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# THE COMBINATION OF ILLUMINANTS AND ITS EFFECT ON COLOUR RENDERING

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## 1. INTRODUCTION

Working interiors are sometimes lit by luminous sources with different colour rendering properties : combination of natural and artificial lightings,combination of high pressure sodium and metal halide lamps in large industrial or sports halls,combination of incandescent and fluorescent lamps in shops and musea . Designing such lighting schemes,the lighting engineers or the interior architects are faced with the problem of predicting the colour rendering properties of the mixed luminous radiation .

In this paper,the influence of the combination of light sources on the general colour rendering index is analysed . It is intended to draw general rules and conclusions,not only for some particular lamps,but for all normal white illuminants . To achieve this,the parametric approach to colour rendering [1,2,3,4] is applied instead of the CIE method which is not suited for this general study . This new approach really improves the understanding of the phenomena .

## 2. THE PARAMETRIC APPROACH TO COLOUR RENDERING

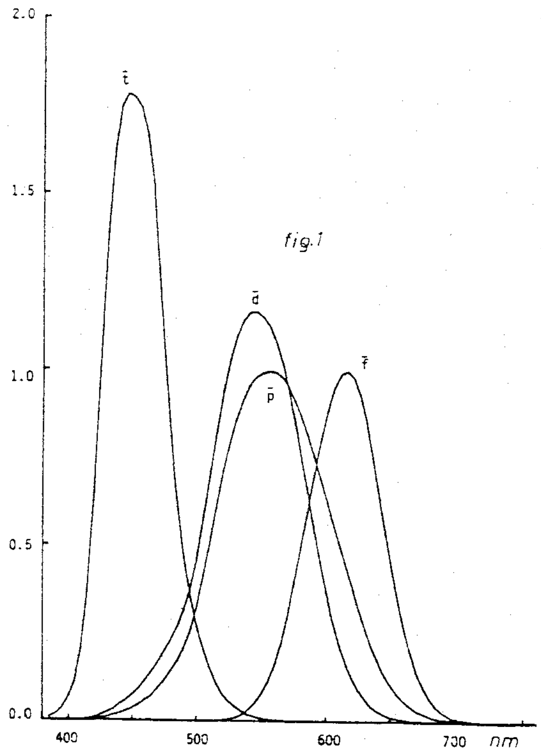
The classical CIE method[5] derives a general colour rendering index from the whole spectrum of an illuminant, that is about 80 data if the spectral power is given every 5 nm, from 380 to 780 nm. This is too much data for a clear relationship between the spectrum and its general colour rendering properties.

The parametric approach rather uses three spectral parameters of the illuminant $e(\lambda)$ :

$$B_y = \frac{1}{Y} \int_{vis} e(\lambda)\, \bar{t}(\lambda)\, d\lambda \quad , \quad Y = \int_{vis} e(\lambda)\, \bar{p}(\lambda)\, d\lambda$$

$$G_y = \frac{1}{Y} \int_{vis} e(\lambda)\, \bar{d}(\lambda)\, d\lambda$$

$$R_y = \frac{1}{Y} \int_{vis} e(\lambda)\, \bar{f}(\lambda)\, d\lambda \qquad (1)$$



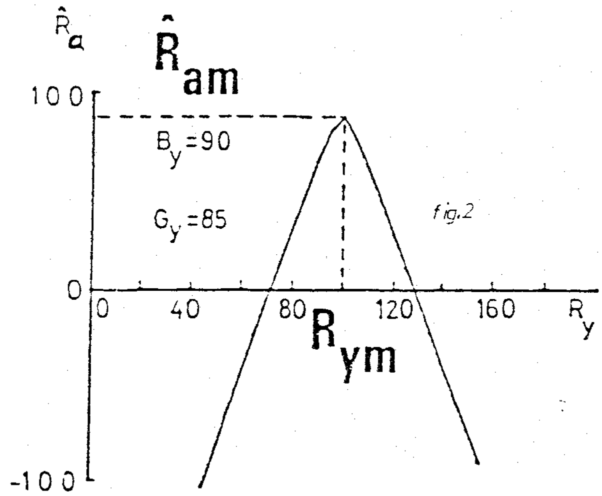




*Figure 1. Spectral tristimulus values $\bar{p},\bar{d},\bar{t}$ and band-pass filter $\bar{f}$.*
*Figure 2. $\hat{R}_a$ as a function of $R_y$ for $B_y$ and $G_y$ fixed.*

