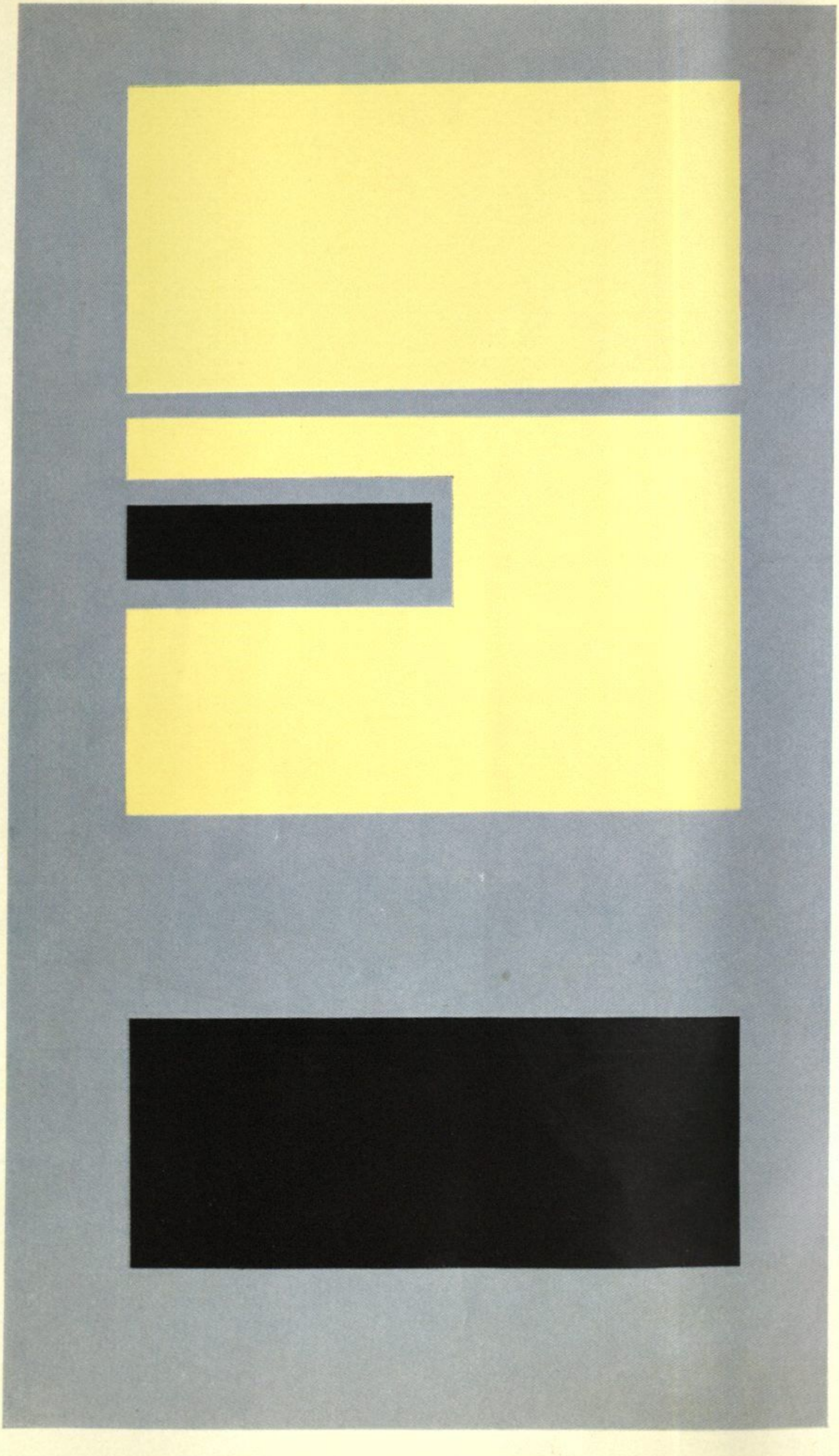


XVIII - 1

Introduction

The book "Interaction of Color" is a record of an experimental way
of studying color and of teaching color.

In visual perception a color is almost never seen as it really is
-- as it physically is.
This fact makes color the most relative medium in art.

In order to use color effectively it is necessary to recognize
that color deceives continually.
To this end, the beginning is not a study of color systems.

First, it should be learned that one and the same color evokes
innumerable readings.
Instead of mechanically applying or merely implying laws and rules
of color harmony, distinct color effects are produced
-- through recognition of the interaction of color --
by making, for instance,
2 very different colors look alike, or nearly alike.

The aim of such study is to develop -- through experience
-- by trial and error -- an eye for color.
This means, specifically, seeing color action
as well as feeling color relatedness.

As a general training it means development of observation and articulation.

This book, therefore, does not follow an academic conception
of "theory and practice."
It reverses this order and places practice before theory,
which, after all, is the conclusion of practice.

Also, the book does not begin with optics and physiology of visual perception,
nor with any presentation of the physics of light and wave length.

Just as the knowledge of acoustics does not make one musical
-- neither on the productive nor on the appreciative side --
so no color system by itself can develop one's sensitivity for color.
This is parallel to the recognition that no theory of composition by itself
leads to the production of music, or of art.

Practical exercises demonstrate through color deception (illusion)
the relativity and instability of color.
And experience teaches that in visual perception there is a discrepancy
between physical fact and psychic effect.

What counts here -- first and last -- is not so-called knowledge
of so-called facts, but vision -- seeing.
Seeing here implies Schauen (as in Weltanschauung) and is coupled
with fantasy, with imagination.

This way of searching will lead from a visual realization
of the interaction between color and color
to an awareness of the interdependence of color with form and placement;
with quantity (which measures amount, respectively extension
and/or number, including recurrence);
with quality (intensity of light and/or hue);
and with pronouncement (by separating or connecting boundaries).

The table of contents shows the order
in which exercises usually lead our investigation.

Each exercise is explained and illustrated --
not to give a specific answer,
but to suggest a way of study.

I Color recollection -- visual memory

If one says "Red" (the name of a color)
and there are 50 people listening,
it can be expected that there will be 50 reds in their minds.
And one can be sure that all these reds will be very different.

Even when a certain color is specified which all listeners have seen innumerable times -- such as the red of the Coca-Cola signs which is the same red all over the country -- they will still think of many different reds.

Even if all the listeners have hundreds of reds in front of them from which to choose the Coca-Cola red, they will again select quite different colors. And no one can be sure that he has found the precise red shade.

exact

And even
if that round red Coca-Cola sign with the white name in the middle
is actually shown so that everyone focuses on the same red,
each will receive the same projection on his retina,
but no one can be sure whether each has the same perception.

When we consider further the associations and reactions
which are experienced in connection with the color and the name,
probably everyone will diverge again in many different directions.

What does this show?

First, it is hard, if not impossible, to remember distinct colors.
This underscores the important fact that the visual memory is very poor
in comparison with our auditory memory. Often the latter is able
to repeat a melody heard only once or twice.

Second, the nomenclature of color is most inadequate.
Though there are innumerable colors -- shades and tones --
in daily vocabulary, there are only about 30 color names.

II Color reading and contexture

The concept that "the simpler the form of a letter the simpler its reading" was an obsession of beginning constructivism. It became something like a dogma, and is still followed by "modernistic" typographers.

This notion has proved to be wrong, because in reading we do not read letters but words, words as a whole, as a "word picture." This was discovered in psychology, particularly in Gestalt psychology. Ophthalmology has disclosed that the more the letters are differentiated from each other, the easier is the reading.

Without going into comparisons and details, it should be realized that words consisting of only capital letters present the most difficult reading -- because of their equal height, equal volume, and, with most, their equal width. When comparing serif letters with sans-serif, the latter provide an uneasy reading. The fashionable preference for sans-serif in text shows neither historical nor practical competence.

