NATIONAL BUREAU OF STANDARDS REPORT

3774

THE DETECTION OF OBJECTS FROM PHOTOGRAPHIC TRANSPARENCIES

by

Deane B. Judd

To

Aerial Reconnaissance Laboratory
Wright Air Development Center
Wright-Patterson Air Force Base
Department of the Air Force

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Photometry and Colorimetry Section
Optics and Metrology Division

To
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PREFACE

This is one of a series of reports prepared under National Bureau of Standards Project No. 0201-20-2325, "Color Reconnaissance Studies". This project is financed by the Aerial Reconnaissance Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio (Air Force Contract No. AF 33(616) 52-21); and it is coordinated with Air Force Contract No. AF 33(616)-262 (Suppl. Agreement S3(54-583)) under Dr. Hugh T. O'Neill, O'Neill Associates, Annapolis, Maryland, who supplies all requests for studies, and all specimens and materials for spectrophotometric and colorimetric analyses, except those directly requested or supplied by the Optics Division and others at the Wright Air Development Center.

The present report resulted from two of Dr. O'Neill's work requests, which were assigned Oral Work Request Serial Numbers: WADC-16/53 and WADC-22/53.

H. J. Keegan, Project Leader

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I. Request

Information in the shape of a short report or memorandum discussing the difference between the two following systems of increasing the degree of contrast between an object and its immediate surrounding on a color transparency:

System No. 1	Eye	Colored filter	Color film	Source of light
System No. 2	Eye	Color film	Colored filter	Source of light

In system No. 1, the eye adjusts itself gradually to a certain degree at least and thus the contrast becomes less sharp. Any summary and literature pertinent to this topic will be appreciated.

The above is the statement of Problem 22. Problem 16 is essentially the same but couched in more general terms: "A discussion of the difference between the results obtained by studying color transparencies (a) by means of filters attached to a frame, such as a spectacle frame, and therefore held between the eyes and the transparency, and (b) by means of a filter placed between the source of light and the transparency". The solution of Problem 22 is thus a partial solution of Problem 16, and perhaps is all that is required until there is supplied a more explicit statement of what, in addition to Problem 22, is meant by "results obtained by studying color transparencies".

II. Introduction

Formulas are available for reasonably reliable prediction of the color difference, or color contrast, between an object and its surround; see NBS Report 3773 [1]*. The variables of the observing condition to

*Figures in brackets indicate the index references at the end of this report.

be specified are (1) the average luminance of the color transparency, (2) angular size of the object or element in the picture to be discriminated, (3) angular size of the surround, and (4) character of the boundary between object and surround. The primary data determining the degree of

contrast, hence the ease or certainty of discrimination of the object from the ground, are the tristimulus values, X,Y,Z, of the object or element, and the tristimulus values, X_o, Y_o, Z_o, of the immediate surround. The formulas referred to above all assume that the average luminance is sufficient for substantially perfect cone vision, that is, 10 millilamberts or more. Formula 1 of NBS Report 3773 further assumes that the object subtends two degrees or more. If objects of smaller angular size than this have to be discriminated, formula 2 must be used in which the constants are expressed as functions of angular size of the contrasting element. To develop whether system 1 or system 2 is superior, we must study the basic quantities (X,Y,Z) and the four variables of observing condition in turn.

III. Basic quantities (X,Y,Z)

If H is the spectral irradiance supplied by the light source, T the spectral transmittance of the picture element to be discriminated, and T_f the spectral transmittance of the colored filter, then the tristimulus values, X,Y,Z, of the picture element are defined for system 1 as:

$$X = \sum H\,T\,T_f\,\bar{x}\,\Delta\lambda$$

$$Y = \sum H\,T\,T_f\,\bar{y}\,\Delta\lambda$$

$$Z = \sum H\,T\,T_f\,\bar{z}\,\Delta\lambda$$

where $\bar{x},\bar{y},\bar{z}$ are the tristimulus values of a spectrum of unit irradiance for the 1931 CIE standard observer.

