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An alternative methodology of light source spectral distribution selection for use in museums

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Abstract

An alternative methodology to select light source spectral distribution for use in Museums is presented. It is based in obtaining the Representative Spectral Reflectance Curve for each artwork and then lighting it with a light source which spectral power distribution is coincident in shape with the object´s RSRC. This should cause minimum damage due to radiation on the object, given that object deterioration due to radiation is an effect of absorbed energy. In order to evaluate presentation quality, colour differences were calculated for three primal colours present in an artwork sample, illuminated under Illuminants D65 and under a simulated illuminant which spectral power distribution matches the RSRC of the object. Also, colour differences were calculated between the same colours under D65 and under a CIE standard illuminant previously selected as having the closest spectral power distribution to the RSRC. Results are in general lower than 3, within the limit for strict tolerance in normal colour rendering.

1. Introduction

The current preservation protocol used in museum lighting is essentially based on the combined use of two criteria: the classification of objects according to their sensitivity to radiation damage and the policy of annual exhibition for preservation of radiation damage (CIE, 2004). Once you know that it is inevitable some degree of damage in any exhibition because of the physical phenomenon that produces (Thomson, 1994), it is necessary to have more precise information about the sensitivity to radiation damage of objects display, specifying as much as possible in their physical characteristics and prediction of their behavior in light and invisible radiation.

The hypothesis of this research is based on the possibility of obtaining a representative reflectance profile of an artwork. Illuminating an artwork with a source whose spectral emission profile is coincident, within experimental limits, with a representative profile of the illuminated object spectral reflectance, can minimize radiation damage, since the main deterioration factor is due to incident lighting, visible and invisible radiation absorbed. This would allow the maximum performance of the function of preservation. Additionally, the resulting visual stimulus interaction between the spectral emission profile of the source (SES) and the representative spectral reflectance curve of the artwork (RSRC), allows adequate enough color vision to fulfill the Presentation feature.

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2. Methodology

For the development of the methodology of acquiring spectral curves, it has been considered that a spectral reflectance curve is representative of a work of pictorial art, to the extent that it contains within itself the spectral information from different parts of the work, taking in account response to variations provided in the final configuration. To spectrally characterize a work of pictorial art, it is considered a random distribution of color on a surface. Factors which influence the measurement of the spectral curve characterization are essentially: that the number of measurements within the area survey the generality of the sectors with all the variations present in the area, and that the information obtained from different sectors take part proportionately in the final spectral curve (Araujo et al., 2010).

A. Definition and sample processing.

Sample: Reproductions of works of art, industrial printing on matte white card, A4 size. A first set of modern art was chosen the "Composition in Blue, Yellow and Red, 1921" by Piet Mondrian, called M1 and three works of Paul Klee, "Iron QU1 color" box, called M2; "Arkitecturder" hereinafter M3 and "Highway" or M4 (Fig. 1).

Fig. 1: Sample of artwork used for measurements

In the first phase, spectral reflectance measurements of the colors present in reproductions of artwork were made. The adopted approach has been measured in constant size, different colors and all the changes detected in the reproductions of artwork sufficient to establish an adequate characterization of it, in four quadrants, as shown in Figure 2.

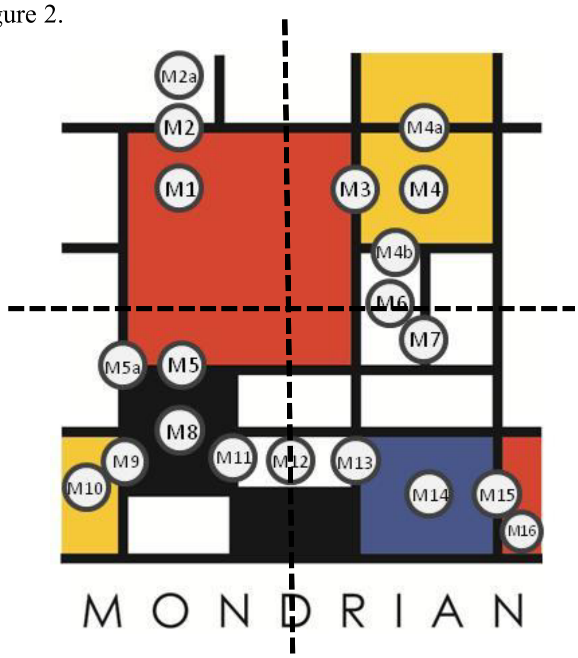

Fig. 2: Measurements taken within four quadrants in M1

Measurements were performed in a purpose built cabin, with white painted internal surfaces, smooth texture and a sample holder. The photo-spectroradiometer employed was Photo Research Spectrascan PR 715. The sources used for measuring were incandescent lamps fed with regulated 54 Amps electric current. Fig 3

Fig. 3: Sample measurement conditions

The acquisition of a methodology and interpretation of spectral reflectance profiles representative of an artwork, is the integration of the spectral information in a representative spectral reflectance curve (RSRC) for each copy of the samples.(Ribes et al, 2005c)

