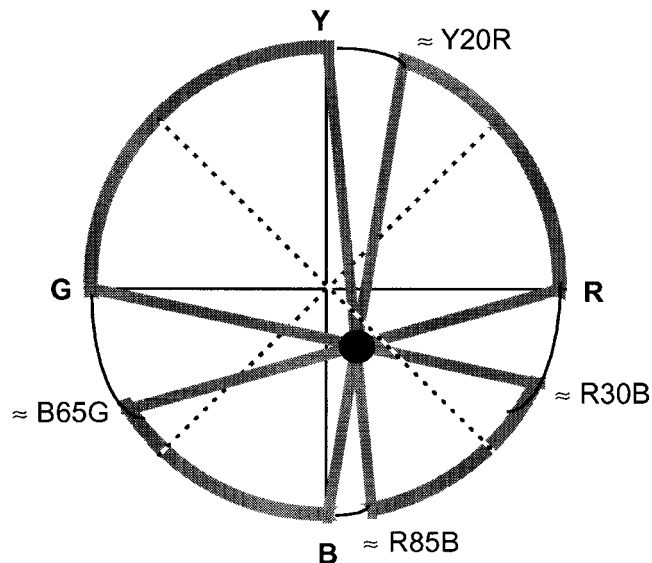


FIG. 20. If, in the NCS Color Circle, straight lines are drawn between the pairs of perceived hues of complementary color stimuli, they all intersect in a point with the approximate position $c = 20, \phi = R75B$. The shadowed parts of the Color Circle circumference indicate areas where the perceived hues of the complementary color pairs are identical with opposite colors according to the NCS.

tains. Not having found documented evidence for the opposite, we question, however, that the same observers would be able to judge whether two simultaneously perceived colors of different hues are complementaries according to any of the definitions (a)–(f), unless they actually perform the various operational experiments.

In spite of the ambiguity of the concept complementary colors, discussed above, the various postulates in the earlier color literature are most often unambiguous regarding which complementary color pairs are self-evident. Further they are, almost always, restricted to those colors that are said to correspond to primary stimuli for either additive or subtractive stimulus mixing. In most cases, the "complementary" to yellow is described as reddish blue, and the one to blue as reddish yellow—which is in line with what is shown in Fig. 20. Goethe, Itten, and others, on the other hand, claim that red and green are complementaries*—something that is in conflict with what is perceived and is just a statement—while Ostwald, on the other hand, says that the complementary to red is blue-green, and to green it is blue-red, in accordance with Fig. 20. Regarding all the hues in between these, it is hard to find descriptions of complementarity according to any of the definitions from (a)–(f). It is obvious that this to a high degree is dependent on the spacing metrics used between the primary stimuli.

Even if we question if it is possible to assess whether two simultaneously perceived colors also correspond to complementary stimuli, this does not imply that we deny the possibility that the two color percepts would be perceived as

* For Goethe the word purple (Purpur) was identical with the elementary red.

having a balanced or harmonious relationship to each other, as is claimed by many artists. An experiment to study if this could be the case was performed with 35 architecture students at the Chalmers University of Technology in Göteborg.¹⁷ They were asked to judge, along a ten-point scale, how harmonious they considered each of eight pictures with color combinations. Two of these were made up of color pairs that represented complementary stimuli according to the definitions (a) and three contained color pairs of opposite hues in the NCS model according to definition (h). Among the pictures was also one with colors that were of the same hue and chromaticness and another where all the colors had the same redness, according to A.e in Fig. 17, and one where there was none of the perceptual similarities present. The diagram in Fig. 21 shows the result of this pilot study.

Most of the subjects in the experiments were supposedly, through their education, familiar with the traditional complementary color concept(s). In spite of this, the results provide no evidence that combinations of complementary stimuli would be experienced as more harmonious than other constellations of colors. The colors that were hue (ϕ), chromaticness (c), and redness (r) identical, on the other hand, were judged as more harmonious than all the others, while the constellation where all the colors were completely different was judged as least harmonious.

It is sometimes said that color percepts of complementary stimuli are perceived as more different to each other than other color pairs. The reason for this, if any is referred to, would be implied in either the physiologically conditioned phenomena of after-image or simultaneous contrast, or that these stimuli in mixtures result in stimuli that are perceived as achromatic white, gray, or black. In an investigation of perceived difference (dissimilarity) between various color-pairs, however, we found no support for this preconception. There was no significant difference in the perception of dissimilarity between complementary stimulus-pairs and NCS opposite pairs. On the other hand, the results indicate that the degree of perceived dissimilarity between color percepts depends on NCS lightness differences (Δv).

Further investigations are needed into the phenomenon that we here call symmetry-similarities, by which is meant that the dissimilarities between the colors have a certain corresponding relation to an elementary color percept, which must not necessarily be present in the actual visual field.

