REFLEX VISUAL SENSATIONS AND ANOMALOUS TRICHROMATISM

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SYNOPSIS.

SECTION 1. INTRODUCTION.

This contains a brief summary of the principle of reflex visual sensations as discovered by Allen. The author, whose vision is somewhat abnormal, sets out to determine the character of these reflexes for his abnormal vision.

SECTION 11. APPARATUS AND METHODS OF MEASUREMENT.

All experiments were performed in a daylight room, using the critical frequency of flicker method. The results, which are quantitative, were obtained by making measurements on pure spectral colors.

SECTION 111. NORMAL CURVES.

Abnormal vision is shown by the character of the persistency curve, taken under normal conditions of daylight adaptation. The type of curve, which was found to be the same for both eyes, is compared with one for normal vision and one for partial red color blindness.

SECTION 1V. REFLEX CURVES.

This contains the descriptions and results of experiments carried out by fatiguing the left eye and making measurements of the changes in the visual response of the right to light from the different parts of the spectrum.

The nature of any change in the response was always found to be an enhancement of brightness of the affected colors. Red and green were found to be more susceptible to this reflex enhancement than the violet. Certain colors, .660μ, .505μ, .425μ, and the entire region .520μ to 480μ, showed no reflex transferred to the other eye. The magnitude of the reflex was greatest for fatiguing colors near the ends of the spectrum. The effect of dark adaptation was also transferred to the other eye similarly to fatigue.

SECTION V. FATIGUE CURVES.

This contains descriptions and results of experiments in which the measurements were made on the fatigued eye, the other being always in daylight adaptation.

It was found that the red sensation was very difficult to fatigue, but very susceptible to enhancement. The violet showed the reverse character, and the green an intermediate position. No effect was obtained for fatigue colors, .665μ, .589μ, .570μ, and only a small effect for .520μ. The effects of darkness and strong white light are very similar, both showing fatigue characteristics.

SECTION VI. THE THEORETICAL CONSIDERATIONS.

The experimental results show that every ray of light produces both a direct and a reflex effect upon all three fundamental sensations, which are shown to be red, green, and violet. The author's type of color vision is shown to be that of an anomalous trichromat, and experimental evidence is applied to give a fuller meaning to the phenomenon as well as to explain it. The principle of visual reflexes is applied to the Young-Helmholtz and Hering theories to show that the two can no longer be regarded as rival theories, but can be harmonized by this principle.

1

INTRODUCTION

In recent investigations by Allen,[1] abundant experimental evidence has been brought forth establishing a new principle of color vision, the application of which to the Young-Helmholtz theory offers simple and satisfactory explanations of many of the phenomena of color perception, which were admittedly inexplicable on the basis of the trichromatic theory.

His results show that the effect of fatiguing a given area of one retina with any spectral color, except an equilibrium one, is to lower the luminous response of that area to colors corresponding to the sensations directly affected by the fatiguing stimulus, and to enhance its response to colors, exciting chiefly the complementary sensations. However, when the colors are

1. J.O.S.A & R.S.I, 7 p.583; 1923

received upon a portion of the retina adjoining the fatigued area,[2] or by the retina of the other eye, the physiological luminosity of the entire spectrum is enhanced. Thus the conclusion is drawn, that every ray of light produces two effects, a direct and a reflex. In the stimulated area of the retina, the direct action fatigues either one or two of the fundamental sensations, according as the color stimulus is simple of compound in its nature; the reflex effect enhances the luminous response of the remaining complementary sensations. It is further concluded that the reflex is transferred to the adjoining areas of the same retina, and also to the other eye, in such a way as to enhance all three sensations.

The author of this paper set out to repeat some of these observations but immediately discovered, from the character of his normal persistency curve, that his perception of light and color is somewhat abnormal. It was therefore of interest to determine the character of these direct and reflex actions of light for one of abnormal vision.

11

APPARATUS AND METHODS OF OBSERVATION.

The apparatus used and the method adopted was, in most respects, the same as that employed by Allen.

2. J.O.S.A. & R.S.I, 7, p.913; 1923.

For the purpose of measurement the apparatus was essentially the same as that originally devised by E. L. Nichols.[3] The source of light was an acetylene flame, for which the gas was supplied at a constant pressure. The light was focused upon the slit of the collimator of a Hilger spectrometer, fitted with four prisms equivalent to three of sixty degrees each. This gave a spectrum of considerable dispersion, narrow strips of which could be isolated in a shutter eyepiece. Between the acetylene flame and the condensing lens an aluminium disk with two opposite open sectors of ninety degrees each was rotated. The speed of rotation, which was regulated by means of a brake, was electrically recorded upon a chronograph. The gas flame was enclosed on all sides, except the top, in a wooden box fitted with a small glass window which transmitted the light to the spectrometer. This box served two purposes, first, in preventing air currents, produced by the rotating disk, from affecting the flame, and second, in shielding the light from the observer's eyes. The spectrometer was properly screened from all extraneous light, and a shield, closely fitting about the eye, was attached to the eyepiece, thus enabling all measurements to be made under exactly the same conditions.