From figure 1, we see that $B_y$, $G_y$ and $R_y$ can be called respectively the blue, green and red parameters of the illuminant. $B_y$ and $G_y$ are exactly related to the chromaticity coordinates (x,y) of the spectrum and so, they represent the chromaticity of the illuminant.

An index $\hat{R}_a$ is derived from these three parameters [3,4]. Its mathematical expression is:

$$\hat{R}_a \approx 100 - \left[a^2 (R_y - R_{yM})^2 + (100 - \hat{R}_{aM})^2\right]^{1/2} \tag{2}$$

In this expression, a, $R_{yM}$ and $\hat{R}_{aM}$ depend only on the chromaticity ($B_y$ , $G_y$) of the illuminant. $\hat{R}_{aM}$ is the maximum available value of the index $\hat{R}_a$ at this chromaticity and $R_{yM}$ is the corresponding value of $R_y$ (figure 2).

The determination of $\bar{f}(\lambda)$ in (1) was such that it minimised the differences between the CIE and parametric indices of several normal white illuminants : fluorescent, incandescent, H.P. Mercury, Metal Halide, H.P. Sodium lamps and also daylight.

Since the correspondence between the two indices is fairly good for the usual illuminants, it is reasonable to think that the conclusions drawn in this paper could be extended to the general CIE index. To verify this, some examples will be presented.

## 3. THE COMBINATION OF TWO ILLUMINANTS : THEORY AND EXAMPLES

If the radiations of two illuminants are combined in the same interior, it is shown [3,4] that the spectral parameters of the combination are linearly related to the parameters of each illuminant, i.e. :

$$
\begin{aligned}
\hat{R}_a(\alpha) &= \hat{R}_a(B_y(\alpha), G_y(\alpha), R_y(\alpha)) \quad , 0 \leq \alpha \leq 1 \\
B_y(\alpha) &= B_{y1} + \alpha(B_{y2} - B_{y1}) \\
G_y(\alpha) &= G_{y1} + \alpha(G_{y2} - G_{y1}) \\
R_y(\alpha) &= R_{y1} + \alpha(R_{y2} - R_{y1})
\end{aligned}
\tag{3}
$$

In these equations, $\alpha$ is the proportion of the combination. It is physically interpreted as the ratio of illumination(lux) due to the second illuminant divided by the total illumination, at a point of the interior where the radiations are mixed.

General rules are formulated on the basis of this general model (3) and of equation(2). The main conclusions can be expressed as follows :

a) *The two illuminants are of the same or nearly the same chromaticity.*

In this case, the function $\hat{R}_a(\alpha)$ is concave (fig. 3). The maximum in $\alpha^*$ is comprised between 0 and 1, (physically significant) if one luminous source emits an excess of red radiations ($R_{yi} > R_{yMi}$) and the other a deficiency of red radiations ($R_{yi} < R_{yMi}$). The conditions are fulfilled in figure 3 : the first illuminant, a corrected "Special de luxe White" fluorescent lamp clearly shows an excess of red radiations in its spectrum whereas the second one, a "White" fluorescent lamp is deficient in red radiations, at this chromaticity (between 4000° K and 4500° K). Note the good correlation between $\hat{R}_a$ and the CIE index $R_a$ which is determined here by computer.

