Metamer Mismatch Volumes of Flat Grey

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Abstract

Metamer mismatching refers to the fact that two objects reflecting light causing identical colour signals (i.e., cone response or XYZ) under one illumination may reflect light causing non-identical colour signals under a second illumination. As a consequence of metamer mismatching, two objects appearing the same under the first illuminant can be expected to appear different under the second illuminant. Metamers of the flat grey reflectance (i.e., 50% across the visible spectrum) are of particular interest since they show the potential seriousness of metamer mismatching. Metamer mismatching of flat grey is very significant for some lights and includes the possibility of 20 objects having the same colour signal as flat grey under red light dispersing into a whole hue circle under a neutral ("white") light. Flat grey under LED illumination is also shown to have a significant metamer mismatch volume when the light is changed to D65.

Introduction

As a result of metamer mismatching two objects appearing as having the same colour under one illuminant can appear as having different colours under a second illuminant. In fact, a single colour under a first illuminant projects into a volume of potential colours under a second illuminant known as its *metamer mismatch volume.* A metamer mismatch volume is a convex body, and as such, it is fully determined by its boundary surface. A theory and associated algorithm have been proposed to evaluate metamer mismatch boundary surfaces [1]. That algorithm evaluates the theoretical limits of metamer mismatching, that is, the maximum amount of potential metamer mismatching that can occur for any given colour signal. Specifically, given a particular colour signal (e.g., XYZ) under one illuminant, the algorithm computes the boundary of the volume into which it spreads due to metamer mismatching under a given second illuminant.

It is frequently believed that metamer mismatching is not all that serious, however, we have found that metamer mismatch volumes can be quite large, even for the case of a flat grey reflectance illuminated by an LED and then relit by D65. Fig.1 plots the spectra of the LED and D65. Fig. 2 shows the metamer mismatch volume inside the object colour solid. Fig. 3 shows the set of chromaticities, referred to as the metamer mismatch area, for the points inside the metamer mismatch volume.

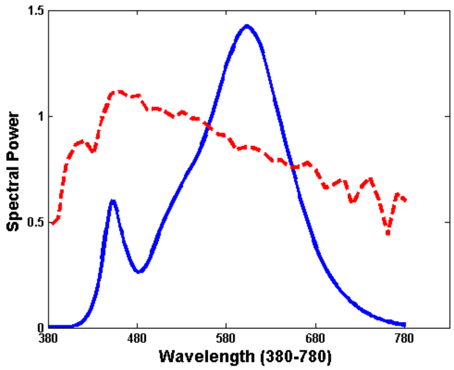

Figure 1 Spectra of LED "white" light (solid blue) and CIE D65 (dashed red).

Logvinenko et al. [1] proposed as a measure of the degree of metamer mismatching, the ratio of the volumes of the metamer mismatch volume to the volume of the object colour solid, as well as a similar measure of the relative areas of the chromaticity mismatch area to that of the chromaticity space. For the LED to D65 volume shown in Fig. 2, the metamer mismatch volume index

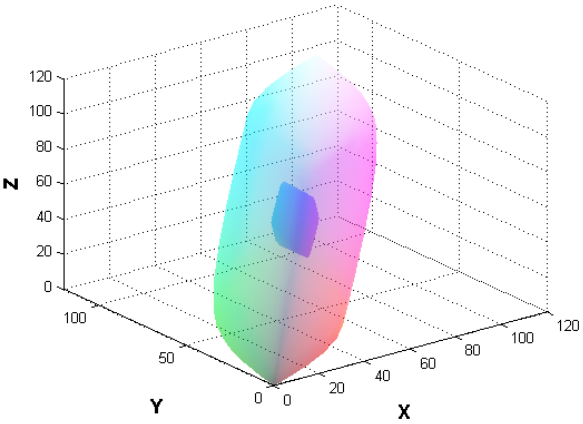

Figure 2 Metamer mismatch volume of flat grey for a change in illuminant from LED to D65.

