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Color.

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"COLOR"

A Dissertation

Submitted to the Faculty

Of the Graduate School of the College of Liberal Arts

In Partial Fulfillment of the

Requirements for the Degree

Of Master of Science

Department of Physics

By

BRUCE B. VANCE

1928

FOREWORD:

Leonardo in his treatis on painting
says: "Those who become enamored of the
practice of the arts without having pre-
viously applied themselves to the diligent
study of the scientific part of it, may
be compared to the mariner who put to
sea in a ship without rudder or compass,
and therefore, can not be certain of
arriving at the wished for port. Practice
must always be founded on good theory."

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INTRODUCTION:

Color, any attempt to apply the
scientific principles of color vision
in the making of a picture must surely
fail if it be not granted at the out set
that it is only to a limited degree that
those principles can apply. Color
appreciation is as much a psychical
as a physiological, and indeed, it is
psychical not only with regard to the
objective impression itself, but also
with regard to the subjective, the
associational mental process. Previous
knowledge and training, experience
traditions, the association of color
impressions with impressions previously
received through other senses and stored
away as memories, all play a part in

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determining the effect which a color
or a pattern of opposed colors has upon
us. But even granting all this, there are
many of the physical and physological
laws of color vision which must be
adhered to before we can expecttto produce
these effects.

The first of these is a physical
one:- It is the dissociation of white
light into the spectral colors by means
of diffraction. When we look at such a
spectrum we are at once struck with the
fact that the colors differ from one
another not only in their hue, but in
their brightness or lumniosity, the
yellow and the immediately adjacent
portions being much brighter than the
others. At once, then, we recognize
two physiological properties for each

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spectral holor, hue and brightness.
There is, however, another property of
color as seen in nature which is absent
in the spectrum, namely, saturation.
This refers to the degree of white light
with which the color is mixed. It is
more or less related to the artist's
term "value" which expresses the
transition of the color into gray, this
may also mean the combination of two or
more colors and their relation to each
other.

Before we go into this latter phase
it may be well to state some of the
foundamental psychical, physiological and
physical theories on color vision and
color mixing. The Young-Helmholtz theory
of the three color sensations, one of
the most important, depends upon the

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action of three independent physiological
processes involving three substances or
sets of nerves. This theory approaches the
matter chiefly from the side of physics;
that, the facts of color mixture are used
in building up the theory. One of these
principles of color mixture is called
the subtractive method and the other the
additive method.

The Subtractive Method: In a sense
color, as we ordinarily encounter it, is
produced primarily by subtraction. That
is, a fabric appears colored as a rule
because the chemicals used in staining
it has the property of absorbing certain
visible rays and of reflecting or trans-
mitting the remaining rays. this sub-
traction of colored rays from white light
results in the residual colored light.

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The integral of the light absorbed is
said to be the complementary to the color
of the light remaining if the total light
in the beginning were white light.

The Additive Method: In the sub-
tractivemethod of mixing color it is easily
seen that if we pass white light through
a filter which permitted only certain
colors to pass then if the light was then
passed through another filter and so on;
in the end the result would be no light
or black. With the additive method the
arrangment is different and always tends
toward the production of white light, or
we may say that it is the reverse of the
subtractive method of mixing color.

Ladd-Franklin: The theory that goes
by this name is one that explains the

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physiological opperations by introducing
two substances called rods and cones.

The Hering Theory: The principle
foundation of this theory consists of
facts such as those of contrast, and the
apparent simplicity of black, white and
yellow as well as red, green and blue.
Hering assumed there were six fundamental
sensations coupled in pairs, namely,
white and black, red and green, yellow
and blue. In order to account for these six
six fundamental sensations he assumed the
presence somewhere in the retinocerebral
apparatus of three distinct substances.
Each substance is capable of building up
(anabolism) or of breaking down (katabolism)
under the influence of radiant energy or
its effects.

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Most of these theories give some
general combinations of colors into
complementary pairs. They are general;
so I have chosen as a problem the grouping
into pairs narrow bands of the spectrum
which when combined by the additive
method of mixing color would give white
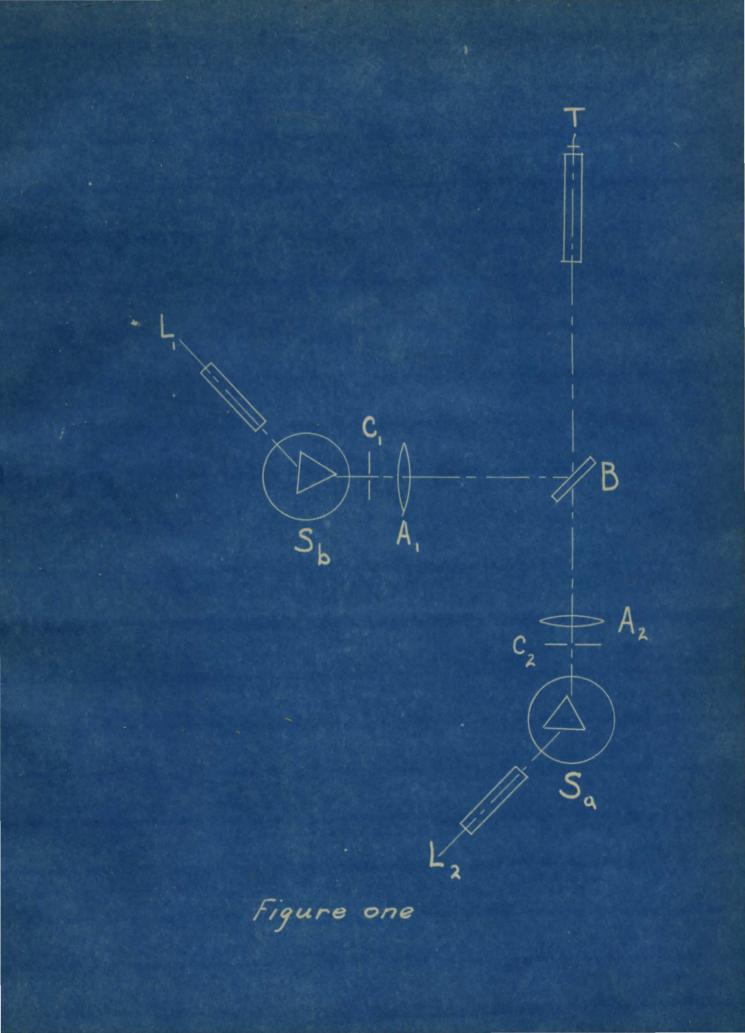or as near white light as possible.

