

LETTER TO THE EDITOR

Dear Editor:

I enjoyed the recent article by Burns, Cohen, and Kuznetsov, "Multiple Metamers: Preserving Color Matches under Diverse Illuminants" (*Color Res. Appl.*, **14**, 16–22 (1989)). The authors bring the power of linear algebra elegantly to bear on the problem of computing finding surface reflectance functions that are metameric under multiple illuminants. They note in their discussion that the same method may be used to solve the the problem of finding different illuminant spectral power distributions such that the receptor responses to light reflected from a given surface will be the same under any of the illuminants.

If the receptor responses to the light reflected from a surface generates are the same under two different illuminants, then changing the illuminant from one of these to the other can have no affect on the color appearance of the surface. Thus understanding when different illuminants have this property is of considerable relevance to understanding how surface color appearance will vary under changing illumination. Only illuminant variation that causes the light reflected from surfaces to generate different receptor responses need be considered in a study the effect of illumination on surface color appearance.

Wandell, Cowan, and I recently analyzed the conditions under which illuminant variation will cause no change in surface color appearance (Brainard, Wandell, and Cowan, "Black Light: How Sensors Filter Spectral Variation of the Illuminant," *IEEE Trans. Biomed. Eng.*, **36**, 140–149 (1989)). In our analysis we show that for any ensemble of surfaces, any illuminant can be expressed as the sum of two components. The visible component of an illuminant is analogous to what Burns et al. call the fundamental metamer of a color signal. The black component of an illuminant is

analogous to what they call the residual of a color signal. We show that only the visible components of illuminants need be considered when studying the change of surface color appearance under illuminant variation. The decomposition of an illuminant into its visible and black components depends both on the receptor responsivities and on the ensemble of surfaces. For reasonable models of naturally occurring surfaces and illuminants, we show that there is a substantial black component in daylight variation. In our paper, we also consider the machine vision problem of optimally designing sensor spectral responsivities.

Although the formal development of our method is quite different from that of Burns et al., the two approaches are very similar in spirit. Both methods work because of the linearity of the physical process of the reflection of lights by surfaces and the linearity of initial encoding of light by the receptors that allows both methods to work. This linearity has also been exploited extensively in recent work on computational approaches to color constancy (Brill, "A Device Performing Illuminant-invariant Assessment of Chromatic Relations" *J. Theor. Biol.*, **71**, 473–478 (1978); Buchsbaum, "A Spatial Processor Model for Object Color Perception," *J. Franklin Inst.*, **310**, 1–26 (1980); Maloney and Wandell, "Color Constancy: A Method for Recovering Surface Spectral Reflectance," *J. Opt. Soc. Am. A*, **3**, 29–33 (1986)).

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