Among other questions of interest for the theory of color combinations would be how harmonious and/or balanced different color combinations are experienced as referred to the various types of Color Chords I, II, III and IV (Fig. 12) and, within these categories, whether or not the colors' degree of similarity to the elementary hues affects the experience. (Critical comments on this issue have earlier appeared in this journal by the present authors.⁹)

Order Rhythm

The third subfactor of the color combination dimension called Tuning refers to the order in which the various Color

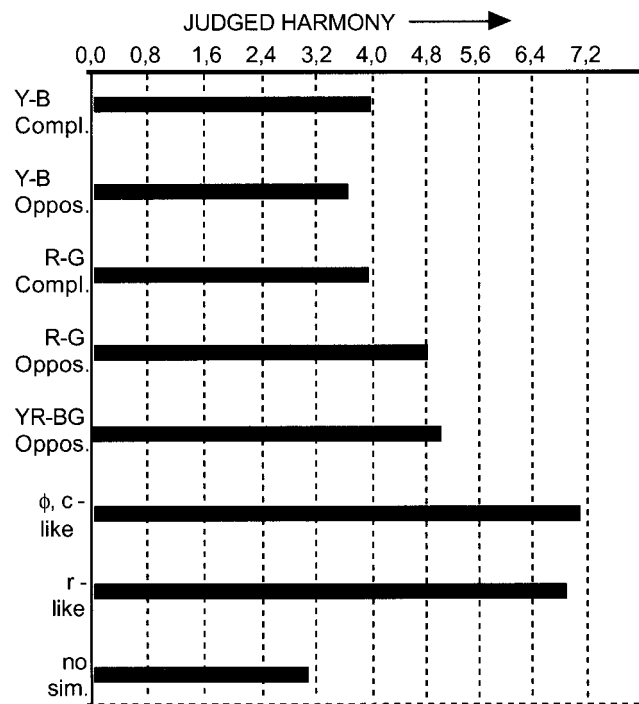


FIG. 21. Mean judgment values of perceived harmony for pictures with different color combinations. Y-B signifies a yellow-blue pair, R-G a red-green, and YR-BG a yellowred-bluegreen pair. Compl. means complementary stimuli and Oppos. means opposite colors according to NCS. ϕ, c -like signifies a picture, where the colors have the same hue as well as chromaticness, r -like means the redness is equally large in all the colors, and the last bar, no sim., shows the judgment of harmony for a picture, where the colors lack any perceptual similarity. The vertical scale-lines notify judgment value distances needed for statistical significance.

Elements in a Color Gestalt are perceived to come, as regards the color per se, their area sizes, and their intervals, and how this may evoke a perception of visual rhythm. The order in which colors, Area Sizes and Intervals recur in one and the same Color Chord can vary from extreme regularity to chaos (complete irregularity). This is most evident in so-called serial compositions, i.e., where the colors are placed in an unambiguous row, e.g., as simple stripes. In such patterns, the order of the Color Elements is perceived to be self-evident. Some examples of stripes with varying order rhythm are shown in Fig. 22.

Color literature is still missing a thorough phenomenological analysis that could be the basis for a structuring of various color, area, and interval rhythms, and we also lack an adequate descriptive terminology for the phenomenon. In spite of this, we have included the factor Rhythm in this Color Combination Theory with the hope that it could initiate further studies of what we call the order rhythm and its effect on the experience of Color Gestalts.

SOME FINAL WORDS

The theoretical model for color combinations that is presented here is certainly far from complete in all details. It

