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J. J. EMBRECHTS
Montefiore Institute
University of Liège
Belgium

COLOUR RENDERING UNDER THE COMBINATION OF DAYLIGHT AND ARTIFICIAL LIGHT

Many interiors are lit by daylight and artificial light, and the CIE colour rendering index (CRI) of the artificial source alone is not a characteristic of the complex situation. Indeed, coloured objects in this situation are illuminated by a combination of illuminants which is not uniform in space, and which is varying with time. So, it seems interesting to analyse the distribution of the CRI in the lighted space.

First, a typical situation is defined. The artificial *relative* spectrum is assumed to be independent of time and space. The daylight relative spectrum is assumed to be independent of space, at a given time "t". The interreflections of light do not influence the colour rendering. The visual field is simplified as it is usually done in colour rendering experiments : the coloured object is seen on a neutral background and receives a natural (E_N) and an artificial (E_A) illuminances. Therefore, the relative spectrum variation in the interior is expressed by the proportion of the combination :

$$\alpha = \frac{E_N}{E_N + E_A} \tag{1}$$

An analysis of daylight spectra [1] showed that typical daylight could be represented by "D" illuminants. As the time dependence of the daylight spectrum is rather random (as it is influenced by the weather and the turbidity of the atmosphere), it is preferred here to consider typical spectra, rather than a rigorous sequence of daylight spectra. The diffuse component of clear sky is represented by standard D illuminant with colour temperature from 6000°K to 12000°K. The global radiation for a clear sky is represented by D5700K (since 97 percents of the analysed spectra were between 5200°K and 6200°K], and the overcast sky by D_{65}.

The CIE test-colour method [2] has been applied to the following spectral power distribution: :

$$s = (P,t,\lambda) = \frac{s_A(\lambda)}{Y_A} + \alpha(P,t)\left(\frac{s_N(\lambda)}{Y_N} - \frac{s_A(\lambda)}{Y_A}\right)$$

$$Y_A = 683 \int_{vis} s_A(\lambda)\ V(\lambda)\ d\lambda \qquad Y_N = 683 \int_{vis} s_N(\lambda)\ V(\lambda)\ d\lambda \tag{2}$$

It is the combination of the artificial (s_A) and the natural (s_N) relative spectra, at the location "P" of the coloured object, and at time "t". So, only the proportion a, expresssed by (1), depends on time and space and, moreover, it is always comprised between 0 and 1. The colour rendering of the artificial-daylight combination is therefore fully represented by the graph of the color rendering index $R_i(a)$, for the proportion $0 \leq a \leq 1$.

Several experiments has then been performed, applying the CIE test-colour method to nine typical artificial illuminants (H.P. sodium, H.P. mercury, incandescent and fluorescent lamps), and three typical daylight spectra (D5700K, D_{65} and D10000K). Figures will be shown that give examples of the results obtained, namely the colour rendering of some CIE test-colours under the combination of daylight and H.P. sodium light.

The conclusions of the experiments are the following :

- for high colour temperature artificial lights, which have (nearly) the same chromaticity as daylight, the dependence between the CRI and the proportion a is linear, which means that the colour rendering of the artificial-daylight combination is *always better* than the artificial light source alone (R_{iA}) :

$$R_i(a) = R_{iA} + \alpha\,(100 - R_{iA}) \qquad (3)$$

• significant non-linearities appear for artificial lights with colour temperature less than 3500°K (see fig. 1). However, these non-linearities often lead to a concave graph $R_i(a)$. Therefore, it can also be concluded that the colour rendering of the artificial-daylight combination is *often better* than the artificial light source alone.

• only if the artificial light source has excellent colour rendering properties, can one find combinations with lower colour rendering indices : the worse situation has been observed for the combination (a=0.5) of the incandescent lamp and D10000K, which leads to a general CRI of 91, instead of 100 for each source separately.

• These conclusions do not depend on the algorithm used to calculate the colour rendering indices [1]. Indeed, the experiments have also been carried out with the Nayatani chromatic adaptation transformation (instead of the Von Kries one), the CIELAB uniform colour space, and a fixed reference illuminant (which was the daylight component) : the conclusions were the same as above.

Possible applications of this study are the following :

• to readily obtain, from the calculation of the illuminances (E_A and E_N), the distribution of the colour rendering indices in a room lit by daylight and artificial light. The linear expression (3) can be used as a first approximation in most cases. This could be applied in the determination of the best locations for workstations, in conjunction with the visual comfort requirements;

• a statistical analysis of the variation of the colour rendering properties in those spaces, from the statistical distribution of daylight illuminances. For example, in reference [1], the yearly average colour rendering indices have been defined.

References

[1] EMBRECHTS, J.J., Color rendering of supplementary artificial lighting, *Color Research and Application*, **17**(3), 1992, 197-204;

[2] C.I.E. Publication n°13.2, Method of measuring and specifying colour rendering of light sources, *Central Bureau of the C.I.E.*, Paris (1974) (Corrected reprint, Vienna, 1988).