Efficacy of a Color Conversion Filter in Color-Vision Testing

J. D. Moreland,* S. Westland

MacKay Institute of Communication & Neuroscience, Keele University, Staffordshire, ST5 5BG UK

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Abstract: C Daylight™ *glasses are designed to convert light from domestic incandescent lamps (≈Illuminant A) to the Illuminant C phase of daylight. The efficacy of this conversion is quantified here for the Farnsworth D15 test. Spectral transmittance and reflectance data for the filter and D15 caps, respectively, are used to compute chromaticities of the caps under illuminants C, A, and the filtered illuminant fA. The chromaticities of A and fA deviate from C by 13 JNDs and 1.6 JNDs, respectively and, similarly disparate shifts occur for the 15 caps. After allowing for von Kries adaptation, the chromatic spacing between some adjacent caps approaches 1 JND for Illuminant A, but is less than 0.1 JND for fA. It is concluded that the color conversion is efficient.* © 2000 John Wiley & Sons, Inc. Col Res Appl, 26, S258–S260, 2001

Key words: color conversion; color vision; color deficient; Farnsworth D15

INTRODUCTION

Schmidt[1] reported impaired screening efficiency of pseudoisochromatic plates when illuminated inappropriately by an incandescent lamp instead of North Sky Daylight. The importance of illuminating pigment-based tests of color vision with a standard phase of daylight is now well recognized. The use of Wratten color filters in the form of spectacles to convert the light from a domestic incandescent lamp to Illuminant C has been described by Pokorny *et al.*[2] and by Higgins *et al.*[3] *C Daylight*™ glasses† are intended to serve the same purpose, and we report spectral transmittance measurements for that filter and calculations related to the performance of the filter for Farnsworth's D15 test.

METHOD

The *Daylight* filter's spectral transmittance was measured on a Perkin–Elmer 550S Spectrophotometer whose wavelength scale was checked against Holmium and Didymium glass standards. Reflectance data for the D15 caps were provided by Prof. S. Dain. Calculations of chromaticities in the CIE 1976 UCS diagram of the three illuminants, C, A, and filtered A (fA), and of the D15 caps under these illuminants both before and after the von Kries adaptation correction were performed using MatLab software.

RESULTS, DISCUSSION, AND CONCLUSION

The spectral transmittance of the *Daylight* filter deviates increasingly from the ideal toward the ends of the visible spectrum: too low below 450 nm and too high above 690

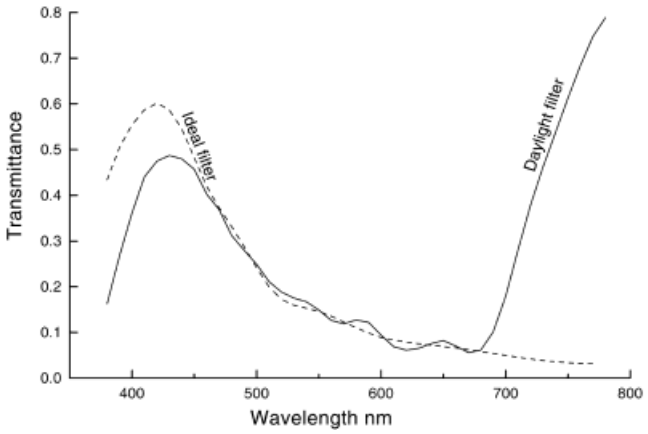

FIG. 1. Comparison of the *C Daylight* filter, measured on a Perkin–Elmer Spectrophotometer, with the *Ideal Filter*, computed as the energy ratio of Illuminant C to Illuminant A (multiplied by an arbitrary constant). The *Daylight* filter deviates increasingly from the *Ideal* toward the ends of the spectrum.

* Correspondence to: Prof. J. D. Moreland, MacKay Institute of Communication & Neuroscience, Keele University, Staffordshire, ST5 5BG UK (e-mail: coa09@keele.ac.uk)

† Available from Gulden Ophthalmics (e-mail: gulden@libertynet.org; www.libertynet.org/~gulden).

