The Effect of Achromatic Conditions On the Color Phenomena of Peripheral Vision

Fernald Grace Maxwell
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THE EFFECT OF ACHROMATIC CONDITIONS ON THE COLOR PHENOMENA OF PERIPHERAL VISION.

BY GRACE MAXWELL FERNALD.

I. INTRODUCTION AND HISTORICAL SKETCH.

INTRODUCTORY STATEMENT.

The present investigation has as its purpose the determination of the effect of achromatic conditions on the color phenomena of peripheral vision.

Von Kries\(^1\) has already shown that the Purkinje phenomenon, in so far as it consists of changes in the relative brightness of the different colors, occurs at the periphery. It has been shown by Miss Thompson and Miss Gordon,\(^2\) as well as by the writer,\(^3\) that the brightness of a colorless background has a decided effect on the tone of peripheral color stimuli and on the appearance and relative frequency of the after-images which follow these stimuli.

In the present investigation a part of the previous work has been repeated and verified; observations have been made under more varied brightness conditions than those employed in our previous work in order to determine (1) what effect these achromatic conditions have on the color phenomena, and (2) just what factors are responsible for the changes observed;


finally, an attempt has been made to correlate the phenomena observed with the facts previously established concerning peripheral and central vision, under conditions of light and dark adaptation respectively.

I wish to express my gratitude to Professors James R. Angell and John B. Watson, of the University of Chicago, for suggestions and assistance throughout the entire investigation. I am also greatly indebted to the observers, instructors and students at the University of Chicago and at Bryn Mawr College, for the time they so generously gave to the work.

HISTORICAL STATEMENT.

A. Methods of Investigation.

Any historical account of the work on peripheral color vision presents a series of seemingly irreconcilable statements. A study of the methods employed in the various investigations serves, however, to explain why such a state of affairs should exist.

As Baird\(^4\) has given an exceedingly accurate and complete history of the experimental work up to the spring of 1905, it will only be necessary here to state the actual differences in methods which may affect the outcome of the investigations, and to give a somewhat detailed description of some of the more recent papers which have direct bearing upon the special problem to be discussed in this monograph. A brief section is also given on the effect of brightness adaptation.

1. Apparatus.

The perimeter has been employed in all the more important investigations of the dark-adapted peripheral retina, as well as in some of the earlier investigations of light-adapted vision. With this apparatus the eye fixation remains constant, while a small sector of the stimulus color is moved in or out along the quadrant of the perimeter arc. The advantage of this method is that the eye takes a fixation straight ahead and does not have to turn to the side when the peripheral retina is stimulated.

INTRODUCTION AND HISTORICAL SKETCH.

In daylight illumination, however, there is a change in the brightness of the color at different points on the arc, unless all the illumination comes from a skylight.

The campimeter has been used in many of the investigations in daylight illumination. The advantage of this apparatus is that it makes possible a more extended background than could be employed with the perimeter and an easier control of the brightness of the stimulus in daylight.

Among the more recent investigators, Hess and Kirschmann used the campimeter in daylight illumination, while Hellpach and Baird used the perimeter in the dark room.

2. METHODS OF OBSERVATION AND STIMULATION.

(a) Moving and Stationary Retinal Image.

Either the eye or the stimulus was moved during stimulation in all the determinations of the color limits up to the time of Hellpach's work in 1900. In the investigations with the perimeter the eye remained stationary while the stimulus was moved in from the periphery to the center of the visual field, or vice versa; while in the work with the campimeter the eye followed a moving fixation point and the stimulus was stationary. An exception to this latter statement occurs in the case of Kirschmann's work on the campimeter. He maintained a stationary fixation and moved the stimulus, thus constantly changing the size of the retinal image. Hess also varied the method slightly by covering and uncovering the stimulus while the eye followed a moving pointer.

In any case the constant movement of the retinal image would be open to the following objections: (1) The observation would be difficult owing to the constant shift of the image; (2) the portion of the retina stimulated at a given moment would not be entirely unfatigued; (3) the constant movement of the image would make it very difficult to record exactly the points at which the various phenomena occur.

In the work with the campimeter, eye movement during stimulation introduces still further difficulties, as it is now well established that eye movement is necessarily irregular and also that vision is influenced by eye movement.
COLOR PHENOMENA OF PERIPHERAL VISION.

A further reason for employing a stationary fixation and a stationary stimulus is that this is the only method which is adapted for the observation of after-images, either in peripheral or central vision.

In the investigations of the peripheral retina, Hellpach and Baird used the method which was also adopted throughout our work, namely, that of stationary fixation and stimulus, with an interval of two or more minutes between stimulations.

(b) Interval Between Stimuli.

If the method of stationary fixation and of stationary stimulus is employed, the question at once arises as to the length of the interval which should intervene between stimulations. Hellpach allowed a three-minute interval. Baird claims that three minutes is not long enough to overcome fatigue effects and consequently he allowed a six-minute interval. Miss Thompson and Miss Gordon allowed a two-minute interval in the first half of their work and a five-minute interval in the remainder. They found no difference whatever in the results in the two cases. In all our work only a two-minute interval has been allowed. The reasons why a longer interval seemed unnecessary have been given in a previous paper.

They are briefly as follows:

1. Though gray, white and black stimuli were frequently used, they always appeared colorless.

2. The stimulus was never seen as the color complementary to the previous stimulus, but always gave a perfectly characteristic response.