First, sans-serifs were designed as letters not for texts but for captions, when pictorial reproductions were introduced with stone lithography. Second, they produce poor "word pictures."

INTERACTION OF COLOR

Interaction of Color

INTERACTION OF COLOR

Interaction of Color

II Color reading and contexture

The concept that "the simpler the form of a letter the simpler its reading" was an obsession of beginning constructivism. It became something like a dogma, and is still followed by "modernistic" typographers.

This notion has proved to be wrong, because in reading we do not read letters but words, words as a whole, as a "word picture." This was discovered in psychology, particularly in Gestalt psychology. Ophthalmology has disclosed that the more the letters are differentiated from each other, the easier is the reading.

Without going into comparisons and details, it should be realized that words consisting of only capital letters present the most difficult reading -- because of their equal height, equal volume, and, with most, their equal width. When comparing serif letters with sans-serif, the latter provide an uneasy reading. The fashionable preference for sans-serif in text shows neither historical nor practical competence.

First, sans-serifs were designed as letters not for texts but for captions, when pictorial reproductions were introduced with stone lithography. Second, they produce poor "word pictures."

INTERACTION OF COLOR Interaction of Color

INTERACTION OF COLOR Interaction of Color

This illustrates that clear reading depends upon the recognition of context.

In musical compositions,
so long as we hear merely single tones, we do not hear music.
Hearing music depends on the recognition of the in-between of the tones,
of their placing and of their spacing.

In writing, a knowledge of spelling has nothing to do with an understanding
of poetry.

Equally, a factual identification of colors within a given painting
has nothing to do with a sensitive seeing
nor with an understanding of the color action within the painting.

Our study of color differs fundamentally from a study which anatomically
dissects colorants (pigments) and physical qualities (wave length).

Our concern is the interaction of color; that is, seeing
what happens between colors.

We are able to hear a single tone.
But we almost never (that is, without special devices) see a single color
unconnected and unrelated to other colors.
Colors present themselves in continuous flux, constantly related to
changing neighbors and changing conditions.

As a consequence, this proves for the reading of color
what Kandinsky often demanded for the reading of art:
what counts is not the what but the how.

IV A color has many faces -- the relativity of color

Imagine in front of us 3 pots containing water, from left to right:

WARM LUKEWARM COLD

When the hands are dipped first into the outer containers,
one feels -- experiences -- perceives -- 2 different temperatures:

WARM (at left) (at right) COLD

Then dipping both hands
into the middle container,
one perceives again
2 different temperatures,
this time, however,
in reversed order

(at left) COLD -- WARM (at right)

though the water is neither of these temperatures, but of another, namely

LUKEWARM

Herewith one experiences
a discrepancy between physical fact and psychic effect called,
in this case, a haptic illusion -- haptic as related to the sense of
touch -- the haptic sense.

In much the same way as haptic sensations deceive us, so
optical illusions deceive. They lead us to "see" and to "read"
other colors than those with which we are confronted physically.

To begin the study of how color deceives and how to make use of this,
the first exercise is
to make one and the same color look different.

On the blackboard and in our notebooks we write:

Color is the most relative medium in art.

Challenging examples of very surprising color changes are shown.
Then the class is invited to produce similar effects

but is not given reasons or favorable conditions.
It starts, therefore, on a trial-and-error basis.

Thus, continuing comparison -- observation -- "thinking in situations" --
is promoted, making the class aware that discovery and invention
are the criteria of creativeness.

As a practical study we ask that 2 small rectangles of the same color
and the same size be placed on large grounds of very different color.

Soon, these first trials are collected and separated into groups
of more and less promise.
The class will become aware that change is a result of influence.
The influencing color is distinguished from the influenced color.

It is discovered that certain colors are hard to change, and
that there are others more susceptible to change.

We try to find those colors which are more inclined to exert influence
and to distinguish them from those which will accept influence.

A second class exhibition of more advanced results should clarify
that there are 2 kinds of changing influences working in 2 directions,
light on the one side and hue on the other. And both occur simultaneously --
though in varying strength.

Since 2 pieces of the same paper, therefore of the same color,
are to appear different -- and, if possible, incredibly different --
we must compare them under equal conditions.
The only colors which are factually different are the large grounds,
though they are alike in size and shape.

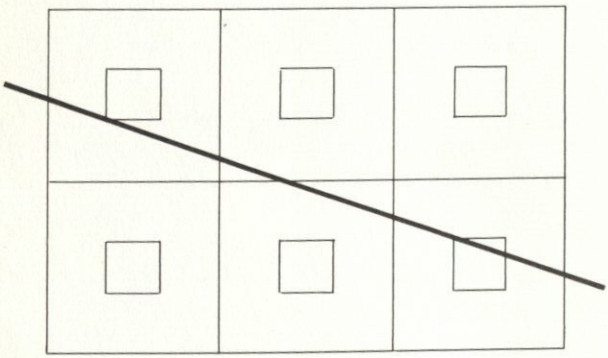
Because of the laboratory character of these studies
there is no opportunity to decorate, to illustrate, to represent anything,
or to express something -- or one's self.

Here, successful studies present a demonstration. Since they cannot be
misread or misunderstood, they prove understanding both
of the principle involved and of the materials to be manipulated.

(See Plates IV -- 3.)

It should be clear that, with these exercises and all others to follow, whether or not we arrive at a pleasant or harmonious color combination is unimportant.

Precision and clean execution are required for all finished studies. To avoid destroying the desired effect, small pieces of paper on small grounds should not be used.
Arrangements such as the one shown below disguise the desired effect and lead to confusion:



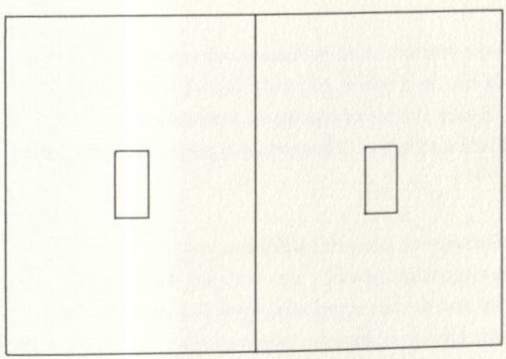
NO

Such studies shown separately in pairs may demonstrate clearly the desired effects. But interlocked in the tile pattern above, their illusional effects annul each other because of:

a) The simultaneous influence from too many directions -- from left and right, and above and below;

b) The unfavorable distribution of area between the influencing and the influenced color.

Consequently, such presentation lacks both sight and insight.



YES

V Lighter and/or darker -- light intensity, lightness

If one is not able to distinguish the difference between a higher tone and a lower tone, one probably should not make music.

If a parallel conclusion were to be applied to color, almost everyone would prove incompetent for its proper use. Very few are able to distinguish higher and lower light intensity (usually called higher and lower value) between different hues. This is true despite our daily reading of numerous black-and-white pictures.

Since the discovery of photography and particularly since the development of photomechanical reproduction processes, we are exposed -- more and more every day -- to pictures from all over the world, the world seen and unseen, visible and invisible.

These pictures, which are predominantly "black and white," are printed in only 1 black on a white ground. Visually, however, these pictures consist of grey shades of the finest gradations between the poles of black and white. These shades penetrate each other in varying degrees.

With the tremendous increase in pictorial information -- through newspapers, magazines, books -- we receive a training in the reading of lighter and darker tones of grey as has never before existed. With the growing interest in color photography and color reproduction, a parallel training in the reading of lighter and darker color is on the way.

However, it is still true that only a minority can distinguish the lighter from the darker within close intervals when obscured by contrasting hues or by different color intensities.

