ACKNOWLEDGMENT

The author wishes to thank Gertrude Kornfeld of this laboratory for valuable discussions.

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Complementary colors: correction

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(Received 12 June 1979)

Previous data on composition and complementary efficiency of optimum color stimuli for various whites are modified.

INTRODUCTION

For a given hue and a given radiant power, the optimum color stimulus is that color (of all possible wavelength combinations and purities) which is most efficient in contributing to color mixture, or in other words, least capable of being dominated or neutralized by any other color. Recently published data[1] on the composition and complementary efficiency of optimum color stimuli have been modified by use of a more accurate method of computation.

Equations (1) to (3) of Ref. 1 apply accurately only to monochromatic colors with monochromatic complementaries. The following material should be read with, and added to the text immediately below Equation (3).

To determine the complementary efficiency of a color with a compound complementary, it is necessary to compute the efficiencies of the various pairs of short and long wavelengths that can form the compound color, in order to find the most efficient pair. Because of the very large number of possible pairs, results were obtained by use of a computer, which calculated complementary efficiencies for the possible pairs of wavelengths (for each compound color) in 1-nm steps.

Equations (1) and (2) (Ref. 1, p. 1490) must be applied twice: to the color and to its complementary, and then to the pair of component colors that form the compound color; there is no direct luminosity value for a compound color; therefore, Eqs. (1) and (2) had to be restructured. Because it is easier for a computer to deal with distances in color space, Eqs. (2a) and (2b) were combined. To compute E (complementary efficiency) for a spectral color with a compound complementary, first a complementary chromaticity and its coordinates are chosen. Next, the following Eqs. (4) to (8) are applied. The sequence is repeated for the various possible chromaticities that may provide the optimum complementary color for each spectral color; each possible chromaticity is tested for the various possible pairs to wavelengths that may form that chromaticity. Thus,

TABLE I. Optimum complementary efficiencies (E) for illuminant D_{65} and compound components. Wavelengths (λ) in parentheses have same dominant λ as the compound color but lower efficiency.

λ nm	Compound components	E	λc
442	—	1.65	567.6
(440)	442 + 613	1.64	567.4
(430)	442 + 613	1.588	567
(410)	442 + 613	1.53	566.65
(390)	442 + 613	1.53	566.5
565c	442 + 613	1.39	565
560c	442 + 613	1.07	560
550c	442 + 613	0.789	550
540c	442 + 613	0.679	540
535c	442 + 613	0.657	535
531.5c	442 + 613	0.653	531.5
525c	442 + 613	0.669	525
520c	442 + 613	0.712	520
510c	442 + 613	0.953	510
500c	442 + 613	1.55	500
495c	442 + 613	2.13	495
(670)	442 + 613	2.43	493.3
(640)	442 + 613	2.51	492.9
(617)	442 + 613	2.72	492
613	—	2.76	491.7

To match neutral:

Proportion of compound color,

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TABLE II. Optimum complementary efficiencies (E) for illuminant A and compound components. Wavelengths (λ) in parentheses have same dominant λ as the compound color but lower efficiency.

λ nm	Compound components	E	λc
495.5	—	1.0	594
441	—	5.4	579.1
(430)	441 + 614	5.186	579.1
(400)	441 + 614	5.18	579
(360)	441 + 614	5.16	579
570c	441 + 614	1.45	570
560c	441 + 614	0.849	560
550c	441 + 614	0.649	550
540c	441 + 614	0.569	540
532.5c	441 + 614	0.553	532.5
520c	441 + 614	0.609	520
510c	441 + 614	0.815	510
505c	441 + 614	1.007	505
(700)	441 + 614	1.06	503.8
(670)	441 + 614	1.06	503.7
(650)	441 + 614	1.09	503.4
(635)	441 + 614	1.12	502.9
614	—	1.21	501.4
610	—	1.24	500.7

$$A = \frac{\sqrt{(x - x_n)^2 + (y - y_n)^2}}{\sqrt{(x - x')^2 + (y - y')^2}}, \tag{4}$$

Proportion of spectral color,

$$A' = 1 - A; \tag{5}$$

To form compound color:

Proportion of short wavelength,

$$A_S = \frac{\sqrt{(x_L - x')^2 + (y_L - y')^2}}{\sqrt{(x_L - x_S)^2 + (y_L - y_S)^2}} \cdot A, \tag{6}$$