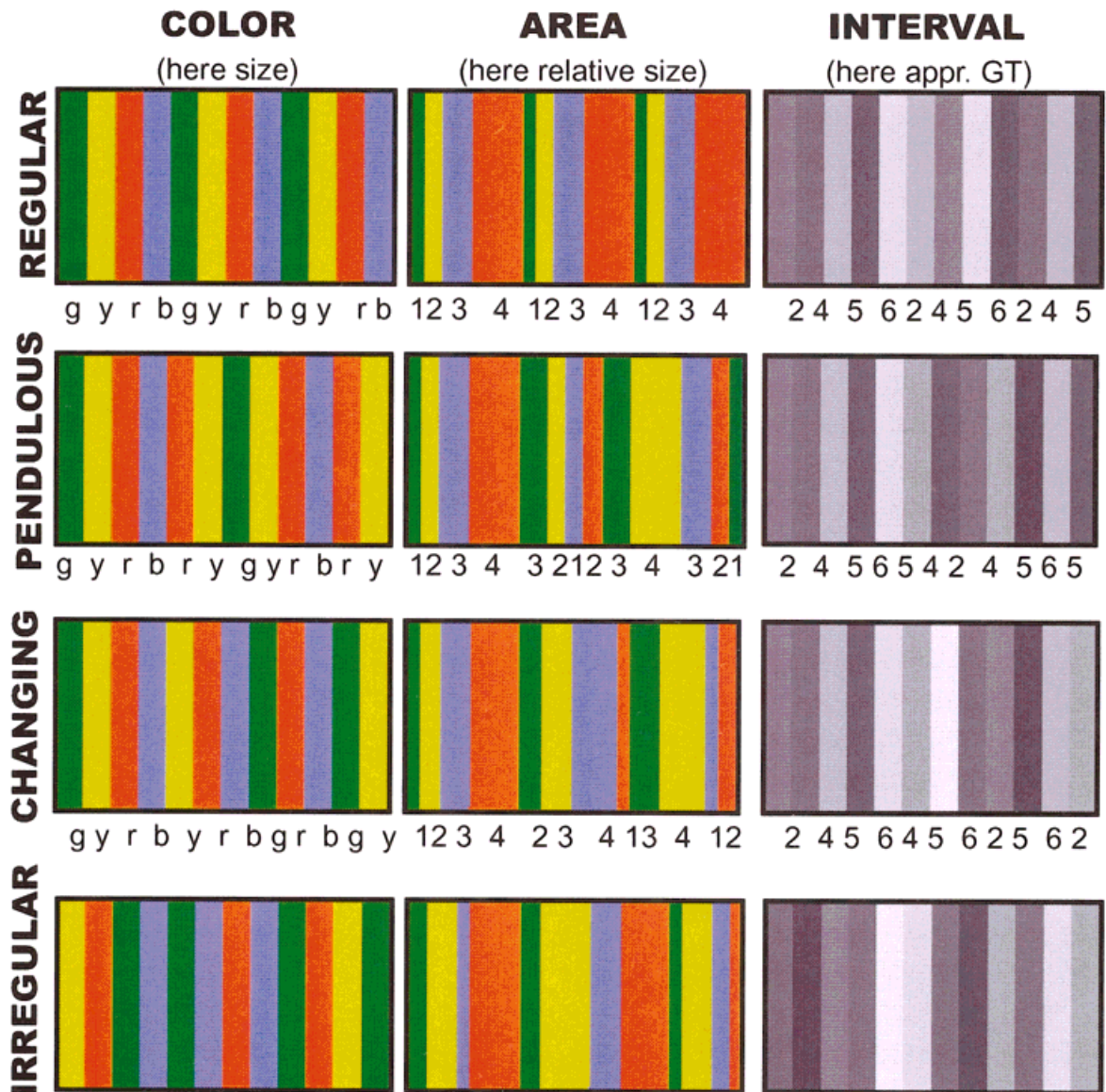


FIG. 22. Examples of various order rhythms regarding colors, Area Relations, and Interval Border Distinctness.

needs to be further scrutinized, both from the aspect of phenomenological analysis of color constellations and its practical value. Regarding its usefulness, we refer primarily to how color combinations can be adequately and unambiguously described in experimental investigations into people's experience of color as a gestalt-forming factor in various contexts, as well as further studies of what artists, architects, designers, and others have created with color constellations.

It should also be pointed out once more that the Color Combination Theory is concerned with questions about the relationships between color percepts. It does not deal with the influence of various lighting and viewing conditions on the perception of different objects with specific inherent colors. It is well known that these circumstances to a great degree determine the appearance of objects, but it is not sufficiently investigated in what way. In addition, the color stimuli influence each other through contrast reinforcement

(simultaneous contrast), which results in colors appearing different seen in juxtaposition compared to when seen apart. This has been excellently demonstrated by Albers.¹⁶ For those who create Color Gestalts, the knowledge about these phenomena is of importance, for example, in which directions and how much such changes occur for different colors. For the spectator, on the other hand, it is exclusively what he or she perceives in a given situation that counts.

As a metaphor, we can say that the colors we perceive constitute a kind of language as they serve as tools of communication—between people and the objects surrounding them, and between people, as for example in art.¹⁸ NCS describes the formal basic elements of the color language, corresponding to theory of word-formulation, and the color “combinatorics” are, so to say, the syntax that accounts for (describes) the construction of the language. In addition, the color language, naturally, also has its semantic content. Some may prefer to consider colors as a system of signs and

not as a language, but still, they have both synthetic and semantic aspects.

The Color Combination Theory outlined here should be seen as a mental model for the formal description of the perceptual color attributes that characterize a Color Gestalt. In its current state of development, we hope that it can be fruitful as a point of departure for further studies, serving as a descriptive model for color combinations in experiments on the color phenomena that are involved in the perception of our environment.

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