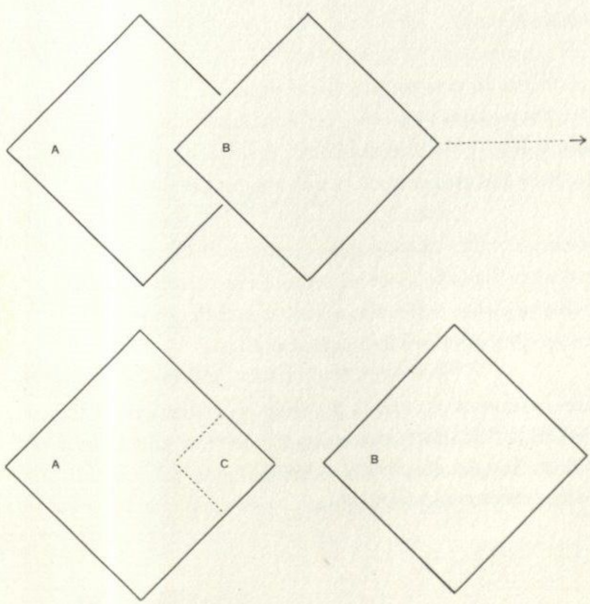
In order to correct a prejudice common among painters and designers -- that they belong to that minority -- we have the students test themselves. We confront them with several pairs of color, from which they are to select and to record which color in a pair is the darker.

The darker one, it is explained, is visually the heavier one, or the one containing more black, or less white. It should be mentioned that the students are encouraged to abstain from making a judgment in any case of doubt. It may also demonstrate that not voting can have a positive meaning.

Though there have always been advanced painting students in the basic color class, the result of this test has remained constant for a number of years: 60% of the answers are wrong and only 40% are right, not counting the undecided cases.

By this experience we are led to the next task: To find colors about which we cannot say immediately which is the lighter or darker. These colors are collected and pasted in pairs, and observed again and again until their light-dark relationship is clearly recognized.

In cases where a decision seems impossible, an after-image effect may be helpful. 2 color sheets are put on top of each other in this way:



Focus longer than the eye wants to on the covering corner (B) of the upper paper and then quickly remove this upper sheet. If area (C) now appears lighter than area (A), then the upper paper is the darker -- and vice versa. After this, repeat the experiment with the papers in reverse order. Frequently only 1 of the 2 reversed comparisons reveals the true relationship.

The usual results (60% wrong) are disillusioning as well as revealing. Voting for the wrong color often needs cover or compensation; also, the disappointment of wrong answers encourages doubts. The doubts often are directed, not against one's own judgment, but against the competence of the teacher: are his answers the right ones?

As the test is to prove whether one has a trained eye or not, the pairs of color presented for discrimination are not easy to decipher. Within the pairs there is no equal light intensity because the conclusive question to be expected from a class is: are there equal light values within these couples? The answer is No.

Another unavoidable question is: will a photograph of these colors reveal their true relationship and thus give the final proof? The answer again is No.

This answer will remain true for black-and-white as well as color photographs, because the sensitivity and consequently the registration of the retina of an eye is different from the sensitivity and registration of a photographic film.

Normally, black-and-white photography registers all lights lighter and all darks darker than the more adjustable eye perceives them. The eye also distinguishes better the so-called middle greys, which in photography often are flattened if not lost.

As an example we showed our class 2 different reproductions of the same Ensor painting, "Masks Confronting Death," of 1888. The first appeared in the catalogue of an Ensor exhibition, the other in a newspaper report on the same exhibition.

The first, the larger and more official reproduction, in very fine screen on coated paper, presumably would be considered more representative than the second, smaller reproduction in a coarser screen and on the cheapest paper.

But the latter was not only much more correct in its whole tonality; it also showed clearly 1 more mask, face, or head which the more expensive, so-called high-key reproduction blotted out entirely -- a small but complete frontal face, lighter than all the others and separated from them, near the left picture edge.

This shows what a higher key in light can lose in photography.

The greatest advantage the eye has over photography is its scotopic seeing in addition to its photopic seeing. The former means, briefly, the retinal adjustment to lower light conditions.

Color photography deviates still more from eye vision than black-and-white photography. Blue and red are overemphasized to such an extent that their brightness is exaggerated. Though this may flatter public taste, the result is a loss in finer nuances and in delicate relationships. Whites rarely appear white but usually look greenish. This makes color slides of Mondrian paintings unbearable.

For practical reasons, certain groups of our color reproductions in the original edition are done in 4-color process which presents subdivided, optically intermixing transparent colors instead of the opaque colors which are characteristic of most of our studies.

Gradation studies -- new presentations

With the experience that often we are unsure and thus unable to distinguish between lighter and darker in color, it appears appropriate, even necessary, to develop a more discriminating sensitivity. To this end, we study gradation by producing so-called grey steps, grey scales, grey ladders. These demonstrate a gradual stepping up or down between white and black, between lighter and darker.

For such exercises, we first collect as many greys in paper as possible, and preferably independent of commercial grey sets, which usually offer a too limited choice, or, worse, unequal steps. Rich sources for many paper greys are black-and-white reproductions from popular magazines.

Selecting from them smaller and larger areas of as many greys as possible, we will be taught first that photography registers and measures light and dark differently from our eyes. That it turns darks darker and lights lighter means, besides a generalization toward the polar contrasts, a loss of the visually more interesting middle greys. Thus, such reproductions confront us with a dominance of very heavy and very light greys, and a consequent scarcity of middle greys.

These cutouts are to be arranged in gradations as described. The softer the steps appear, and the more equal the steps are, the more valuable and convincing the study. As any lines or empty spaces between the steps interfere with a direct comparison, such separating in-betweens prove nonsensical. We also reject the still-recommended but misleading stepping-up of thin layers of water colors or India ink, as explained in Chapter XX. In order to avoid such mistakes, and also any mechanical repetition of the too-familiar illustrations of color books, we aim at a more creative, more challenging, more instructive presentation. Thus we subdivide and mount our grey scales to show new interactions, particularly between graduating and non-graduating greys, and vice versa.

Color intensity -- brightness

After the study of "Lighter or Darker" and with some training in gradation studies, one can expect to come to an agreement on different light intensities.

However, when it comes to color intensity (brightness), occasionally one may find agreement among a few people but hardly within a large group such as a class.

As "gentlemen prefer blondes," so everyone has preference for certain colors and prejudices against others. This applies to color combinations as well.
It seems good that we are of different tastes.
As it is with people in our daily life, so it is with color.
We change, correct, or reverse our opinions about colors, and this change of opinion may shift forth and back.

Therefore, we try to recognize our preferences and our aversions -- what colors dominate in our work; what colors, on the other hand, are rejected, disliked, or of no appeal. Usually a special effort in using disliked colors ends with our falling in love with them.

The exercise in color intensity consists of sorting all possible shades and tints within a hue. From these is chosen the most typical hue (the bluest blue, the greenest green, etc.) and it is placed within the group accordingly.

VI 1 color appears as 2 -- looking like the reversed grounds

Having presented, in the previous problem, a very detailed explanation of a step-by-step method of teaching and learning, the following problem permits a briefer description.

With the first exercise in color interaction we make
1 color look like 2, or, what means the same,
3 colors look like 4. The next step is to make
3 colors look like 2, or, describing it as in the previous task,
1 color is to show 2 faces which refer to the 2 colors
of the reversed grounds,
or, the changed color is to echo the 2 changing ones.

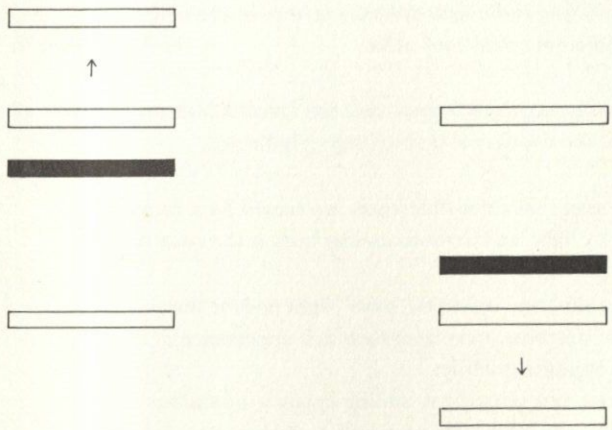
After showing a few examples, the task of producing similar effects is introduced with the question:
Which color will play simultaneously the roles
of the 2 colors of the 2 reciprocal grounds?