3. The after-images when experienced were the characteristic after-images of the immediate stimulus and not of previous stimuli.

4. As shown by the work of Miss Thompson and Miss Gordon, the results were in no wise altered by increasing the length of the interval.

* Baird found that, when stimuli are given in too close succession, a stimulus sometimes appears as the color complementary to the previous stimulus. Cfr. pp. 57, 58.

(c) Retinal Area of Stimulus.

Several attempts have been made to determine the effect produced by a change in the size of the retinal image. There is a decided disagreement in the conclusions reached as a result of these investigations. The experiments of Woinow⁷ and Krükow⁸ show no change whatever in the limits of the retinal fields due to change in the size of the stimulus. Kirschmann⁹ found the limits for all the colors greatly widened on the upper and nasal half-meridians, but little changed on the lower and temporal, as the size of the retinal image was increased. All the other investigators who have worked on this problem agree that increase in the size of the retinal image results in a widening of the limits for all the colors.

It is quite possible that the lack of agreement may be due to the different amounts by which the stimuli were decreased as well as to the difference in the size of the original stimulus. It seems probable that, starting with a minimum visible stimulus and gradually increasing the size of the stimulus as much as is practicable, different phenomena would accompany various degrees of change. It is also true that in most cases, there is no way of determining the relative brightnesses and saturations of the stimuli used by different investigators, so that either or both of these factors may be at least partly responsible for the lack of uniformity in the results.

(d) Urfarben as Stimuli.

Bull¹⁰ (1881) found that there are only four colors which do not change in tone as they are moved from the center to the periphery of the visual field. These colors are a blue-green, a purple, a yellow and a blue. The colors were equated in saturation by using such proportions of the complementary Urfarben that 180° of one cancelled 180° of the other. This

¹ M. Woinow, 'Zur Farbenempfindung,' Fos Graefe's Archiv, XVI, 1, 1870, S. 218-224.
² Krükow, 'Objective Farbenempfindungen auf den peripherischen Theilen der Netzhaut,' Fos Graefe's Archiv, XX, 1, 1874, S. 255-296.
method serves simply to equate the red with its complementary green and the yellow with its complementary blue. Unfortunately there seems to be no way of equating the saturation of the blue and the yellow with that of the red and the green. Bull found the limits for green and red practically coincident. The fields for blue and yellow were practically equal in extent, the field for blue being somewhat wider than that for yellow, and were in every case considerably wider than the fields for green and red.

Hess\(^1\) (1889) determined the color limits for the Urfarben, after the complementary Urfarben had been equated with each other in saturation and all the colors had been matched in brightness to a neutral gray screen. He found the limits for the Uroth equal to those for the Urgrün and the limits for the Urblass equal to those for the Urgelb. The limits for the latter pair of colors were wider than those for the former pair.

Hegg\(^2\) repeated and confirmed the work of Bull and Hess. The greater part of all three investigations was made with pigment colors in daylight illumination.

The only determination of the limits of the stable colors with the dark adapted retina is that made by Baird and reported in the monograph already referred to.\(^3\) For stimuli he used light transmitted through gelatin filters. The complementary Urfarben were equated in saturation and all four Urfarben were equated with each other in brightness. The coincidence of the fields of the two pairs of stable colors, already established in the case of light-adapted vision, was found to exist also in dark-adapted vision. Unfortunately there seems to be no way of determining whether the tone of the color which was the Urfarbe in light-adapted vision was the same as that of the Urfarbe in dark-adapted vision, nor whether, as has already been suggested, the blue and the yellow equalled the red and the green in saturation.

\(^1\) Hess, C., 'Ueber den Farbensinn bei indirektem Sehen,' Fou Gearte's Archiv, XXXV, 4, 1889, S 142 (Ann. Soc. d'Ocul. CN, p 177)


\(^3\) Baird, Carnegie Monograph, 1904.
It seems to be established, however, beyond question that, under fixed conditions of illumination, there are four and only four colors which do not change as they are moved from the center of the field of vision to the periphery, and that when the Urroth and Urgrün and the Urbau and Urgelb, respectively, are equal in saturation and brightness, the fields for the Urroth and Urgrün and for the Urbau and Urgelb, respectively, are equal in extent.

(e) Brightness of Background.

In the work carried out in daylight illumination there has been as great a diversity in the backgrounds upon which the stimulus has been exposed as in the various other conditions. Very little work has been done for the express purpose of determining what influence the background exerts on the extent of the color fields and on the character of the color perceived.

Aubert used both black and white backgrounds and found that all the colors were perceived further out on the black background than on the white background.

Woinow and Krükow insist that change in the brightness of the background, like change in other conditions, has no effect on the distribution and size of the color fields.

Hess carried out some experiments with backgrounds of different degrees of brightness. He states that the widest fields were obtained when the color and background were of equal brightness but does not give in detail the data upon which his conclusion is based.

During the years 1903–1905 the writer\(^4\) attempted to determine the effect of the brightness of a colorless background on the appearance of color stimuli and on the extent of the color fields in peripheral vision. During the years 1905–1906 Miss Thompson and Miss Gordon made a special study of peripheral after-images.\(^5\) As the method and the apparatus were practically the same in the two cases, the results of the two investigations will be summarized together. They are in brief, as follows.

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\(^4\) *Psychol. Rev.,* Vol. XII, 1905; Vol. XV, 1908.

\(^5\) *Psychol. Rev.,* XIV, 1907.