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CIE Central Bureau
Babenbergerstrasse 9
A-1010 Vienna
Austria
Tel.: +43 1 714 3187
e-mail: ciecb@cie.co.at
www.cie.co.at

SEMANTIC INTERPRETATION OF THE CIE 2017 COLOUR FIDELITY INDEX

Bodrogi, P., Guo, X., Khanh, T. Q.
Technische Universität Darmstadt, Laboratory of Lighting Technology, Darmstadt, GERMANY
bodrogi@lichttechnik.tu-darmstadt.de

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Abstract

The CIE 2017 Colour Fidelity Index (R_f) was defined as a scientifically accurate measure of colour fidelity with respect to a reference illuminant. The present paper deals with the interpretation of the different R_f values on its numeric scale in terms of categories based on a psychophysical experiment. The question is which specific R_f value corresponds to a “very good” or a “good” visual colour fidelity impression. The “good” R_f level represents a psychophysically relevant user acceptance criterion to design a spectrum for e.g. a working environment in which colour fidelity is still an important colour rendition aspect.

Keywords: Colour Fidelity Index, R_f, semantic interpretation

1 Introduction

The CIE 2017 Colour Fidelity Index (R_f) was defined as a scientifically accurate measure of colour fidelity with respect to a reference illuminant (CIE, 2017). After reading the Technical Report CIE 224:2017, the present authors identified the following technical issue that required further research: How can we define specific values on the numeric scale of R_f corresponding to “very good”, “good”, “moderate”, “poor” and “bad” colour fidelity?

The criterion value of R_f corresponding (in average) to the “good” subjective colour fidelity impression of the observers ($R_{f,crit}$) in a psychophysical experiment can be used by lighting engineers as an *acceptance criterion* value by optimizing or evaluating a spectrum.

To obtain these specific R_f values, we carried out a visual psychophysical colour fidelity experiment. Observers scaled their subjective impression of the similarity of the colour appearance of a set of real (natural, not artificial) coloured objects under a test light source and a reference light source under four different correlated colour temperatures (CCTs). Spectra were provided by a stabile, high-end, high-power RGBW LED engine. The reference light source was the one with the maximum possible R_f value at each CCT obtained by optimising the RGBW driving values of the four LED channels.

2 Experimental Method

An interval scale between 0 and 100 (called visual colour fidelity scale or VCF scale) was used. This interval scale was labelled at certain specific values by the following rating categories: excellent, very good, good, moderate, poor, bad, very bad. 34 observers rated their visual colour fidelity impressions on this scale. The observers' task was to rate their colour fidelity impressions on the VCF scale according to the following question: How similar is the colour appearance of eight real (i.e. natural, not artificial) coloured objects (orange, lemon, banana, purple onion, lettuce, blue-lilac rose, red rose, own hand) arranged on a table with a white cloth (see Figure 1) under the test light source to their colour appearance under the reference light source by considering all objects at the same time?

The LED light engine (red, green, blue, warm white) provided 36 spectra at different R_f values between 58 and 93 at four CCTs, 3100 K, 4100 K, 5000 K, 5600 K (see Table 1) at the fixed luminance value of the white table cloth (see Figure 1) of 242 cd/m^2. One spectrum (with the maximum possible R_f value at each CCT) was considered as reference at each CCT.

Figure 1 – Arrangement of seven coloured objects in the psychophysical experiment illuminated by the LED light engine. The 8th object was the subject's own hand (not depicted)

Table 1 – Colorimetric properties of the 36 spectra (in the randomised order of presentation) generated by the LED light engine. Δ*u'v'*: distance from the white point of the reference light source (bold numbers)