The first class exhibition of preliminary solutions shows that most of the trial colors selected appear closer to one ground than to the other.

However, when one tries to find a color that is equally close or equally distant from both grounds, one will discover that even a large collection of color paper (even that of the entire class) may not provide the fitting tone.

Then, instead of pushing the in-between color to one or the other side, we must consider changing 1 or both of the grounds, either moving closer to or more distant from the in-between color. (See diagram.)

After repeated trials it must be concluded that the only fitting color is the one which is topologically in the middle of the colors of the 2 grounds.



The task is to find this middle color.

This is relatively easy when the 2 grounds are of the same hue,
as with a lighter and a darker green ground,
or with a lighter and a darker violet ground.

It is a more challenging task to find the middle color
between 2 different hues
but it is particularly interesting when the 2 grounds
are of opposing (complementary) colors.

VII 2 different colors look alike -- subtraction of color

The fact that one and the same color can perform many different roles is well known and is consciously applied.

Less well known is the possibility in the previous exercise of giving a color the look of reversed grounds.

Still more exciting is the next task, the reverse of the first: to make 2 different colors look alike.

In the first exercise it was learned that the more different the grounds, the stronger is their changing influence.

It has been seen that color differences are caused by 2 factors: by hue and by light, and in most cases by both at the same time.

Recognizing this, one is able to "push" light and/or hue, by the use of contrasts, away from their first appearance toward the opposite qualities.
Since this amounts virtually to adding opposite qualities, it follows that one might achieve parallel effects by subtracting those qualities not desired.

This new experience can be achieved first by observing 3 small samples of 3 reds on a white ground. They will appear first of all -- red.

Then when the 3 reds are placed on a ground of another red their differences, which are differences of hue as well as of light, will become more obvious.

Third, when placed on a red ground equal to 1 of the 3 samples, only 2 of the reds will "show," and the lost one is absorbed -- subtracted.
Repeated similar experiments with adjacent colors will show that any ground subtracts its own hue from colors which it carries and therefore influences.

Additional experiments with light colors on light grounds
and dark colors on dark grounds prove that the light of a ground
subtracts in the same way that its hue does.

From this, it follows that any diversion among colors
in hue as well as in light-dark relationship
can be reduced if not obliterated visually on grounds
of equal qualities.

Such studies provide a broad training in analytical comparison
and usually evoke surprising results, leading the student
to an intense study of color.

VIII Why color deception? -- after-image, simultaneous contrast

For a better understanding of why colors read differently
from what they really (physically) are, we show now
the cause of most color illusions.
(See Plates VIII -- 2.)

First: In order to prepare for the second part of this demonstration, cut out in red and white color paper 2 equal circles (of ca. 3-inch diameter) and mark their centers with a small black dot.

Then paste them -- horizontally related -- the red circle to the left and the white one to the right, on the blackboard or a piece of black paper or black cardboard, ca. 10 inches high and 20 inches long, with about equal amounts of black before, between, and after the two circles.

Now, by staring steadily at the marked center of the red circle (up to half a minute) one soon discovers how difficult it is to keep the eye fixed on a point. After a while, moon-sickle shapes appear, moving along the circle's periphery. In spite of this, one must continue to focus on the red center point in order to assure the desired experience.

Suddenly, one shifts the focus to the center of the white circle. Then from the class one usually hears noises which indicate surprise or astonishment. This happens because all normal eyes suddenly see green or blue-green instead of white. This green is the complementary color of red or red-orange.

The phenomenon of seeing green (in this case) instead of white is called after-image, or simultaneous contrast.

Second: On the left are yellow circles of equal size which touch
each other and which fill out a white square.
On the right is an empty white square of the same size.
Each is on a black ground.

After staring for half a minute at the left square, one shifts the focus suddenly to the right square. Here one experiences a very different after-image. Instead of seeing the complement of the yellow circles (blue), diamond shapes are seen -- the leftover shapes of the circles -- in yellow. This illusion is a double and thus reversed after-image, sometimes called contrast reversal.

A plausible explanation:

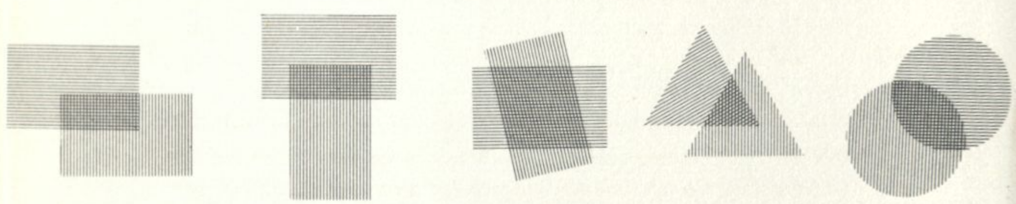
One theory maintains that the nerve ends on the human retina (rods and cones) are tuned to receive any of the 3 primary colors (red, yellow, or blue), which constitute all colors.

Staring at red will fatigue the red-sensitive parts, so that with a sudden shift to white (which again consists of red, yellow, and blue), only the mixture of yellow and blue occurs. And this is green, the complement of red.

The fact that the after-image or simultaneous contrast is a psycho-physiological phenomenon should prove that no normal eye, not even the most trained one, is foolproof against color deception.
He who claims to see colors independent of their illusionary changes fools only himself, and no one else.

If we name 2 mixture parents A and B, and their mixture C,
then our first task is to find C's, which are mixtures of A and B,
another task will be " " B's conditioned by A " C,
or, a third task, " " A's " " B " C.

This invites one to draw conclusions backward, that is, to guess -- from a mixture and 1 mixture parent -- the other mixture parent.



X Factual mixtures -- additive and subtractive

Though the color class (as a rule) abstains from the use of colorants (meaning pigments and paints) for reasons explained before, the color studies in paper are related to the actual use of paint as often as possible.

Therefore, after the introductory studies of mixture as illusion, factual mixing is analyzed. There are 2 kinds of physical mixture:

a) Direct mixture of projected light,
b) Indirect mixture of reflected light.

a) Color light, or direct color, probably is most familiar through its practical application in theater and advertising. The scientific analysis of the physical qualities (wave length, etc.) is not the problem of the colorist; it is the concern of the physicist. When he mixes his colors, he projects them on a screen, 1 on top of or overlapping the other. In any such mixture where there is overlapping, it will be obvious that every one of these mixtures is lighter than any of the mixture parents. By means of a prismatic lens, the physicist easily demonstrates that the color spectrum of the rainbow is a dispersion of the white sunlight. With this he proves also that the sum of all colors in light is white. This demonstrates an additive mixture.

b) When pigment or paint is mixed on a palette or in a container it is seen by the eye as reflected light. This mixing will never result in white as the sum of colors. On the contrary, the more color that is mixed, the more the mixture approaches a dark grey leaning toward black. This we call subtractive mixture. Also, the psychologist, who mixes colors of reflecting colorants optically on the rotating wheel, is not able to arrive at mixtures lighter than the lighter color parent of the mixture.