If the two illuminants are of the same categorie with respect to red radiations, $\hat{R}_a(\alpha)$ is nearly linear, as shown in figure 4;

b) *The chromaticities of the two illuminants are far from one another.*

In this case, the theory is a bit more complex. Two illuminants from different categories tend to form, in addition to a maximum, a local minimum between $\alpha=0$ and $\alpha=1$, more probably if both colour rendering indices are high. In figure 6, the convex part of the curve announces this minimum. Note that the chromaticities are here well different : 4500 ° K for the first illuminant and 2700 ° K for the second one. Note also that the "De luxe Home Comfort" fluorescent lamp has a small deficiency in red radiations with respect to the black body at this chromaticity.

If the two illuminants are of the same categorie, the function $\hat{R}_a(\alpha)$ is no longer linear. In general, the concavity is well marked and a local maximum may even appear, most probably

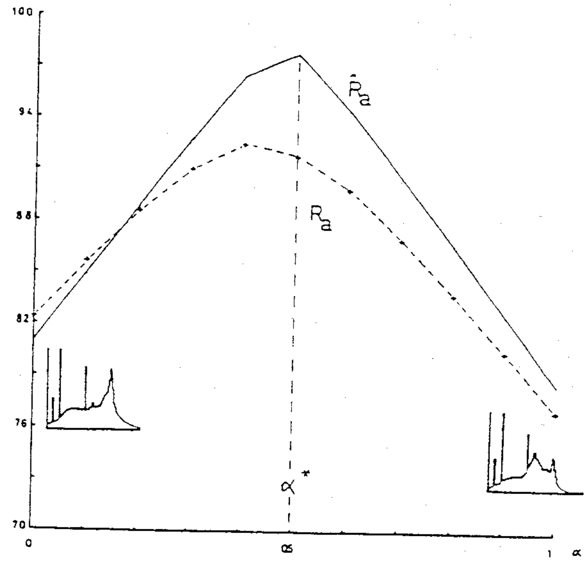



fig.3

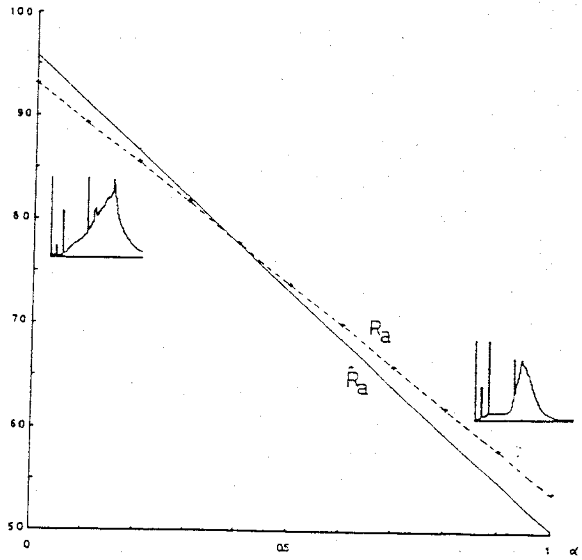



fig.4

*Figure 3. Combination of a corrected "Special de luxe White" and a "White" fluorescent lamps*
*Figure 4. Combination of a "De luxe Home Comfort" and a "Warm white" fluorescent lamps*

