Reports

Induction of Fechner Colors in Black and White Photographs

Abstract. Fechner colors are visible when two black and white photographs of a scene which have been taken with long-wavelength and short-wavelength light, respectively, are viewed in an alternating sequence. Such colors may be combined with spatially induced, two-primary colors to enhance or reduce the vividness of the latter.

Several recent publications by Land (*1*) have attracted considerable attention to situations in which colors which include a broad range of hues can be discriminated in projected photographs, even when the spectral composition of illumination is restricted to two narrow wavelength bands which are quite close in the spectrum. The method consists of viewing two photographs, one of which has been taken with long-wavelength (red) light and the other with middle-wavelength (green) light, when these are projected, in register, on a screen. When the projection illumination of the photograph made with red light is restricted to relatively long wavelengths and that of the other to relatively shorter wavelengths, the colors of objects in the picture show a striking correspondence in hue to the colors of the same objects viewed directly in white illumination. The phenomenon is an old one and was reported as early as 1897 (*2*). Land's primary contribution has been to explore in some detail the range of spectral distributions which can be used.

These color phenomena may be attributed to simultaneous contrast, or spatial interaction, since colors can be perceived in short flashes during which adaption effects or afterimages cannot be expected to have any influence. The perceived colors cannot be attributed to the observer's "expectations" based on familiarity with the objects portrayed. Radical changes in hue are perceived when the long- and short-wavelength illuminations are interchanged, and these changes are readily perceived in 0.01-second flashes. Land himself has employed the flash technique to demonstrate the immediacy of perception of the colors with a stereo shutter which is mounted on a pair of goggles.

There is another method, quite different from the method which has been employed by Land, by which colors may be induced with hues which do not bear the usual relation to the spectral character of the illuminant. This method, which involves temporal induction, was reported as early as 1826 (*3*). It gives rise to the so-called Fechner colors. One example of the method consists of illuminating an area of the retina in various temporal sequences with a homogeneous dark stimulus, a homogeneous light stimulus, and a pattern of lines on a light background (Benham's Top). It occurred to me that the kind of transparencies employed by Land might yield sensations of color if they were viewed in an appropriate temporal sequence when illuminated with white light.

A variety of temporal sequences was investigated. Colors could be perceived in transparencies which were viewed successively in the following manner: A disk chopper is so arranged that white light from the transparency which was photographed through a green filter first stimulates the eye. Immediately upon termination of this stimulation the eye is stimulated by white light from a transparency photographed through a red filter. This stimulation is followed by a dark interval approximately equal in duration to the total interval during which stimulation occurred. The cycle is then repeated. At a rate which produces noticeable flicker, objects in the picture assume colors of very low saturation which correspond approximately in hue with the colors of the original objects. Although relatively unsaturated, the colors are identifiable by the majority of observers. If the cycle is reversed by reversing the direction of rotation of the chopper, there is a change in the apparent colors. Formerly reddish objects appear greenish or bluish and formerly greenish objects appear pink.

It is possible to combine the Fechner colors with spatially induced, two-primary colors by locating long- and short-wavelength filters in the viewing system such that the two transparencies are illuminated with long and short wavelengths, respectively, instead of white light. When the direction of chopper rotation is such that the hues of Fechner colors correspond with those of the objects photographed, the two-primary colors are enhanced noticeably at rotation rates which produce flicker. This enhancement effect disappears when the rotation rate is increased to a point where there is no obvious flicker. If the direction of rotation is reversed, the vividness of the two-primary colors may be reduced at rates which produce flicker to the point where they disappear. As the rotation rate is then increased to a point where flicker disappears, the two-primary colors gradually emerge.

It would appear that spatial and temporal interaction effects in the retina which give rise to the perception of hues not ordinarily associated with the spectral distribution of the stimulating light are sufficiently distinct in their mediation to inhibit or enhance each other. These observations may afford new avenues of approach toward an understanding of the physiological bases of color perception.

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References and Notes

1. E. H. Land, *Proc. Natl. Acad. Sci. U.S.* **45**, 115, 636 (1959); *Sci. American* **200**, No. 5, 84 (1959).
2. A. Ducos du Hauron, *La triplace photographique des couleurs et l'imprimerie* (Gauthier-Villars, Paris, 1897).
3. B. Prevost, *Mém. soc. phys. et d'hist. nat. Genève*, **3**, 121 (1823–2 → J. Cohen and D. A. Gordon, *Psychol. Bull.* **46**, 97 (1949).

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Instructions for preparing reports. Begin the report with an abstract of from 45 to 55 words. The abstract should *not* repeat phrases employed in the title, it should work with the title to give the reader a summary of the results presented in the report proper.

Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* **125**, 16 (1957)].

Value of X-ray Films of Hand and Wrist in Human Identification

Abstract. As seen in the x-ray film, the individual bones of the hand and wrist differ sufficiently in form from one person to another so that such films can be valuable aids in establishing personal identification in either the living or the dead.

The difficulties experienced in Korea and elsewhere in attempting to identify the interred remains of servicemen which were unaccompanied by identification tags and which had no distinguishing dental or other features em-