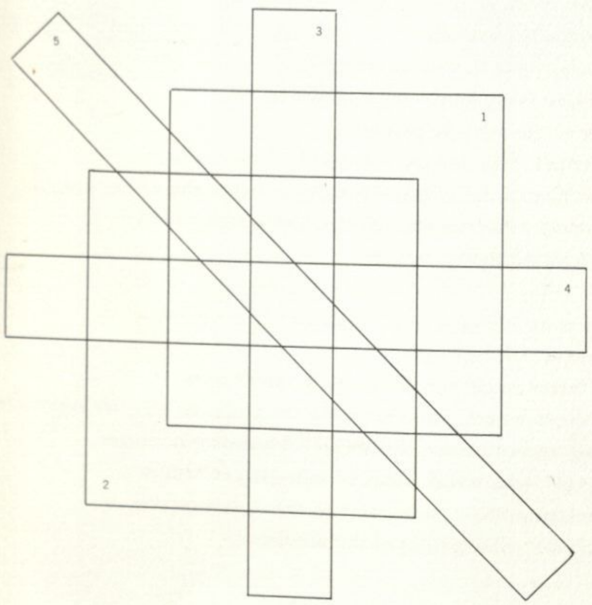
As optical mixture usually means less loss of light than mechanical mixture, the psychologist's sum of all his colors normally approaches a middle grey instead of the dark grey of the painter.

The conclusion is: mixtures gain light only in direct color, as in (a), whereas mixtures of reflected colors lose light, as in (b).

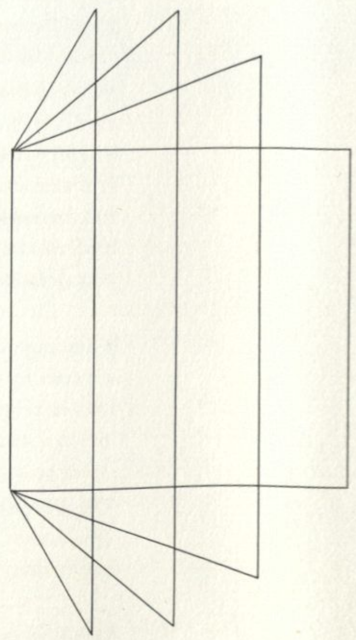
Though direct color or color light normally is not the medium of the colorist, examples of this effect should be indicated. Additive and subtractive mixtures should be made in appropriate studies in transparence illusions. These will provide a preparatory training for studies to follow.

For the sake of simplicity and to avoid difficult complications, these mixtures should be done in 1 thin color mixing preferably with white (or black), and then reversing the first study.

Sample arrangements:



AND REVERSED



AND REVERSED

XI Transparence and space-illusion

Color boundaries and plastic action

A study of color mixture in paper leads to 3 important discoveries.

First, under normal conditions, a subtractive mixture is not as light as the lighter of the color parents nor as dark as the darker one. Furthermore, the mixture is reciprocally neither higher nor lower in color intensity than the color parents.

Second, a mixture depends upon the proportion in which colors are mixed. Varying amounts of blue and yellow, for instance, define the character of a green. This indicates a possible predominance of 1 color parent.

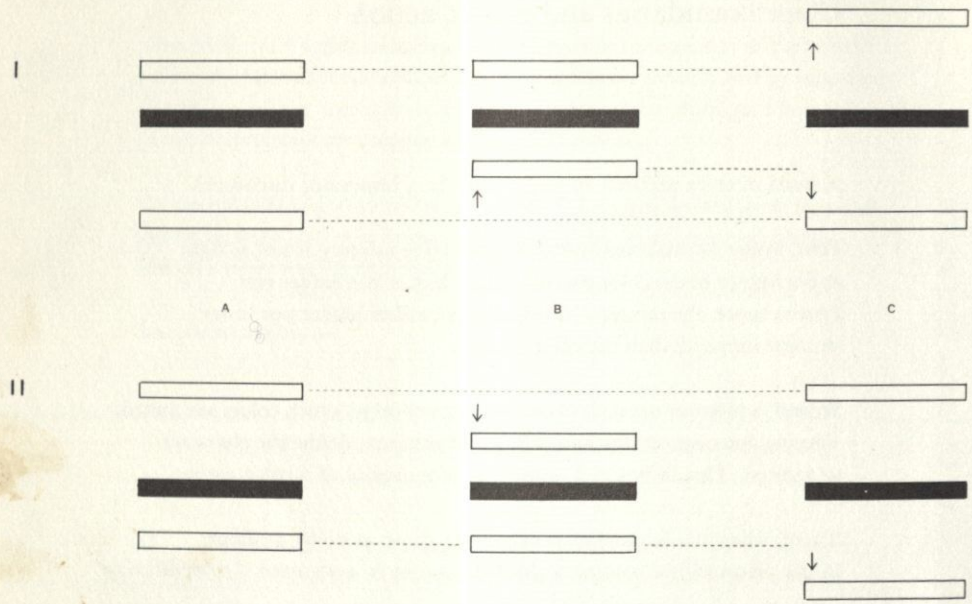
Third, when 1 color is read as appearing above or below another in the transparence studies, a third deception is recognized -- space-illusion.

This leads to the next task:
To produce different illusionary mixtures which derive from 1 pair of parent colors. If the parents are again a blue and a yellow, some greens will be found with yellow dominance and others with blue dominance. With more mixing experience it will become apparent that the nearness of a mixture to one side (let us say yellow) necessitates distance from the opposite side (in this case blue).

After having found several mixtures of different pairs of parent colors, we then try to find the most significant and the most difficult mixture -- the middle mixture. Topographically, this middle mixture demands precise placement, and therefore additional means of measure are necessary.

Since the middle mixture presupposes equidistance from the color parents, it therefore depends equally upon the absence of any predominance of the color parents.

Here, the following diagrams may be helpful:



Of the 3 bars in each diagram, the black bar
(which appears either above, or below, or in the middle) represents
an in-between color, the mixture in question; that is, the one
to be "equidistant" from the accompanying white bars.
The latter represent possible color parents for a color mixture.
The upper bar represents a lighter (higher) color,
and the lower bar represents a deeper (heavier) color.

In IA the mixture line is nearer to the upper line, and is therefore too light;
in IIA the opposite happens. The middle color-to-be is nearer to the
lower bar and consequently is too dark. For the necessary corrections
in IA, we must look for a lower (darker) middle, and in IIA for a higher
(lighter) middle.

Unfortunately, those higher and lower tones are often not available.
In such cases, we should try to adjust the outer (upper or lower) colors

-- instead of the middle color -- in order to exercise another way of correct placement.

Thus, in IB the lower bar is lifted from the dotted line, e.g. a lighter color is chosen; in IIB the upper bar is lowered. In C similar changes take place but in an opposite direction from B. Comparing groups B and C will demonstrate that correct arrangements may become closer to or more distant from the middle color.

Such efforts forth and back in our search for a middle color -- to be specific, for a middle placement -- provide through continued comparison a thorough visual training: "thinking in situations."

Besides an explanation of the above diagrams on the blackboard, a physical demonstration in space may clarify this further. When discussing the first trial studies, exhibited on the floor with the students standing around them, 2 hands held horizontally 1 above the other may act as the 2 outer colors. And a third hand held between them may demonstrate various possibilities of color selection and placement, either by moving the hand indicating the middle color up or down, or by moving the outer hands up and/or down, singly or together.

With a more developed sensitivity for mixtures, it will be discovered that distance, nearness, and equidistance between colors can be recognized through the boundaries between the mixture and the mixture parents.

By exercising comparison and distinction of color boundaries, a new and important measure is gained for the reading of the plastic action of color, that is, for the spatial organization of color. Since softer boundaries disclose nearness implying connection, harder boundaries indicate distance, separation.

In both interpretations colors are placed above or below each other, or in front of or behind each other. They are read as here and there, as over, and beyond there, and therefore in space.

All this seems to change with colors producing middle mixtures. Sometimes

they appear as if meeting within a 2-dimensional plane; at other times
they can be read -- interchangeably -- as higher or lower than the mixture.