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APPARATUS:

The apparatus as finally used is
shown in figure one.

S_a and S_b are two spectrometers. S_a
being adjustable by the observer at T.
C_1 and C_2 are slits, A_1 and A_2 lenses. L_1
and L_2 are 150 watt Mazda lamps. T is an
observer telescope. B is a plane surface
piece of glass.

The light from L_1 and L_2 passing
through the spectrometer S_a and S_b is
refracted into band spectrum on the backs
of the slits. C_1 and C_2 are so adjusted
that the narrow band of light that passes
through is as near monochromatic as
possible. The lenses A_1 and A_2 are used
to eliminate the defraction effect that is
caused by the narrow slits. The band from

Figure one

C_2 passes through B and is observed at T,
the band from C_1 is reflected from B and
the system of S_b is so adjusted that the
two bands will coincide in the telescope
T. In this manner the two bands of color are
are mixed.

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PROCEDURE:

First both spectrometers were cali-
brated with a Cooper Hewitt Lab-Arc, (the
calibration curves are shown in figures
two and three).

After this calibration, which was
made at the beginning and the end of each
set of readings, S_b was set at a parti-
cular color. Then S_a was adjusted so the
band that appeared in the telescope was as
near white as possible. This adjustment was
arrived at by approaching the limit from
both sides and then taking the average
of a large number of readings. For example;
suppose S_b is set so we have a blue band
of color, then suppose with S_a we approach
a mixture from the red and determine a white,
then we pass through and approach the

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Dispersion Curve of S_a

Figure two

Dispersion Curve of
S_b

Figure three

mixture from the blue side and obtain a white. By repeating this opperation and taking the average we are able to obtain to a fair degree the mixture of two bands of color that would produce white light.

S_b was set first at random starting on the red side of the spectrum and going to the blue. Later I started with a band of red as near that end of the visible spectrum as possible, then bands at intervals of 0.05μ were observed. The results are tabulated in the tables.

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TABLE:

S_a	S_b	S_a	S_b
0.584μ	0.415μ	0.640μ	0.556μ
0.563μ	0.416μ	0.675μ	0.550μ
0.568μ	0.416μ	0.442μ	0.550μ
0.576μ	0.433μ	0.583μ	0.560μ
0.572μ	0.436μ	0.487μ	0.581μ
0.577μ	0.443μ	0.582μ	0.585μ
0.574μ	0.450μ	0.530μ	0.600μ
0.572μ	0.450μ	0.502μ	0.600μ
0.579μ	0.459μ	0.576μ	0.607μ
0.656μ	0.482μ	0.534μ	0.622μ
0.578μ	0.485μ	0.541μ	0.650μ
0.571μ	0.489μ	0.515μ	0.650μ
0.630μ	0.500μ	0.549μ	0.656μ
0.657μ	0.500μ		

μ stands for μ

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CONCLUSION:

On the preceeding page I have given a list of figures; the interpretation of these figures is another question.

In the Introduction I mentioned several theories on color vision and color mixture. The apparatus, that I have used, has mixed two bands of as near monbchromatic light as could be obtained by the additive method of mixing color. By this I mean that the effect upon the retinocerebral apparatus is that of adding colors together. If a pair of colors are added and the result is white or near white then they are said to be complementary colors.

Then the several pairs that I have listed can be said to be complementary one to another.

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It has been a long disputed question between scientist and painter, wheter blue and yellow were complementary colors.

If we take the region between 0.433μ and 0.450μ as blue,,the table of results shows us that its complement will lie between 0.572μ and 0.577μ which happens to be about in the center of the yellow portion of the spectrum.

Now if we take the region between 0.482μ and 0.500μ which could be called greenish-blue, more blue than green, and its complement lies between 0.578μ and 0.657μ,(with the exception of 0.571μ which in all probility was an error), this region is yellow-orange.

The red - green combination worked out as usual, but not as well as it does with

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by the flicker method of mixing color.
If we call the region from 0.600μ up, red,
we find that its complement lies between
0.502μ and 0.549μ, (with the exception of
0.607μ - 0.576μ which again we can take
as an error). 0.5461μ is our beautifull
green Mercury line.

One other very interesting observance
is that for the most part the reversal of
the colors from S_a to S_b check in the results.

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ADDENDUM:

Now at the end may I express my deep
appreciation for the kind, sympathetic and
inspiritional assistance of Dr. Leo G. Raub,
and Dr. Donald M. Bennett.