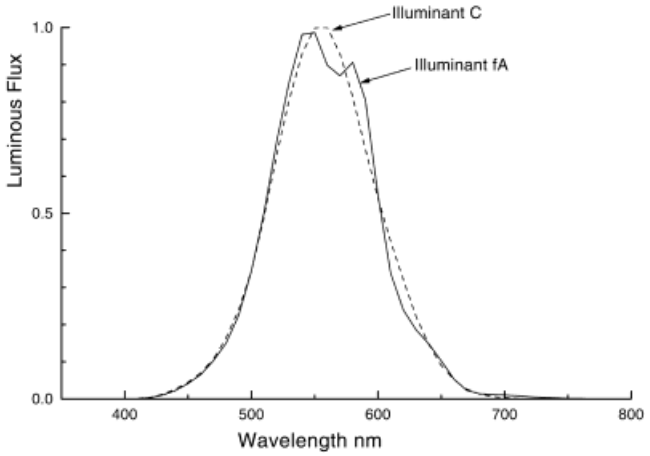

FIG. 2. Comparison of luminous fluxes for (broken line: normalized at its peak) Illuminant C and for (full line: scaled for equal areas under the curves) filtered Illuminant fA. This plot discounts the spectrum end deviations seen in Fig. 1, and gives greater weight to the mid-spectrum deviations.

nm (Fig. 1). In terms of luminous flux, however, differences between illuminants fA and C seem more significant in the mid-spectral region between 530–630 nm (Fig. 2).

A more appropriate insight into the filter's efficacy for color-vision testing is obtained by considering chromaticities under C, A, and fA in the CIE 1976 UCS diagram. The chromaticity of Illuminant A deviates from Illuminant C by about 13 JNDs (Fig. 3), while the filtered Illuminant fA deviates by only 1.6 JNDs[§]. Chromaticity shifts for the D15 caps are similarly disparate.

[§] The conversion used here (1 UCS unit = 154 JNDs) is based on the average of Wright's[4] "steps" in the D15 region of the chromaticity chart and adopting his assertion that one "step" is equivalent to 3 JND.

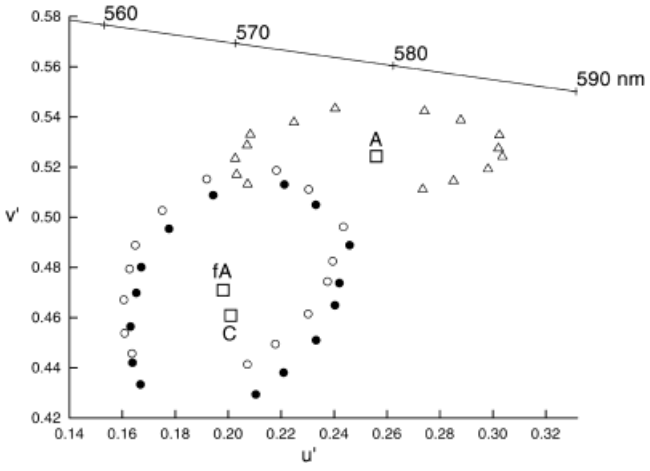

FIG. 3. Chromaticities of the D15 caps under Illuminants C, A, and filtered A (fA) in the CIE 1976 UCS diagram: (squares) illuminants; (filled circles) D15 under C; (empty circles) D15 under fA; (triangles) D15 under A. Illuminant A is displaced from C by 13 JND toward 583 nm on the spectrum locus, and fA deviates by 1.6 JND toward 563 nm.

