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Subjective After-Color (Complementary Color). By Charles A. Oliver, M.D.

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Last year the writer brought forward, in "The American Journal of the Medical Sciences," a series of papers upon "A Correlation Theory of Color-Perception," in which this subject was exhaustively treated both from theoretical grounds and experimental standpoint. In a desire to isolate a few special data upon "Complementary Color," and to place them upon record, he has separated this part of the paper, and abridged it into a series of definite formulæ, which are here presented to the Society. Before arranging any conclusions, a brief synopsis of the theory will be given, so as to allow a correct understanding of the basis upon which they are placed. Starting with the assumption that all natural imponderable stimuli are the resultants of a mere difference in the number of vibrations of one and the same ether, and that the organs for the receipt of the different varieties must be but analogues and modifications of each other, it was shown by comparison with the senses of touch and hearing that the usually received theories of color-perception are incorrect. The question was then asked, Why take the trouble to give a series of organic elements, a coarse, unnatural division of fibre in an effort to harmonize them with an arbitrary and unscientific naming of visible color, when we have the difference of result dependent upon a difference in cause acting upon an ever-ready material?—a difference in the character of natural impression affecting one and the same organic element to a greater or less degree, producing exact and equivalent answers. It was then shown that each and every optic-nerve fibre tip has a passive receiving power equal to its individual strength; that each and every healthy optic-nerve filament transmits to the color-centre for recognition, nerve-energies equal to as many special sensations as its peripheral tip is capable of receiving; and that the innumerable quantities of nerve filaments, placed side by side on a sheet or membrane, serve to give greater field, and to allow many colors to be seen at one time, thus making our every-day and momentary pictures. These assertions brought forward the following theory. Color-perception takes place through each and every optic-nerve filament. It consists in the passive separation of a specific nerve-energy equal to the exposed natural color, from a supposed "energy-equivalent," resident in the peripheral nerve tip, by an active chemico-vital process of the impinging natural color-vibration upon the sensitized nerve terminal. The separated nerve-energy is transmitted to the central terminus of the filament in the cerebral retina, where it is fully evolved into such a condition as to be transformed into an automatic and, finally, an intelligent perception. The moment that the primary portion of this action (*i. e.*, the separation) has taken place, there has been left in the peripheral tip of the primarily impinged sensory filament, a nerve-energy material equal to the difference between that individual nerve's "energy-equivalent"

and the transmitted nerve stimulus ; the healthy peripheral nerve tip returning to its "energy-equivalent" or normal nerve power, the moment that the specific energy separated by the received natural vibration has been forwarded for transmission and recognition, whilst the transmitting filament and excited cerebral expansion regain their normal conditions the moment that the energy has passed them. After the consummation of such an action, the filament is again ready for any other natural color-vibration. In other words, a natural wave motion equal to natural color sets a peripherally placed life force into an equivalent life motion, which is transmitted to a central organ of perception where it is perceived. It is the action of natural wave motion upon sensory life motion, the life motion being produced by a loss and restitution of working material, *i. e.*, a chemico-vital action. Thus to see red, the nerve is first supposed to be charged to its normal physiological condition by its inherent vitality and sensitizing material. Vibrations of say five hundred trillions per second (some natural red color), are allowed to be thrown upon this sensitized tip. To see the color, the peripheral negative (an unused energy equal to the commencing sensation of a "green") must be allowed to rest, by the separation of a quantity of nerve-force equal to a supposed red energy, from the "energy-equivalent," through the excitation of the impinging ray. This separated specific energy is transmitted and perceived. The moment that the red-energy has left the nerve tip, the terminal is again charged to its "energy-equivalent" and is ready to receive any other color-vibration that may be cast upon its surface. Each and every natural color causes the separation of a specific energy equal to itself, which is properly transmitted and correctly perceived, if the conducting and central nerve structures be normal and intact.

Based upon this theory, the following conclusions in reference to subjective after-color may be formulated :

First. Definition of Subjective After-Color.—Color-perception resulting directly from provoked remaining nerve-energies. The exciting stimulus may be either peripheral or central ; the former is produced from the external world or natural light stimulus, and the latter from some internal stimulation, either in the visual apparatus or in the cerebrum beyond it.

Second. Cause of Subjective After-Color.—"Complementary Color" is caused by the presentation of a second stimulus, either external or internal, of greater power than the remaining nerve-energy left from a previous color-action, before the visual apparatus has had time to return to its normal condition.

Third. Equivalence of Result.—The result is always equal to the difference between the amount of nerve-energy separated by the primary stimulus and the normal condition (energy equivalent) of the impressed portion of the optic-nerve filament.

Fourth. Passing Subjective After-Colors.—Two varieties ; non-reëxposed and reëxposed. The former depends upon the fact that the primary stim-

ulation has been of such great intensity that it has left an irritant action which separates specific nerve-energies from the reforming material as fast as it is poured into the exhausted nerve; this, coupled with the fact that the irritant action is ever decreasing, with a proportionate gain of nerve-energy material, is the cause of the succession of subjective after-colors. The latter variety has the same character of passing subjective after-color, except that here they progress in a *reverse* order. This is readily explained. During the time that the re-impressed tip is gradually gaining sufficient nerve-energy to transmit the second natural white stimulus, there is a corresponding separating process continually taking place, dependent upon the great intensity of the second natural white stimulus. These separated amounts of nerve-energy are forwarded to the perceptive centres where they are recognized. This continues in a definite order of gain until at last the second natural white stimulus is able to be properly received, which is transmitted and perceived as "white."

Fifth. Transferred Subjective After-Color.—This is dependent upon a transformation of a "remaining energy" of one of the primarily used perceptive color-cells belonging to a strongly impressed visual apparatus, to an equivalently placed perceptive color-cell belonging to a weakly impressed visual apparatus, due probably to the fact that at the time of the double action, the perceptive cells of each channel are physically and physiologically thrown into connection with each other. That there is an organic or life connection at such times is known by the blending of the finite results.

Sixth. Simultaneous Contrast-Colors.—These show that either the action of simultaneously powerful and feeble intensities of natural color stimuli, or of a prolonged exposure of a strong and a weak natural color impression upon a series of contiguous peripheral nerve terminals of the same visual apparatus, can readily provoke an internal irritant action in the strongly excited perceptive color-cell, which will, in its turn, cast the entire brunt of its remaining nerve-force upon its feebly excited neighbor, and thus rouse the now secondarily impinged cell into a corresponding action.

Seventh. Alternating Subjective After-Colors.—These are dependent upon momentary alternating regains and discharges of sufficient energy material to perceive color-energies, equal to, first, the primary energy, and then its subjective after-color, after having perceived the subjective after-color.

Eighth. Other Varieties.—These are produced by modifications of the just-described exciting agencies and conditions of physical material.

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