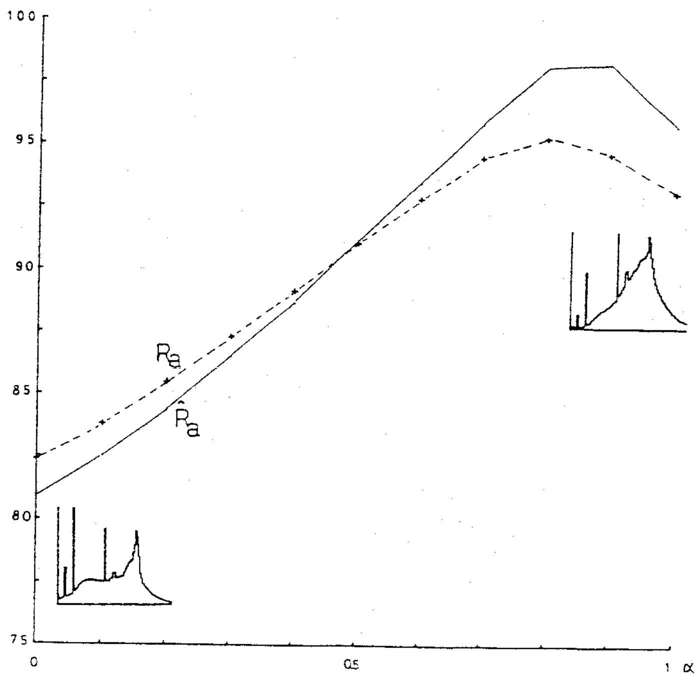


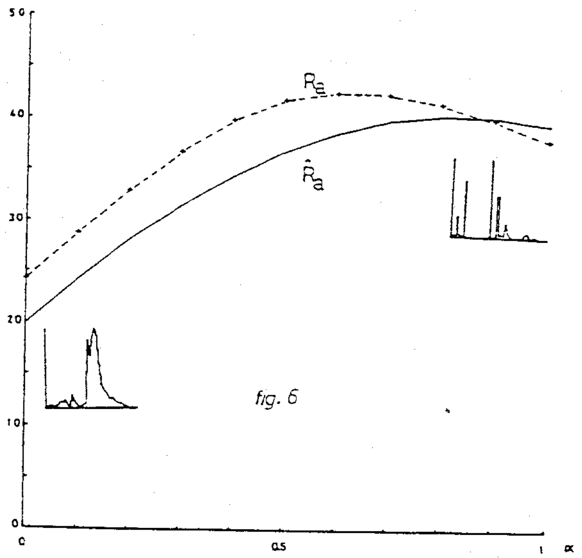

*Figure 5. Combination of a corrected "Special de luxe White" and a "De luxe Home Comfort" fluorescent lamps.*

if both colour rendering indices are of the same magnitude order (see figure 6 ). If moreover both colour rendering indices are high, the combination $\hat{R}_a(\alpha)$ shows a minimum between two maxima. In figure 7, the two maxima are in $\alpha = 0$ and $\alpha = 1$, and the minimum clearly appears.

A more detailed analysis can be found in references [3,4].

## 4) CONCLUSION

These simple rules, formulated on the basis of the parametric approach of colour rendering can help the lighting engineers and the interior architects in the design of coloured environments of great quality. In any case, care should be taken to avoid (if possible) combinations with a convex behaviour. On the contrary, concave behaviours are very interesting from an economical point of view.



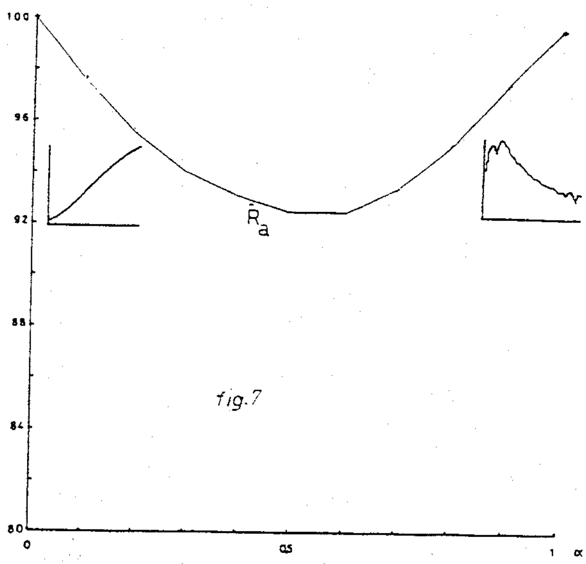




*Figure 6. Combination of a HP.Sodium lamp and a HP.Mercury fluorescent lamp.*
*Figure 7. Combination of the black body at 3000 °K and the D10000 °K illuminant.*

## 5) REFERENCES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