No.	CCT (K)	Δ*u'v'*	CIE R_a	CIE R_f	No.	CCT (K)	Δ*u'v'*	CIE R_a	CIE R_f
1	3100	-0.002	80.6	88.1	19	5000	-0.001	66.5	77.0
2	**3100**	**0.001**	**96.4**	**93.1**	20	5000	-0.001	86.3	87.2
3	3100	-0.002	64.5	79.0	21	5000	-0.002	78.7	83.7
4	3100	-0.001	89.3	92.1	22	5000	-0.001	60.8	73.8
5	3100	0.000	82.6	83.9	**23**	**5000**	**-0.002**	**93.9**	**89.2**
6	3100	-0.002	56.6	74.4	24	5000	-0.003	90.1	88.6
7	3100	-0.002	29.2	58.6	25	5000	0.000	41.5	62.9
8	3100	0.000	90.8	89.3	26	5000	0.000	73.2	80.6
9	3100	-0.002	73.2	84.0	27	5000	0.001	92.9	88.0
10	4100	0.000	73.1	81.3	28	5600	0.001	59.0	71.2
11	4100	0.000	95.4	89.6	29	5600	0.002	65.2	74.7
12	**4100**	**0.000**	**94.8**	**90.4**	30	5600	0.002	93.0	87.0
13	4100	-0.002	91.2	87.2	**31**	**5600**	**0.001**	**94.1**	**87.7**
14	4100	0.000	87.0	88.0	32	5600	0.003	85.1	84.8
15	4100	0.000	80.1	84.9	33	5600	0.000	47.8	64.8
16	4100	0.000	58.6	73.2	34	5600	0.002	90.7	86.9
17	4100	-0.002	39.8	62.9	35	5600	0.002	79.1	81.9
18	4100	-0.001	66.1	77.5	36	5600	0.000	72.7	78.5

One of the eight test light sources was switched on for 15 seconds and then the reference light source was shown for another 15 s. This procedure was carried out twice. Then, observers had to rate their similarity impression on the VCF scale. After changing CCT, a 2 minute re-adaptation period was included. Both the four CCTs and the nine spectra within a CCT were shown in a randomised order. The categories on the VCF scale had the following values: ‘excellent’ 97.9; ‘very good’ 91.6; ‘good’ 79.6; ‘moderate’ 52.9; ‘poor’ 41.2; ‘bad’ 26.5; and ‘very

bad' 12.8. These specific values of the interval rating scale at the categories resulted from a previous study (Bodrogi et al., 2014).

3 Results

The mean visual colour fidelity scale (VCF) values of the observers were depicted as a function of R_f at each CCT. The reference light source was also compared with itself (without the knowledge of the observers). The reference obtained "excellent" similarity ratings in case of every CCT (VCF>98.1). S-type fit curves ($a + b / [1 + (R_f / c)^d]$ with optimised a, b, c and d parameters) were fitted to the resulting mean VCF(R_f) data points at every CCT, see Figure 2.