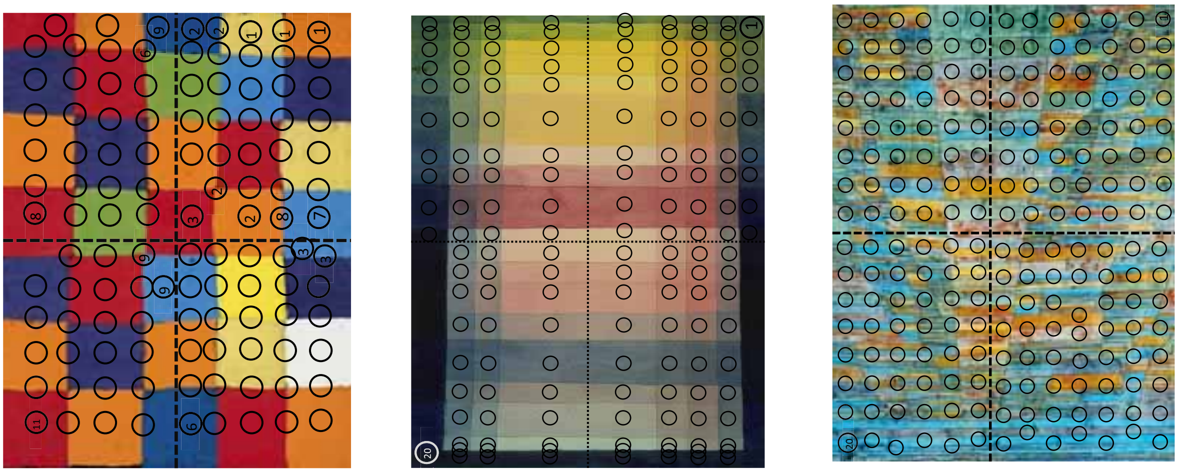

Fig. 4: Measurements taken within four quadrants in M2, M3, M4 respectively

Representative spectral reflectance curves (RSRC) of the samples were obtained. The procedure followed for the preparation of RSRC was performing an average of all and each of the spectral measurements in each of the quadrants in which the artwork reproduction was previously divided to give the spectral reflectance curve for each of the quadrants. Later they were averaged together to obtain the spectral reflectance curve (SRC) of each of the samples. At the time of weighing the value of each spectral measurement and its subsequent participation in the final integration of the curve of spectral reflectance, a criterion of double weighting was chosen: the first method used was to obtain a weighting area, considered as one who expresses the representativeness of each measurement of one or more colors depending on the total area of the object. The area weighting obtained for each measurement is then multiplied by the spectral profile of the corresponding measurement. With this process, a weighted value ratio of each of the measurements in the integration of spectral reflectance profile of each of the samples was obtained. The second method of weighting was obtained by analyzing the histograms of digital image reproductions. The criteria used was to relate the histogram distribution of RGB pixels in each of the measurements of the partial areas of the object, the proportion deducting such distributions within the RGB histogram represents the whole image of each object in the sample. The coefficient of pixels (CP) is multiplied then by the spectral profile of the measurements, obtaining a weighting ratio for each measurement, which is compared to the geometric method. From this emerges for each object in the sample its Representative Spectral Reflectance Curve (RSRC). Fig 5

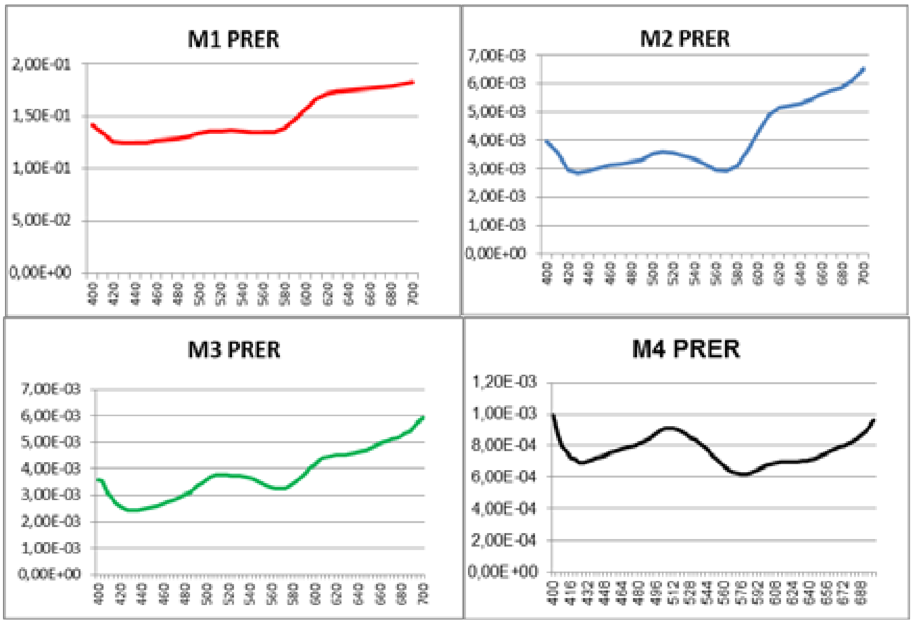

Fig. 5: Representative Spectral Reflectance Curves (R.S.R.C.) for the Samples.