Thus, with a middle mixture all boundaries are equally soft or hard.
As a consequence, a middle mixture appears frontal, as a color by itself.
This is comparable to the reading of any symmetrical order
and the middle mixture will behave unspatially,
unless its own shape, or surrounding shapes, decides differently.
(See Plate XI -- 3.)

Such a study, or a similar recognition, in my opinion, led Cézanne
to his unique and new articulation in painting. He was the first
to develop color areas which produce both distinct and indistinct endings
-- areas connected and unconnected -- areas with and without boundaries --
as means of plastic organization.

And, in order to prevent evenly painted areas from looking flat and frontal,
he used emphasized borders sparingly, mainly where he needed
a spatial separation from adjacent color areas.

XII Optical mixture -- after-image revised

XIII The Bezold Effect

In contrast to after-image, so far the main concern of our studies, here is another very different color illusion called "optical mixture." Instead of 2 (or more) colors changing each other, "pulling" or "pushing" each other into different appearances (toward both greater difference and greater similarity), here 2 colors (or more), perceived simultaneously, are seen combined and thus merged into 1 new color. In this process, the 2 original colors are first annulled and made invisible, and then replaced by a substitute called optical mixture.

From the Impressionist painters we have learned that they never presented, let us say, green by itself. Instead of using green paint mixed mechanically from yellow and blue, they applied yellow and blue unmixed in small dots, so that they became mixed only in our perception -- as an impression. That the dots mentioned were small indicates that this effect depends on size and on distance.

The discovery of the mixing of colors in our perception led in the last century not only to the new painting technique of the Impressionists, and particularly of the Pointillists, but also to the invention of new photomechanical reproduction techniques, the 3- and 4-color process for paintings, and the halftone process for black-and-white pictures. In the first case, 3 or 4 color plates subdivided into tiny printing dots mix to innumerable color shades and tints. In the second case, a plate for black also subdivided by a screen in tiny dots mixes with the white paper in just as innumerable tones of white -- grey -- black.

There is a special kind of optical mixture, the Bezold Effect, named after its discoverer, Wilhelm von Bezold (1837–1907). He recognized this effect when searching for a method through which he could change the color combinations of his rug designs entirely by adding or changing 1 color only. Apparently, there is so far no clear recognition of the optical-perceptual conditions involved.

XIV Color intervals and transformation

The tune of "Good morning to you" consists of 4 tones. It can be sung in a high soprano, a low basso, and in all in-between voices, as well as on many levels and in many keys. It can be played on innumerable instruments.

In all possible ways of performance, this melody will keep its character and it will be recognized instantly.

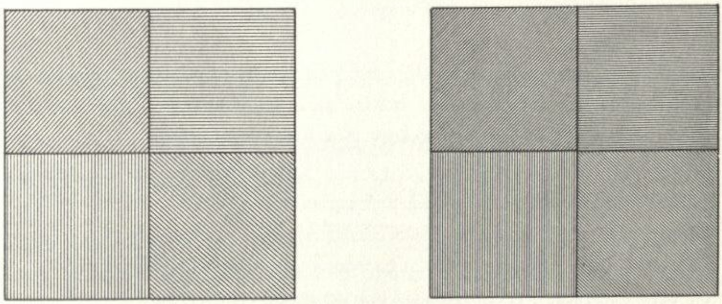
Why? The intervals of the 4 tones, that is, their acoustical constellation (again comparable with a topographic relationship), remains the same.

Although it is not common practice, one can also speak of intervals between colors.
Colors and hues are defined, as are tones in music, by wave length.

Any color (shade or tint) always has 2 decisive characteristics:
color intensity (brightness) and light intensity (lightness).
Therefore, color intervals also have this double-sidedness, this duality.

As has been stated before, after some training one might easily agree on light relationship, that is, which of 2 colors is lighter and which is darker. However, there is rarely agreement on color intensity, that is, which among a number of reds is the reddest red.
For this reason the interval transformation exercise is concerned mainly with light intensity.

To prepare a basic exercise in color transformation, combine 4 equal squares of different colors to make 1 larger square.
Within this grouping of 4 squares, the lighter will differentiate from the heavier, darker color. Therefore, the squares will connect with each other or separate according to contrast and affinity, as vertical, horizontal, or diagonal pairs, or as a trio forming an angle, embracing or opposing a fourth square. (See diagrams.)



The task is to transfer these specific relationships to a higher or lower key within 2 or more groups of equally large rectangles. Of course, if the first group contains the darkest color available, one cannot go lower. Similarly, the lightest white would not permit any transference to a higher key.

It is rarely possible to retain the first 4 rectangles selected. Frequently it will be impossible to find 4 colors equally raised or lowered when compared with the original set. If so, the original set should be changed in order to transfer more successfully.

In a successful study, both groups should show equal relationships in equal placement, as a constellation. Then, as with the study of varying mixtures, the boundaries between the 4 rectangles will also appear similar in both groups.

Again, the aim of this exercise is not to present a pleasant, perhaps harmonious look, but to present a study aiming at one distinct relationship -- parallel intervals.

How do we prove such similarity, such parallelism?
As has been learned from gradation studies done at the beginning, it is poor "psychological engineering" to present the gradation steps unconnected, that is, separated by black lines. Similarly, in the transformation exercise it is hard to compare the boundaries within the original group of 4 rectangles with the raised or lowered boundaries in the second, separated group.

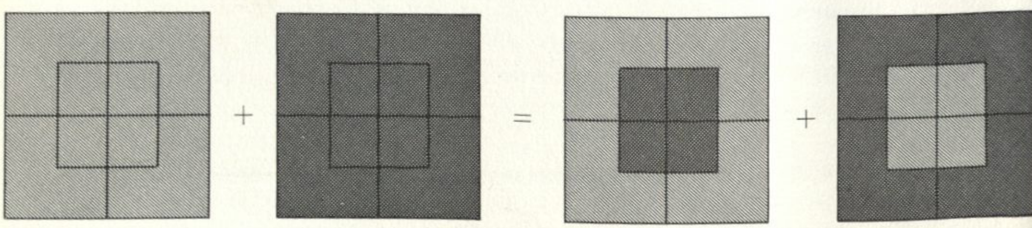
The only way in which the 2 groups can be compared easily and accurately is to superimpose 1 group on the other.

For this purpose we cut from the center of the first group a small rectangle and exchange it with an equally shaped and placed small rectangle of the second group. (See diagrams below.)

Immediately, the superimposed rectangles will show whether the stepping up or down within 1 group corresponds with the stepping in the other. A further comparison should be made between each small rectangle and the larger group beneath it. The sample studies will also show that the boundaries provide an important means of comparison.

Usually, as shown, a lower color tetrachord is transferred to a higher key, or opposite; one may also break with habit and try to make a low color constellation still lower, or a high one still higher.

By keeping the stepping -- up or down -- small, a special effect of transparence is achieved called film color, to be described in Chapter XVII.



XV The middle mixture again -- intersecting colors

Our studies of illusionary transparence have shown how difficult it is
to find middle mixture.

A true middle mixture is distinguished by being equidistant
-- in light and in hue --
from either mixture parent.

Unfortunately, for an untrained eye, it is hard to recognize
such equidistance.
We have seen that the color boundaries between the mixing color
and the mixed one have proved to be helpful measures.

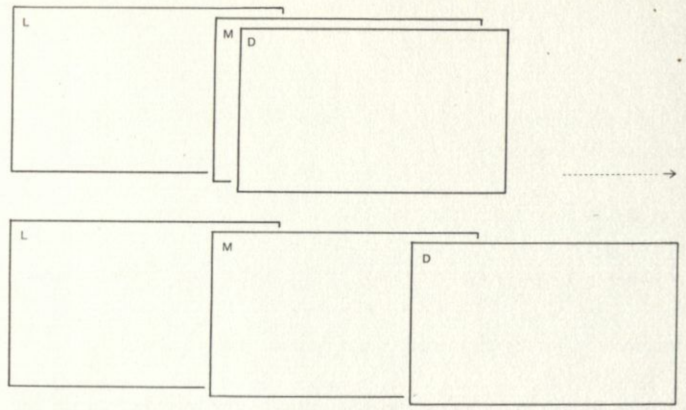
The purpose of the new problem, intersecting colors,
is to show and to produce a certain constellation
by which even an untrained eye will recognize
within a mixture not only the constituents
but also their respective amounts within that mixture.