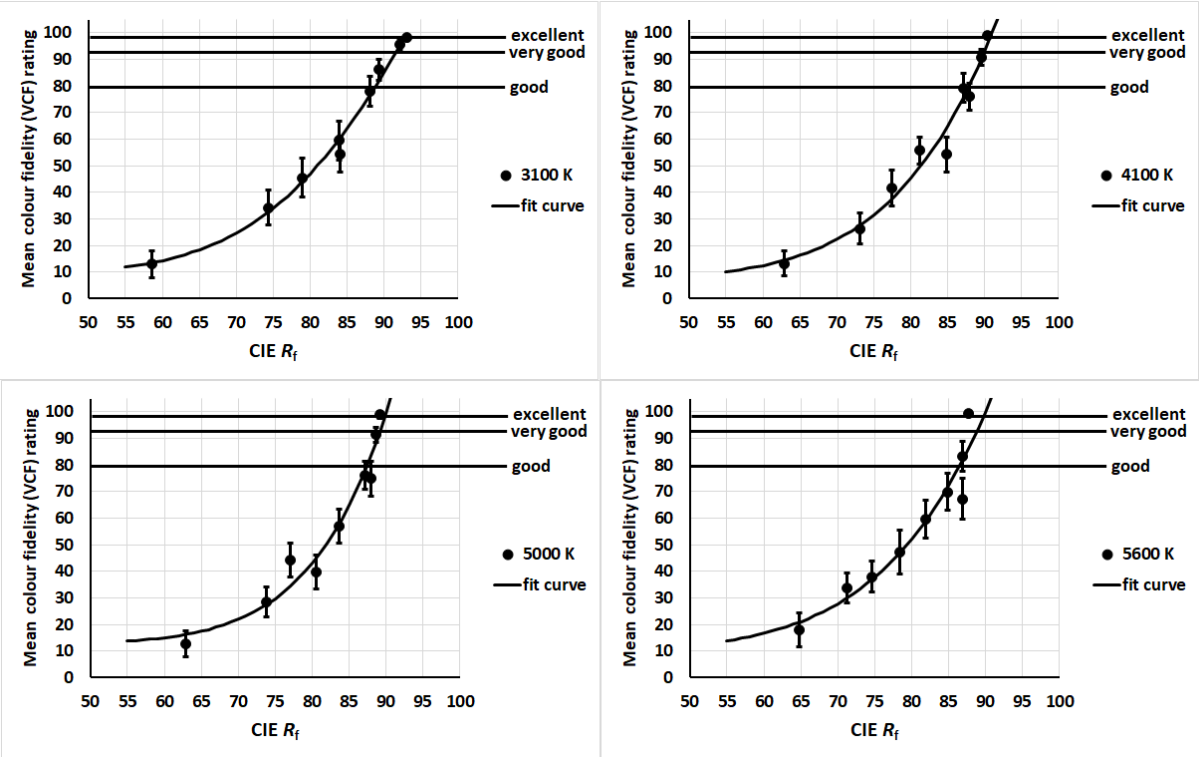

Figure 2 – Mean visual colour fidelity scale (VCF) ratings of all 34 observers with 95% confidence intervals and S-type fit curves (a + b / [1 + (R_f /c)^d])

Specific R_f values corresponding to the categories 'excellent' (VCF = 97.9), 'very good' (VCF=91.6) and 'good' (VCF=79.6) were calculated from the fit curves of Figure 2. In an application, changing the driving values of e.g. the red, green, blue and warm white LEDs of a four-channel LED light engine, the lighting engineer should achieve at least the value of R_f=$R_{f,crit}$(CCT) corresponding to the category 'good' for general user acceptance i.e. "good" colour fidelity. Table 2 contains the R_f values obtained at the above mentioned specific values of the VCF scale at the categories 'excellent' (VCF = 97.9), 'very good' (VCF=91.6) and 'good' (VCF=79.6).

Table 2 – R_f values obtained from Figure 2 at the specific values of the VCF scale at the categories 'excellent' (VCF = 97.9), 'very good' (VCF=91.6) and 'good' (VCF=79.6).

CCT (K)	'excellent' (VCF = 97.9)	'very good' (VCF=91.6)	**'good' (VCF=79.6) $R_{f,crit}$**
3100	92.7	91.4	**88.8**
4100	90.7	89.8	**87.8**
5000	89.8	89.1	**87.4**
5600	89.7	88.7	**86.5**

Observers were also asked to prioritise the eight objects according to their relevance in terms of making a judgement about the similarity of colour appearance. They had to assign the numbers 1 (highest), 2, 3, 4 and 5 (lowest) only to five objects (to those considered most relevant) out of the entire set of eight objects. The following median values (in parentheses) were obtained: orange (1), red rose (2), own hand (3); lemon, banana, lettuce, blue-lilac rose (4), purple onion (5). This finding emphasizes the role of orange-red objects in making visual colour fidelity assessments.

4 Discussion

Besides other aspects of colour rendition (e.g. colour preference, colour vividness, etc.), colour fidelity is still an important aspect for those lighting applications that require a neutral environment e.g. official working situations with high colour naturalness. If the criterion $R_f > R_{f,crit}$ is fulfilled then one also obtains good colour discrimination and good visual clarity provided that the illuminance level is high enough.

The present results are valid for this specific RGBW LED light engine. Although its four LED channels are able to produce spectra with outstanding colour fidelity (as a reference light source) in order to provide the category “excellent” for every CCT, further experiments are necessary with multi-LED light engines comprising more than four LED channels hence able to generate even higher maximum R_f values.

References

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