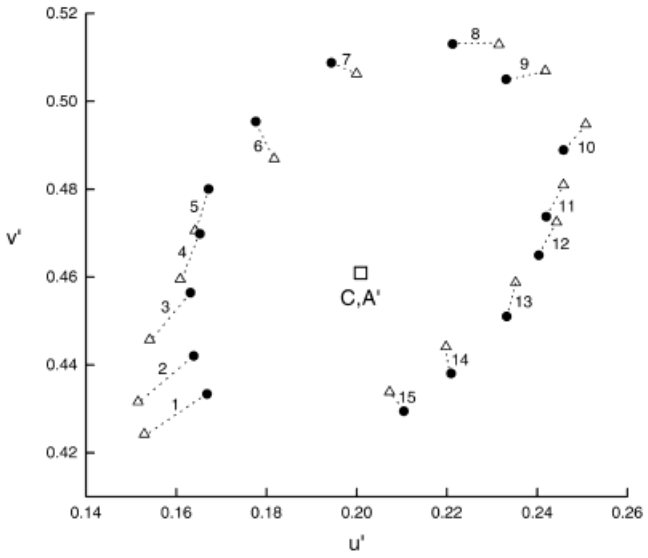

FIG. 4. Chromaticities of the D15 caps under Illuminants C and A following correction for von Kries adaptation: (square) Illuminants C and A′ (the von Kries corrected A); (filled circles) D15 under C; (empty triangles) D15 under A′. Distortions in the D15 locus approach 2.5 JND and may help some red-green color defectives to sort the caps correctly.

Taking C as the standard illuminant and allowing for von Kries adaptation to Illuminants fA and A, the D15 chromaticity shifts are greatly reduced. Those for fA are very small, but those remaining for Illuminant A are significantly larger, and the D15 locus retains a distortion in shape, which could help some red-green color defectives to sort the caps correctly (Fig. 4). This finding supports Schmidt's negative assessment of the use of incandescent lamps in color-vision testing.

The chromatic separation of adjacent caps is an important feature in the design of the D15 test (Fig. 5). Chromatic

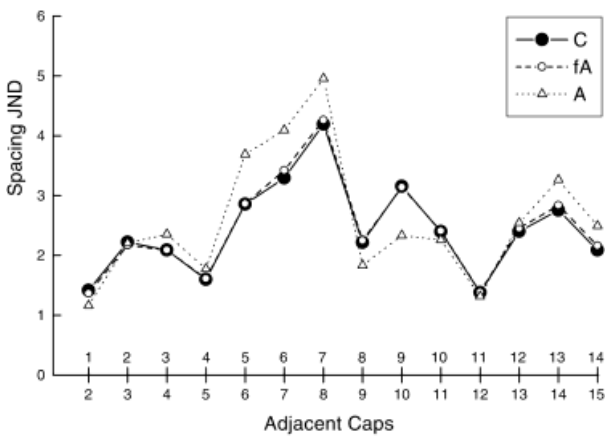

FIG. 5. Chromatic spacing between adjacent D15 caps under Illuminants A, fA, and C after allowing for von Kries adaptation to the Illuminants A and fA. Cap spacing under the filtered Illuminant fA correlates very well with that under C ($r^2 = 0.997$) with a maximum deviation of +0.1 JND, while that under Illuminant A shows large deviations approaching ±1 JND.

spacing under Illuminant fA correlates very well with that under C ($r^2 = 0.997$) with a maximal deviation of only 0.1 JND. By comparison, the spacing for Illuminant A shows deviations approaching 1 JND. None of the deviations of the *Daylight* filter from the ideal are colorimetrically significant for the D15 test, and we conclude that the filter conversion from Illuminant A to Illuminant C is satisfactory.

1. Schmidt I. Effect of illumination in testing color vision with pseudo-isochromatic plates. J Opt Soc Am 1952;42:951–955.
2. Pokorny J, Smith VC, Lund D. Technical characteristics of "Color Test Glasses." Mod Probl Ophthalmol 1978;19:110–112.
3. Higgins KE, Moskowitz–Cook A, Knoblauch K. Color vision testing: An alternative "Source" of Illuminant C. Mod Probl Ophthalmol 1978;19:113–121.
4. Wright WD. Characteristics of normal and defective colour vision. London: Kimpton; 1946 (Fig. 114, p 187).