Proportion of long wavelength,

$$A_L = A - A_S; \tag{7}$$

To compute complementary efficiency:

Complementary efficiency,

$$E = \left(\frac{A_L y_L}{\bar{y}_L} + \frac{A_S y_S}{\bar{y}_S}\right) \Big/ \frac{A' y}{\bar{y}'}, \tag{8}$$

where A', A, are the proportions of the spectral color and its complementary compound color, respectively; subscripts L and S refer to the long-wavelength component and the short-wavelength component, respectively, of the compound color; $\bar{y}'$ and $\bar{y}$ refer to the value of luminosity function of spectral color and its complementary, respectively; x' and y' are the spectral color's coordinates, and x and y the compound color's coordinates; and x_n, y_n are the neutral-point coordinates.[2]

TABLE III. Primary-waveband data for 15 selected whites from 2000 K to infinite K, including CIE illuminants, giving chromaticity coordinates, approximate color temperature, primary waveband limits (S and L), and midpoint (M) of complementary structure. The midpoint to S and L is nearly constant at 527.5 nm, but the midpoint (M) to Sc and Lc varies with color temperature and provides a comparative numerator for a white's center of balance relative to other whites. S and L data are accurate to ±0.5 nm (but to ±0.05 nm for White C).

White	Neutral point coordinates	Band limits S, L (nm)	Midpoint M to Sc, Lc
1 (2000 K)	x.525, y.410	441, 616	547.2
A (2850 K)	x.4476, y.4075	441, 614	540.3
2 (3300 K)	x.42, y.40	441, 613	538.1
3 (4000 K)	x.38, y.38	441, 613	535.0
B (4870 K)	x.3485, y.3518	441, 613	532.5
D_{55} (5503 K)	x.3324, y.3475	442, 612	531.2
Equal Energy	x.3333, y.3333	441, 613	531.2
D_{65} (6504 K)	x.3127, y.3290	442, 613	529.6
C (6770 K)	x.3101, y.3162	441, 613	529.4
D_{75} (7504 K)	x.2990, y.3150	441, 613	528.4
4 (7800 K)	x.295, y.315	442, 613	528.0
5 (10000 K)	x.28, y.29	441, 613.5	526.6
6 (13500 K)	x.27, y.27	441, 614	525.7
7. (27000 K)	x.25, y.25	441, 614	523.2
8. (Infinite K)	x.24, y.2342	441, 614.5	521.7

Tables I and II show the results for illuminants D_{65} and A, respectively. Table III gives primary-waveband data for 15 selected whites, including seven CIE illuminants, from 2000 K to infinite K color temperature. These data improve upon the original Tables I, II, and III and Secs. V and VI of Ref. 1.

Wavelengths outside the primary waveband cannot form or contribute to optimum color stimuli.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the work of Stephen Dain of the University of New South Wales and Bryan Powell of the Australian Broadcasting Commission in designing the complementary-efficiency equations for compound colors and the associated computer program.

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[2]CIE Publication No. 15 (E-1.3.1), 1971, Table 2.1.

Optical Society of America. Journal A: Optics, Image Science, and Vision

Title Details | Table of Contents

▼ Basic Description

Title	Optical Society of America. Journal A: Optics, Image Science, and Vision
ISSN	1084-7529
Publisher	Optical Society of America
Country	United States
Status	Active
Start Year	1984
Frequency	Monthly
Volume Ends	Dec
Language of Text	Text in: English
Refereed	Yes
Abstracted / Indexed	Yes
Serial Type	Journal
Content Type	Academic / Scholarly
Format	Print
Website	http://www.opticsinfobase.org/josaa/journal/josaa/about.cfm
Email	jamss@osa.org
Description	Covers basic research on optical phenomena. Includes atmospheric, physiological and statistical optics; image processing; scattering and coherence theory, machine and color vision; design and diffraction.

▶ Subject Classifications

▶ Additional Title Details

▼ Title History Details

Formerly (until 1993): Optical Society of America. Journal A, Optics and Image Science (United States) (0740-3232)

Which superseded in part (in 1983): Optical Society of America. Journal (United States) (0030-3941)

Which superseded in part (in 1929): Optical Society of America. Journal. Review of Scientific Instruments (United States) (0093-4119)

Which was formerly (until 1922): Optical Society of America. Journal (United States) (0093-5433)

▶ Publisher & Ordering Details

▶ Price Data

▶ Abstracting & Indexing

▶ Other Availability