For an initial experience in this direction
find 3 equally large sheets of 1 red in 3 shades,
a light red, the same red darker, and the almost always elusive
middle mixture of these reds. Or, if not available in red,
take any other color providing a lighter, a middle, and
a darker shade or tint. (See diagrams, next page.)

Place them adjacent to one another,
with the lighter red to the left and overlapped by the edge of the middle red;
then place the dark red on top of the middle red, allowing only a narrow strip
of the middle red (about ¼ inch wide) to remain visible.

Then, very slowly, pull the dark sheet to the right,
gradually making the narrow strip of the middle red wider.

By staring at the middle red, observe that the wider it grows, the more it appears
not as 1 but as 2 colors, becoming lighter and lighter
at the right edge, and, at the same time, darker and darker
at the left edge.



By doing this repeatedly, it becomes obvious that the middle color plays the role of both mixture parents, presenting them in reversed placement.

Repeating this experience with other colors will show that in a true middle mixture the mixture parents will appear in equal amounts.

In most cases, however, the larger amount of 1 of the 2 colors reveals its predominance.

Such exercises are exciting as well as revealing, particularly when extended to different and opposing colors.

These exercises remind us that the basic after-image presentation, the simultaneous contrast, is the cause of all color deception.

Whereas the first measuring of middle mixtures led us to space illusion through connecting and separating boundaries, this direct reading of the mixture constituents leads us to a new deception: an illusion of volume.

It is an effect we have seen in the channelings of the Doric column and is called a fluting effect. (See Plate XV -- 2.)

XVI Color juxtaposition -- harmony -- quantity

Harmony

Color systems usually lead to the conclusion
that certain constellations within a system provide color harmony.
They indicate that this is mainly the aim and the end
of color combination, of color juxtaposition.

As harmony and harmonizing is also a concern of music, so
a parallelism of effect between tone combinations and color combinations
seems unavoidable and appropriate. Although
a comparison of composed colors with composed tones is very challenging,
it should be mentioned that, while it can be helpful,
it is often misleading.

This is because different basic conditions of these media result in
different behavior.

Tones appear placed and directed predominantly in time from before
to now to later.

Their juxtaposition in a musical composition is perceived
within a prescribed sequence only. Vertically, so to say,
1 tone, or several simultaneously,
sound for a varying but restricted length of time.
Horizontally, the tones follow each other,
perhaps not in a straight line, but of necessity in a prescribed order
and only in 1 direction -- forward.
Tones heard earlier fade, and those farther back disappear, vanish.
We do not hear them backward.

Colors appear connected predominantly in space. Therefore,
as constellations they can be seen in any direction and
at any speed. And as they remain, we can return to them repeatedly
and in many ways.

This remaining and not remaining, or vanishing and not vanishing, shows only 1 essential difference between the fields of tone and color.

The accuracy of perception in one field is matched by the durability of retention in the other, demonstrating a curious reversal in visual and auditory memory.

Tone juxtapositions can be defined by their acoustical relationship and thus measured precisely by wave length.

Consequently, a graphic registration of tones in musical composition has been developed.

Color, also, can be measured, at least to some extent, and particularly so when it is presented as direct color -- as the physicist registers it, by optical wave length.

Reflected color, however, coming from paint and pigment -- our main medium -- is much more difficult to define.

When analyzed with an electrical spectrograph reflected color shows that it contains all visible wave lengths. Therefore, any reflected color -- not just white -- consists of all other colors.

This many-sided relationship between colors is clearly visible in the plates of a 4-color reproduction, when singly shown, because each of the 4 plates, although presenting only 1 color, shows a complete picture.

Color, when practically applied, not only appears in uncountable shades and tints, but is additionally characterized by shape and size, by recurrence and placement, and so on, of which particularly shape and size are not directly applicable to tones.

All this may signify why any color composition naturally defies such diagrammatic registration as notation in music and choreography in dance.

With regard to constellation, tone intervals, such as third, fifth, and octave, differentiate exact vertical distance. We say "vertical" probably because tones are described as low and high.
Slide deflections (aberrations), such as in flat and sharp, remain equally precise.
Color terms which could be considered parallel to tone intervals are complementaries, split complementaries, triads, tetrads, and octads. Though these characterize distance and constellation within color systems, their deflections, such as incomplete triads and incomplete tetrads, indicate that their measure is only arbitrary.

Significantly, complementaries, though they are the basic color contrast or interval, are topographically quite vague.

In principle, a complementary is a color accompanied by its after-image.

However, the complement of a specific color, when placed in different systems, will look different.

Similarly, a triad or tetrad of one system will hardly fit into another system.

Usually, illustrations of harmonic color constellations which derive from authoritative systems look pleasant, beautiful, and thus convincing. But it should not be overlooked that they are usually presented in a most theoretical and least practicable manner, because normally all harmony members appear in the same quantity and the same shape, as well as in the same number (just once) and sometimes even in similar light intensity.
Such outer equalization may unify them, but at the expense of the more important inner relatedness -- namely, as color only.

When applied in practice, these harmony sets appear changed. In addition to quantity, form, and recurrence, wider aspects exert still more changing influences.
These are:

> Changed and changing light -- and, even worse,
> several simultaneous lights;
> reflection of lights and of colors;
> direction and sequence of reading;

presentation in varying materials;
constant or altering juxtaposition of related
and unrelated objects.

With these and other visual displacements, it should not be a surprise that the sympathetic effect of the original "ideal" color combination often appears changed, lost, and reversed.

Observe the interior and exterior, the furniture and textile decoration following such color schemes, as well as commercialized color "suggestions" for innumerable do-it-yourselves.

Our conclusion: we may forget for a while those rules of thumb of complementaries, whether complete or "split," and of triads and tetrads as well.
They are worn out.

Second, no mechanical color system is flexible enough to precalculate the manifold changing factors, as named before, in a single prescribed recipe.

Good painting, good coloring, is comparable to good cooking.
Even a good cooking recipe demands tasting and repeated tasting while it is being followed.
And the best tasting still depends on a cook with taste.

By giving up preference for harmony,
we accept dissonance to be as desirable as consonance.

In searching for new color organization -- color design --
we have come to think that quantity, intensity, or weight, as principles of study,
can lead similarly to illusions, to new relationships, to different measurements,
to other systems, as do transparence, space, and intersection.

Besides a balance through color harmony, which is comparable
to symmetry, there is equilibrium possible between
color tensions, related to a more dynamic asymmetry.

Again: knowledge and its application is not our aim;
instead, it is flexible imagination, discovery, invention -- taste.

quality - phaedrus

With this study of color effects, that is, of color deception, a special interest in quantity -- amount as well as recurrence -- has developed.

Quantity

Although quantity and quality often are considered disparate, in art and music they appear closely related. We may even hear, "Quantity is a quality," because here quantity not only designates amounts, as of weight or number, but also is a means of underlining, of pronouncement, and a means of equilibrium, of balance.

One who particularly recognized the latter was Schopenhauer. When he tried to improve Goethe's 6-part color circle -- to Goethe's dismay -- he changed the previous presentation of 6 equal areas to decidedly different quantities.

