Comparative analysis of the New Deviate Observer (JF-DO) against the metameric reflectances for the CIE-1931 Standard Observer and the CIE-1989 SDO

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ABSTRACT

Recently, in our laboratories, a set of color-matching functions (cmf's) has been formulated for small fields by using two groups of real observers: JAM, MM, CF and AY, JR, MR, JL, JA, FP. The measurements of these cmf's have been made using different experimental devices and methods and it has enabled us to propose a New Deviate Observer for small fields (JF-DO). This new Jf-DO was derived from the average observer of our 9 real observers, following the technique used by the CIE to establish the Standard Deviate Observer (CIE-1989-SDO), which was established for fields of 10º, despite that the CIE assumes that it can be applied to smaller fields. In the present work, we report experimental results of the JF-DO using metameric reflectances in comparison to the CIE-1931 Standar Observer and to the CIE-1989-SDO.

1. INTRODUCTION

Some works assume, based on physiological causes of the variability of the cmf's of real observers, that deviate observers (DO) proposed for 10º fields are also applicable to smaller fields [1,2,3]. Previous works have shown the variability between the cmf's of some observers and certain discrepancies with respect to the CIE-1931 Standard Observer and the CIE-1989 SDO[4,5,6,7]. All this has given us the opportunity to obtain two new deviate observers[8,9] (Poza-SDO and JF-DO) with the use of the same technique used by the CIE[1], though the cmf's are referred to the new system of unreal primaries X'Y'Z' by the use of the new transformation matrix[10] T. Here, we present an analysis of the experimental behavior of the new JF-DO as opposed to the CIE-1931 Standard Observer, Poza-SDO and CIE-1989 SDO. For this, we followed the guidelines of the CIE[3], using metameric reflectances both for the CIE-1931 Standard Observer as well as for the CIE-1989 SDO.

2. METHOD

Two metameric reflectances for one observer (with a certain illuminant) will cease to be so if, for example, we change the observer. The color difference, ΔE, is evaluated in CIELAB space. The results on observers' metamerism gathered by the CIE, have provided a special metamerism index for evaluation, and a specific procedure for calculating the discrimination ellipse at 95% confidence-interval in a chromatic coordinate diagram, (u, v), from a pair of metameric reflectances for the CIE-1931 Standard Observer. This ellipse should include 95% of the chromaticity coordinates (u, v), which are derived from the discrepancies between the CIE-1931 Standard Observer and cmf's themselves of each of the real observers. In this sense, previous works[4,5] have shown some disagreements between classical observers and the CIE-1931 Standard Observer. Some of these differences have had a certain importance, particularly when using the Stiles-Burch cmf's for small fields.

Four reference reflectances were considered, following the recommendations of the CIE[11], each with a different color (blue, green, yellow and red, which we call b420, g400, y34 , and r57). We used the D65 simulated illuminant and the following observers: CIE-1931 Standard Observer, CIE-1989 SDO, Poza SDO, and JF-DO. The method followed to generate the metameric reflectances (given the observer and certain illuminants) from a reference reflectance was based on Fourier analysis.

As stated above, all the calculations, representations, etc, are given in our reference of unreal primaries X'Y'Z' to avoid having negative values in any color space.

Considering the CIE-1931 Standard Observer, we have 4 reference reflectances: b420, g400, y34 and r57. From each one, we generated three metameric reflectances; thus, for the reference reflectance b420, the three metamers are b420_m1, b420_m2 and b420_m3, and so on. The metameric reflectances for CIE-1989-SDO which were generated in the same way. Figure 1 provides a clear and representative example of the general case described above. With the use of the observers Poza-SDO and JF-DO, the reflectances were no longer metameric, giving different chromaticity coordinates (u' v') for each observer. Following the CIE[3] procedure, we obtained, for all the color hues considered, 24 different ellipses at 95% confidence (6 different ellipses for each color hue corresponding to each reference reflectance).

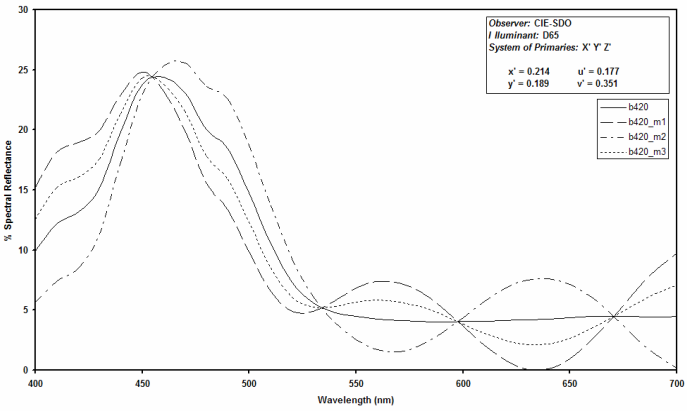

Figure 1: Reference reflectance b420 and its metamers obtained by the Fourier method.

3. RESULTS AND CONCLUSIONS

We have compared the results between observers on using the metameric reflectances for the CIE-1931 Standard Observer and for the CIE-1989-SDO. Table 1 show the chromaticity coordinates (x' y') and (u' v') of the reference reflectances (b420) and of the metamers generated (b420_m1, b420_m2, b420_m3), for each of the observers studied (CIE-1931, JF-DO, Poza_SDO, CIE-1989-SDO). As stated above, the reflectances were metameric for the CIE-1931 Standard Observer but not for the rest the observers: CIE-1989-SDO, Poza-SDO, and JF-DO.