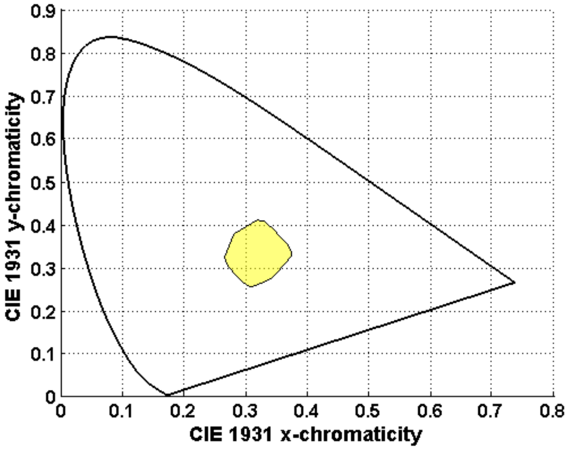

Figure 3 Metamer mismatch area (yellow) in the CIE xy chromaticity diagram for the case of flat grey for a change in illuminant from the LED to D65.

is 0.010, and the metamer mismatch area index is 0.033, both of which are significant. Since volume changes as a function of the cube of a linear scaling, the cube root of the metamer mismatch volume index, 0.22 in the present case, provides additional intuition as to the relative size of the volumes. In other words, the relative “scale” of the metamer mismatch volume in Fig. 1 is 22% that of the object colour solid.

Metameric Hue Circle

In the case of the chromaticity metamer mismatch area (Fig. 2) the area surrounds (1/3,1/3) so there are points within the metamer mismatch volume whose chromaticities include many hues, although they will not be very saturated. However, for more strongly coloured lights, the set of points will form a hue circle of quite saturated colours. For example, in the case of the flat grey reflectance under a red light and then a neutral light (see [2] for the spectra of these lights) the metamer mismatch volume is very large, with 0.20 as its metamer mismatch index, or 0.58 as the cube root of the index. Under the neutral light, 28% of the 1600 Munsell papers reflect light having CIE XYZ tristimulus values that fall into the metamer mismatch volume in question. While papers from this subset of the Munsell collection are by no means metameric to the flat gray under the red illumination, these Munsell papers represent the colours of a subset of the objects whose XYZs fall within the metamer mismatch volume. In other words, they indicate the range of colours that metamers to the flat grey reflectance under the red illumination can disperse into under the neutral illumination. As can be seen from Fig. 4, this range is very large. This figure, in fact, includes Munsell papers coming from every second page of the Munsell book of Colour. Note their significant Munsell Chroma. It is quite surprising that metamer mismatching can occur to such a large degree that it can lead to the possibility of 20 objects having the same colour as the flat grey reflectance under a red light that then disperse into a whole hue circle of colours under a neutral light.

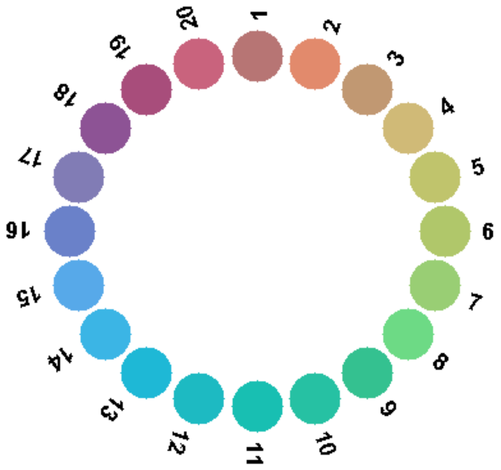

Figure 4 Pictorial representation of the 20 Munsell papers (5R6/8, 10R7/10, 5Y7/6, 10YR8/6, 5Y8/6, 10Y8/6, 5GY8/6, 10GY8/8, 5G7/8, 10G7/8, 5BG7/8, 10BG7/8, 5B7/8, 10B7/8, 5PB7/8, 10PB6/10, 5P6/8, 10P5/12, 5RP5/12, 10RP6/12) lying inside the metamer mismatch volume for a change from red illumination to neutral illumination.

Conclusion

Metamer mismatching can potentially be very serious. Of course, the examples given here represent the worst-case effects of metamer mismatching. One might argue that such situations will never occur in practice. However, until we have a good theory as to why the worst-cases can never occur they need to be taken into account.

References

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