Thus yellow, the lightest color, appears in the smaller amount, and its opposite, violet, as the darkest, in the largest amount. He first allotted 3 equal thirds of a color ring to the 3 pairs of opposites -- yellow & violet -- blue & orange -- red & green. Second, he subdivided those thirds, for the same order of pairs, in $\frac{1}{4} + \frac{3}{4}$ -- $\frac{1}{3} + \frac{2}{3}$ -- $\frac{1}{2} + \frac{1}{2}$. These figures in fractions of 12ths (relatively 36ths) are proportionate to $3 : 9$ -- $4 : 8$ -- $6 : 6$ equal parts.
When seen in a color circle, from yellow around to green, they present the following quantities: $3 : 4 : 6 : 9 : 8 : 6$.

The 2 basic quantity questions, how much and how often, distinguish 2 kinds of quantity:
1 of size -- extension in area -- and
1 of recurrence -- extension in number.
Both measurements concern predominance and emphasis.
They establish weight in space -- and weight in time.

Such considerations are both the source and result of our quantity studies in which 4 colors usually appear in 4 different juxtapositions, so different that all 4 studies appear as unrelated as possible.

And thus they present changes in climate or temperature, in tempo or rhythm -- that is, changes of atmosphere or mood, so that the factual contents (the same 4 colors) are hidden or, better, hardly recognizable.

To use a theatrical parallel:
A set of 4 colors is to be considered -- singly as "actors," together as "cast." They are to be presented in 4 different arrangements -- as "performances."

Although they remain unchanged in hue and light, in "character," and appear in an unchanging outer frame, the "stage," they are to produce 4 different "scenes" or "plays," each to be so different that one and the same set of colors will be seen as 4 different sets, presented by 4 different casts.

And all this can be achieved mainly through changes in quantity which result in shifts of dominance, of recurrence, and consequently of placement.

The essential question: which group of colors is ready to lose its identity as a cast?

A parallel question: which distribution of appearance (quantities of space, time, and weight) protects, disguises recognition of the same color cast?

Such quantity studies have taught us to believe that, independent of harmony rules, any color "goes" or "works" with any other color, presupposing that their quantities are appropriate.
We feel fortunate that so far there are no comprehensive rules for such aims.

Here we may point to a discovery made by a few contemporary painters, that the increase in amount of a color -- not merely in size of canvas -- visually reduces distance. As a consequence, it often produces nearness -- meaning intimacy -- and respect.

XVII Film color and volume color -- 2 natural effects

Usually, we think of an apple as being red.
This is not the same red as that of a cherry or tomato.
A lemon is yellow and an orange is like its name.
Bricks vary from beige to yellow to orange,
and from ochre to brown to deep violet.
Foliage appears in innumerable shades of green.
In all these cases the colors named are surface colors.

In a very different way, distant mountains appear uniformly blue,
no matter whether covered
with green trees or consisting of earth and rocks.
The sun is glaring white in daytime, but is full red at sunset.
The white ceilings of houses surrounded by lawns or the white-painted
eaves of a roof on a sunny day appear in bright green, which is
reflected from the grass on the ground.
All these cases present film colors.

They appear as a thin, transparent, translucent layer between the eye
and an object, independent of the object's surface color.

For a very different color effect compare the coffee in a cup with the
coffee in the stem of a percolator or with the coffee in a silex glass.
It is easy to discover that, though all 3 containers hold the same
coffee, the containers show this coffee in 3 different browns:
lightest in the stem, darker in the cup, darkest in the silex glass.

In the same way, tea will look lighter in a spoon than in a cup.
Here we are dealing with volume color,
which exists and is perceived in 3-dimensional fluids.

The water of a swimming pool with blue walls will look dyed with blue
because of diffused reflection. Observing the white or blue steps
within the water, we will discover that with each step down
the blue of the water increases progressively, which presents a true
volume color effect.
In Chapter XX it will be explained in what proportion the blue increases.

XXII Vibrating boundaries -- enforced contours

As a deception, this effect is related to our earlier experience
in which 2 colors appeared as 3 or 4 colors.

However, the additional illusionary colors
often are hard to define as to their hue.

They often appear as shadow on one side of the boundary
and as light reflected on the other side.

Or sometimes this vibration presents just a duplication
or triplication of the boundary line.

The conditions for these varying effects occur between colors
which are contrasting in their hues but also close or similar
in light intensity.

Though this effect refers to the after-image,
its physio-psychological function apparently
seems not to have been clarified.

Often, under the same conditions, it is perceived by some people
and not by others.

It is visible and not visible with or without glasses;
or, similarly, with interchanging of near and far focus.

This initially exciting effect also feels aggressive
and often even uncomfortable to our eyes.
One finds it rarely used except for a screaming effect
in advertising, and as a result it is unpleasant, disliked, and avoided.

XXIII Equal light intensity -- vanishing boundaries

Though rarely perceived, it is a fact that articulate boundaries between colors can be made nearly unrecognizable, or made practically invisible -- through the choice of color alone.

This very surprising and most exciting of all color phenomena depends, like all other effects, on specific conditions.

The effect is the opposite of the aforementioned vibrating boundaries, and it is not possible between very contrasting hues.
It is confined to adjacent, neighboring colors and depends most decisively on equal "light intensity." Only real equality in lightness or an equivalent real equality in darkness produces the effect here aimed at and searched for.

Now, since the term "equal value" has unfortunately been misused too often for colors lacking just this quality, incompetent judgment has distorted this term to a falsified measure. In this way, "equal values" are more spoken about than realized -- than actually seen.

Thus, we can safely state that very few people -- including many colorists and painters -- have ever seen 2 adjacent colors of true equal light value -- that is, of exact equality in light, of the same level of light, or, in a sense, the same altitude of light.

This will indicate that equal light intensity presents, besides a most challenging exercise, a most difficult task demanding most of all -- patience.

Because several of our color classes were not able to present even 1 convincing color couple of equal light intensity, this makes it an exercise for teachers willing to demonstrate that in all teaching the personal example is the strongest incentive.

Earlier, right after the test "Which is the lighter and/or darker?"
we had the opportunity to prepare for this difficult exercise,
which usually is the last exercise of our course.

When we were collecting pairs of colors hard to distinguish as lighter or darker
we were often tempted to
consider some of them to be of "equal value."

At that time we learned that in cases difficult to decide upon,
which we named "near-equal light intensities," or "almost-equals,"
the after-image test can be a helpful measure. (See diagram, page 13.)

Though sometimes it may appear hopeless to find equal light intensities in paint
and painting, in color papers, or in our surroundings, we have found that
nature occasionally provides an opportunity to see them on cumulus clouds
against blue sky.

When these clouds, often lined up in horizontal groups,
appear gleaming white in their upper part in full sunlight,
separated from and rising against a distant deep blue,
then underneath they show grey tones as shaded white.
These shades merge, or even hinge, with the same
but here very close blue. Why very close? This grey is
of the same light intensity as the neighboring blue below.
Thus, the boundaries between grey and blue vanish,
and we do not see where clouds end and where sky begins.
With such clouds, this is best observed with the sun at our backs.
(See Plate XXIII -- 2.)

In order to produce this provocative color effect -- but also the most
delicate one -- all disturbing effects of paper (such as different surfaces)
and of montage (visible edges or paste marks) must be carefully avoided.

Therefore, the 2 papers of equal light intensity must be mounted as inlay (known also as "intarsia").

In this process the papers are placed within each other, instead of on top of each other. Thus the thickness of the paper does not show, and, more important, its very disturbing shadows are eliminated -- provided the papers are of equal thickness.

For precision fitting, so that the joints will not show, the papers to be inlaid are formed simultaneously in a single cutting.

The finer the knife (best, the thinnest razor blade), the thinner the paper, and the harder the ground to cut on (preferably glass), the better the fitting will be and the less the joints will show. It is also essential that no glue seep in to mark the joints.

As the selection of the papers here demands patience, so their presentation demands skill and cleanliness.