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 (1823–26); 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-

phasized the need for some additional means of determining the identity of human skeletal remains. On the basis of rather extensive experience in working with x-ray films of the hands and wrists of children and adults, I had gained the impression that the various skeletal features visible in the posterior-anterior radiograph of the hand and wrist might be found to differ sufficiently from one person to another to permit identification of individuals from these alone. This report summarizes the results of an attempt to determine the usefulness of those radiographic features for this purpose (*1*).

It was established that, as seen in the posterior-anterior radiograph, the various bones of the hand and wrist show individual differences in form and in other features which, in the aggregate, are sufficient to distinguish the radiograph of the hand of one person from that of another. To begin with the ends of the radius and ulna and proceed distally, these features are: (i) the shape and relative size of the distal end of the radius and of the styloid process of the ulna; (ii) the shape of the individual carpal bones; (iii) the size and shape of the individual metacarpals, the relative width of their cortices and medullary cavities, and the individual differences in the outline of the inner margin of the cortex (that is, the margin immediately adjacent to the medullary cavity); (iv) the shape and position of the irregular white lines visible in the heads of the metacarpals; (these lines are composite shadows to which parts of the volar and dorsal surfaces and structures lying between them make variable relative contributions); (v) the differences in the shape and relative dimensions of the individual phalanges; and (vi) the fine details of trabecular pattern visible in the shafts of the various bones, especially in the proximal and middle phalanges.

A study of a series of radiographs of the hand made at regular intervals on the same individuals, from early childhood over a long period of years, disclosed that the skeletal features which are useful for individual identification usually become established during late adolescence and remain relatively unchanged until at least well into the thirties, the age of the oldest men on whom such film series were available to us. Since, however, the same features were observed in radiographs of the hand of several hundred men and women who were in their seventies and eighties, it is thought that most of those features remain recognizable throughout the life of the individual, even though they occasionally become modified somewhat by changes associated with aging.

In the radiograph of the hand and wrist, 27 complete bones and parts of two other bones (the distal ends of the radius and ulna) are visible. Since most of these possess a number of structural features which can differ from one person to another, the chance that radiographs of the hands of any two persons will be identical in all of these features would seem to be very small—if, indeed, such identity ever occurs.

Harold E. Jones, director of the Institute of Child Welfare of the University of California at Berkeley, kindly permitted me to study radiographs of the right and left hands of 70 pairs of like-sexed twins on whom he had previously made some other observations. Approximately 40 of these pairs appeared to be identical twins. While there was a very striking resemblance between x-ray films of the hand of the two members of each presumably identical pair, there were in every instance some features which made it possible to distinguish the hand and wrist bones of one person from those of his or her twin. The over-all similarity was so great, however, and our observations were so few, that we ought not ignore the possibility that skeletal features which we have found adequate to distinguish between radiographs of the hand of unrelated persons and of ordinary siblings are, in some instances, not sufficiently discriminating to distinguish an x-ray film of the hand of one identical twin from that of the other member of the pair. However, as mentioned above, no such instance was encountered among the cases which we were able to study.

In about 500 of the young men whom we x-rayed, separate radiographs were made of both the right and the left hand. Though, as might be expected, an individual bone of one hand or wrist is not always identical in form with the corresponding bone of the other side, it was found that there was a sufficiently close over-all similarity in the shape and proportions of the bones of the two hands to permit successful pairing of the two films of the same man when all identifying marks had been covered and the films were studied in a random order. It should, therefore, be possible to identify skeletal remains in which the bones of the forearm, wrist, and hand of only one side are present, by comparing the radiographic features of these bones with those visible in an x-ray film which had previously been made of the same or of the opposite side.

It might be thought that the ease with which the radiograph of the hand of one person can be distinguished from that of another in our population may, to some extent, be due to the heterogeneity in race and in national antecedents of the people of the United States. Our study of films of the hands of several hundred Apache Indians from the White River Reservation in Arizona and of a larger number of American-born Japanese living in California established, however, that the same individual differences in the skeletal features which we had observed in the more heterogeneous white population in our country exist also among American Indians and Japanese. Radiographs of the hand can, therefore, be used satisfactorily for purposes of individual identification within those groups and, presumably, among other racial groups as well.

These findings demonstrate that it is quite possible to establish the identity of an individual from the skeletal features visible in an x-ray film of his hand and wrist. Since many of those features remain relatively unchanged even after years of burial, the films could also provide conclusive proof of the identity of persons in whose remains other identifiable features are lacking.

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Note

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Electronmicroscopy of Dental Calculus

Abstract. Electron microscopy of ultrathin osmium-fixed sections of dental calculus, cut with a diamond knife without prior decalcification, revealed densely mineralized areas entrapping many degenerating microorganisms, within which were deposited similarly electron-dense crystals. Two principal forms of crystals were found, the predominant type being of the same order of magnitude and shape as those found in bone, and showing the typical characteristics of apatite in selected area electron diffraction patterns.

At present it is not possible to propose a single mechanism sufficiently inclusive to explain calcifiability of such diverse structures as endoskeletons, exoskeletons, teeth, kidney stones, or pearls, to name but a few of many normal and pathological types of calcification in biological systems (*1*). The most attractive conceptual scheme hitherto suggested to account for mineral deposition in vertebrate hard structures of mesodermal origin has evolved from the electron microscopic observations by Robinson (*2*) and Robinson and Watson (*3*), who studied adult human bone and dentin; by Jackson and Randall (*4*),