For system 2 the definition becomes:

$$X = \sum H\,T_f\,T\,\bar{x}\,\Delta\lambda$$

$$Y = \sum H\,T_f\,T\,\bar{y}\,\Delta\lambda$$

$$Z = \sum H\,T_f\,T\,\bar{z}\,\Delta\lambda$$

It will be noted that the only difference in these two definitions is that T and T_f are interchanged in accord with the order of placement of film and colored filter, and since this makes no difference in the evaluation of the indicated products, systems 1 and 2 are identical as far as the basic quantities X,Y,Z are concerned. The same argument applies to the tristimulus values, X_o, Y_o, Z_o, of the immediate surround.

IV. Average luminance of the color transparency

The value of Y for the color transparency as a whole is its average

luminance, and, as just shown, this quantity remains unchanged regardless of which of systems 1 and 2 is used.

V. Angular size of picture element

Obviously the change from system No. 1 to system No. 2 leaves the angular size of picture element unchanged.

VI. Angular size of surround

The condition most favoring the detection of a small color difference between two contiguous elements is that the eye be adapted to a color half-way between the two to be discriminated (Schönfelder, 1933) [2]. System No. 1, placing the colored filter directly in front of the eye as in a spectacle frame, is probably significantly better than system No. 2 in this respect. The entire visual field is filled with light that has passed through the filter and adaptation to nearly the most favorable color is facilitated. System No. 2, placing the colored filter between the light source and the transparency, effectively reduces the size of the surround, and thus provides for less complete adaptation to the color of the filter. For transparencies of large angular subtense (40° or more) this advantage of system No. 1 is negligible unless the element to be discriminated is near the border.

The specific question whether system No. 1 promotes adaptation and thus reduces contrast relative to system No. 2 may be answered as follows: Yes, system No. 1 promotes adaptation relative to system No. 2, but this should result in a gain rather than a loss in contrast. Note that the eye of the operator constantly changes its fixation point as a part of the searching process, just as the color matcher constantly looks from one half-field to the other in an attempt to discriminate a small difference. The best discrimination of local details by the roving eye is obtained with the eye adapted to the average color of the transparency. If the eye remained perfectly fixed, the details would have to be discriminated immediately if at all, because adaptation reduces almost to zero in a few minutes the perceived size of any color differences originally perceptible, and this decline in perceptibility takes place very rapidly in the first few seconds of exposure. Even in this condition, it would favor discrimination to pre-adapt the eye by system No. 1 to the average color of the transparency, and then to present the transparency, rather than to use system No. 2.

VII. Character of the boundary between object and surround

If the boundary between object and surround is sharp, the detection of an object lighter or darker than the surround is greatly facilitated; see NBS Circular 478, Colorimetry, page 30 [3]. If the optical quality

of the colored filter is perfect, systems 1 and 2 alike leave the character of the boundary unchanged. But if, as is likely in practical cases, the colored filter has minor imperfections (haze or striae in the filter material; pits, scratches, dirt, grease, or dust on the surfaces), system No. 2 is definitely advantageous. By system No. 1, these imperfections may so degrade the sharpness of the boundary in the retinal image between object and surround as to hide small objects otherwise easy to detect; but by system No. 2 no such degradation can result, since the eye may then view the transparency directly without any intermediate optical surfaces.

VIII. Summary

The relative advantages of placing the colored filter between the transparency and the eye on the one hand (system No. 1), or between the transparency and the light source (system No. 2) on the other, have been analyzed on the basis of the fundamental formulas for size of color contrast and on the basis of the pertinent variables of the observing condition. It is shown that system No. 1 provides somewhat better chromatic adaptation, and that system No. 2 provides better freedom from the bad effects of optical imperfections in the colored filter. In other respects the two systems are identical. System No. 2 is recommended.

IX. References

[1] D. B. Judd, Determination of Colors of Maximum Contrast, NBS Report No. 3773, November 12, 1954.

[2] W. Schönfelder, Der Einfluss des Umfeldes auf die Sicherheit der Einstellung von Farbengleichungen, Z. Sinnesphysiol., 63, 228; 1933.

[3] D. B. Judd, Colorimetry, NBS Circular No. 478, page 30, March 1, 1950.

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.00). Information on calibration services and fees can be found in NBS Circular 483, Testing by the National Bureau of Standards (25 cents). Both are available from the Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

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