Following the CIE procedure, we paired each group of reflectances considered metameric for the CIE-1931 Standard Observer and calculated the corresponding ellipses at 95% confidence-interval. For each hue, we plotted 6 different ellipses, and, as there were 4 different hues, we

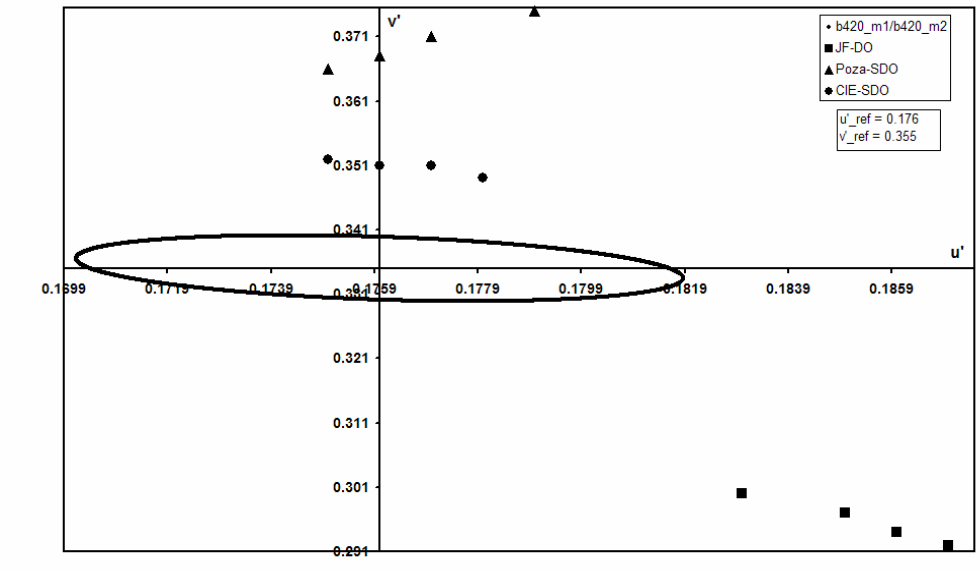

Figure 2: Ellipse generated for the pair of the metameric reflectance of the reflectances b420_m1/b420_m2 for the CIE-1931 Standard Observer and the chromaticity coordinates of these reflectance for the JF-DO, Poza-SDO and CIE-1989-SDO.

calculated a total of 24 separate ellipses.

The equation of the ellipse was:

$$\sum^{11}(\Delta u'')^2 + 2\sum^{12}(\Delta u'')(\Delta v'') + \sum^{22}(\Delta v'')^2 = \chi^2(2,0.05) = 5.991$$

where the $\sum^{ij}$ are the matrix elements to be compared, $\chi^2(2,0.05) = 5.991$ is 5% of the Chi-squared distribution for 2 degrees of freedom, and

$$u'' = \frac{4X}{X + 15Y + 3Z}$$

$$v'' = \frac{9Y}{X + 15Y + 3Z}$$

Table 1: Chromaticity coordinates of the reflectance b420 and their metamers b420_m1, b420_m2 and b420_m3 for the CIE-1931 observer

OBSERVER			**Chromaticity coordinates**			
CIE-1931	**Reflectance**		***u'***	***v'***	***x'***	***y'***
	b420	0.176	0.335	0.214		0.193
			Chromaticity coordinates			
	Reflectance		***u'***	***v'***	***x'***	***y'***
JF-DO	b420	0.185	0.297	0.199		0.142
	b420_m1	0.187	0.292	0.199		0.138
	b420_m2	0.183	0.300	0.199		0.145
	b420_m3	0.186	0.294	0.199		0.140
			Chromaticity coordinates			
	Reflectance		***u'***	***v'***	***x'***	***y'***
SDO-Poza	b420	0.177	0.371	0.224		0.209
	b420_m1	0.175	0.366	0.219		0.203
	b420_m2	0.179	0.375	0.228		0.212
	b420_m3	0.176	0.368	0.221		0.205
			Chromaticity coordinates			
	Reflectance		***u'***	***v'***	***x'***	***y'***
SDO-CIE	b420	0.177	0.351	0.214		0.189
	b420_m1	0.175	0.352	0.212		0.190
	b420_m2	0.178	0.349	0.214		0.187
	b420_m3	0.176	0.351	0.213		0.189

The centers of each of ellipses corresponded to the chromaticity coordinates (u', v') in common for each pair of reflectances considered in calculating each ellipse, as these reflectances were metameric for the CIE-1931 Standard Observer.

The most notable result of this study was to show the high variability between the observers considered here when they perceive a given color, and on the other hand, except for one ellipse, none of the 23 other ellipses covered any of the chromaticity coordinates (u' v') when using the cmf's of the rest the observers. This shows a strong discrepancy with the respect to the CIE[3] procedure. Figure 2 provides a clear and representative example of the general case described above. The center of the ellipse corresponds to the common coordinates (u' v') for the CIE-1931 Standard Observer. Furthermore, the results show that the new JF-DO observer provides chromaticity coordinates (u',v') that are far from the center of the ellipse than do when using the other observers. However, those chromaticities align quite good with the longer semi-axis of the ellipse, as well as those from CIE-1989 SDO, than do the chromaticities obtained with Poza-SDO.

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