The spectrum used for fatiguing the eye, in the case of nearly all the reflex and also for some of the fatigue curves, was obtained from an arc light by

3. E. L. Nichols, Am. Jour.Sci. 28; 1884.

means of a two-prism Browning spectrometer. A narrow but quite long rectangular patch of the spectrum was isolated by the shutter eyepiece. The spectrum was so intense that the colors in the middle portions of it approached whiteness in appearance. For the majority of the fatigue curves a constant deviation Hilger spectrometer was employed to furnish the fatiguing color. With this instrument the source of light for the blue and violet was always the electric arc, and for the remainder of the fatiguing colors, sometimes the arc was used, and at other times an incandescent bulb, which produced a red of about the same intensity as that of the arc spectrum. The use of the Hilger spectrometer and incandescent bulb made a more convenient arrangement of the apparatus, enabling measurements to be made within a few seconds after removing the eye from the fatiguing color.

While fatiguing one eye, or making measurements, which was always done with the right, the unused eye was directed at a neutral grey surface about ten inches away. Sometimes, when recording observations on the dim ends of the spectrum, the left eye was closed for a few seconds, which did not exceed half a minute. No difference could be detected in the time of the critical frequency of flicker, as recorded for the brighter parts of the spectrum when the left eye was closed for a few seconds, and it was assumed that the time was unaffected for the dim colors.

All the apparatus was mounted in a room well illuminated with daylight. Measurements were not attempted if it was too cloudy or dull or towards sunset, and never with artificial lighting, for Allen has shown that dim light and darkness tend to obscure the reflex action of light.

The rotating sectored disk produced a flickering sensation in the isolated patch of the spectrum, due to the rapid succession of equal intervals of color and darkness. After adjusting the speed of the motor until the flicker was just imperceptible, the chronograph was started, and while the record was being made, which required about half a minute, the speed of the disk was varied slightly, keeping the flicker just on the point of appearing and disappearing. At least two independent records, representing the time of 120 to 400 revolutions of the disk, were made for each point, and if these did not show good agreement more readings were taken. So constant were the conditions, that the independent records gave values for the duration of a single flash, at the critical frequency of flicker, with a variation seldom greater than 0.0002 sec., except for points in the dim ends of the spectrum. The values used in plotting points in the bright parts of the spectrum were means of usually two or three imdependant measurements, and for the extreme violet and red the mean of about four readings was taken.

These experiments stretched over an interval of about fifteen months, most of the work being done, however, during the first three and the last five months. The curves were not necessarily taken in the order presented in this paper, although nearly all of the reflex curves were completed during the first three months and before any fatigue curves were attempted.

111

NORMAL CURVES.

In making measurements for a normal curve, the following procedure was adopted. The spectrometer was set so that the shutter eyepiece isolated a narrow rectangular patch of the spectrum, the mean wave length of which was known. The spectral color was observed by the right eye, while the speed of the disk was regulated to give the critical frequency, which was then recorded. Care was taken to fixate the color directly, and to prevent the eye from wandering while judging the point of critical frequency. The eye was then rested for a minute or two, and a second chronographic record made on the same portion of the spectrum. Between the measurements made on different points in the spectrum the eye was rested in the diffuse daylight of the room for from five to ten minutes, according to the brightness of the spectral color. Since the spectrum, upon which all measurements were made, was not very brilliant, and the time required to record one reading about half a minute, the eye was not likely to become appreciably fatigued. In this way, observations were made on fifteen or more points of the spectrum.

The persistency curves, obtained by plotting wave lengths as abscissae and the persistence of vision as ordinates, show that the duration of these light impulses varies as some inverse function of the luminosity of the color observed. It was discovered by Ferry,[4] and subsequently in another manner by Porter,[5] that the duration of the sensation of undiminshed brightness of a flash of light, at the critical frequency of flicker, depends only on the luminosity of the light and in no way on the wave length. The Ferry-Porter law, as it is known, is represented by the equation, $D = \frac{1}{k \log L + k_1}$ where D is the persistence of vision, L the luminosity, and k and k_1 two constants. According to this law, a lowering of the persistency curve may be in-terpreted as an increase, and an elevation as a decrease, in the luminosity of the spectrum as perceived by the eye.

Considerable difficulty was experienced at first in obtaining a satisfactory normal curve. The author was not aware that his vision was abnormal in any way, and expected to get a smooth curve as obtained by other observers of normal vision. After every set of readings, the curve proved to be irregular between .59µ and .66µ, and it was thought for a time that this was

4. Am.Jour Sci. Vol. 44, 1892.
5. Proc. Roy. Soc. Vol. 63, 1898; Vol.70;1902.

due to the writer's inexperience in making such measurements. The readings were repeated again and again, the greatest care being taken to make correct observations, yet a smooth curve was never obtained through this region. After two weeks of strenuous work and several hundred measurements the writer was forced to realize that his color vision was not completely normal. The normal curve was finally plotted showing the abnormal elevation between .594μ and .66μ, the exact character of which was accurately determined by making observations on several additional points in this part of the spectrum.

Another difficulty experienced in obtaining a satisfactory normal was the gradual lowering of the entire curve as the constant re-reading of the points continued from day to day. This gradual depression of the curve, which was most pronounced during the first three weeks and before a satisfactory normal was obtained, continued to drop very slowly for several weeks more. The phenomenon appears as one peculiar to the author himself, for three other observers, using the same apparatus and working under the same conditions for several months, did not experience it. One observer was noticeably color deficient in red, while the other two were of normal color vision and obtained almost identical persistency curves. Because of this gradual lowering of the normal the readings were repeated every few