B. Evaluation of the lighting according to the preservation and presentation.

One of the objectives of this research is to develop a method of selection and evaluation of CIE illuminant, in order to have a menu of illuminating profiles that can be loaded into an illuminating adjustable device, which would fulfill acceptably presentation and preservation missions to illuminate a displayed object. We used a standard assessment of the CIE illuminants consisting of the following:

a) To select C.I.E. illuminant spectral curves closely coincident in shape to the representative spectral reflectance curve (R.S.R.C) of the reproduction sample which is to be illuminated under the given illuminant in the simulation. In order to do so, a calculation method has been developed to establish the existing power gap between every C.I.E. illuminant and the R.S.R.C. of the sample to be illuminated. The power gap found for each case is called deteriorating factor. The lesser the deteriorating factor -power gap- between the two curves, a better preservation performance of the C.I.E. illuminant is to be expected (Miller, 2006).

b) To design four Illuminant curves based upon the representative spectral reflectance (R.S.R.C.) of the each sample (M1,M2,M3,M4) which shapes are coincident to the corresponding sample and are capable with an amount of emission power. Such designed illuminants are named MATCH 1, 2, 3 and 4, according to the sample from which they originate.

c) Given that the hypothesis of this work implies adequate comply of presentation, quality presentation of the sample colours have been evaluated as follows: CIEL*a*b* colour differences (CIE, 1976) have been calculated for the colours present in each sample under all C.I.E. and MATCH illuminants in comparison under C.I.E. illuminant D65, taken as reference illuminant for colour rendering measurements (Miller, 2006)

d) Design of the emission profile of an illuminant from representative spectral reflectance curve (RSRC) of each of the samples (M1, M2, M3 and M4), whose shape is identical and coincident to the RSRC of the corresponding sample, which is provided with an emission power. By illuminating the designed profile has been called MATCH 1,2,3 or 4, depending on the purpose of the sample from which its design.

Evaluating the quality of presentation of the colours present in the sample, illuminated by a spectral emission profile which comes from the selection of CIE illuminant or illuminant profile is designed as MATCH for the object. The criteria was as follows: to refer to the Iluminant D65 as illuminant which is most widely used for color measurements and the calculation of color difference in CIELAB (1976) units between the colors present in the sample, illuminated under the spectral emission profile of D65 and the same colors, illuminated profiles chosen from CIE illuminants.

The color difference was calculated between the colors of an object under the illuminant D65, compared with the same colors under Illuminant MATCH designed for that purpose

3. Results

After the calculations of color difference, the MATCH profiles 1,2,3 and 4 were introduced into a LED illuminator adjustable lamps and the corresponding power spectrum of the resulting spectral emission measurements on each case were performed. With the measurement results of the MATCH emission curve a calculation of color difference was made CIELAB color difference (1976) of the colors present in the object in the sample, under Illuminant D65 emission compared to the same colors on the measure emission from the illuminator charged with MATCH emission profile for the same object illuminated (Table 5).

Table 5: Results of color difference CIE L*a*b* (1976) for samples M1-4 under MATCH 1-4 and D65

SAMPLE M1	M1	M4	M14	
Calculation	3,22	2,24	1,27	
Experimental	3,64	2,69	1,38	
SAMPLE M2	M2 19	M2-47	M2b-20	M2c-12
Calculation	2,30	2,13	1,30	1,19
Experimental	3,07	2,56	1,89	1,39
SAMPLE M3	M3 c8	M3 45	M3 b6	M3 d5
Calculation	2,17	2,98	0,24	0,33
Experimental	2,19	2,98	0,25	0,33
SAMPLE M4	M4 a50	M4 e33	M4 g40	M4 c50
Calculation	0,22	0,11	0,44	0,06
Experimental	0,22	0,11	0,44	0,06

4. Contrast experiment

An experiment was proposed in order to compare the measurable damage in three reproductions of the M2 exposed to the emission of three different sources: a) An illuminating LED lamps adjustable device ; b) An incandescent lamp and; c) A fluorescent lamp.

The LED lamps' Illuminator was a purpose built one to be used in the experimental stage; it is an array of five LEDs lamps, three of them equivalent to RGB and two with an emission of white light, warm white and the remaining cold white, placed in a horizontally sliding support.

More specifically, the LED illuminator is provided with three RGB lamps emitted power in the spectral ranges 440, 520 and 640 nm. approx. Furthermore there is a lamp cool white and warm white LED add to smooth and homogenize the mixture. They are mounted on a luminaire provided a diffusion lens and aligned in a medium that allows overlapping emissions and moving along an axis.

The lamps are connected to a console capable of regulating each lamp independently and have the ability to record six scenes, or different modeled emissions.

Despite this, both the number of lamps, but the spectral range of their emissions, and also to some extent due to the degree of sensitivity of the regulation of the console has been found as an experimental boundary on the possibility to reproduce the emission profile match2 accurately, to illuminate the corresponding sample.

Fig. 6: LEDs' lamp adjustable device

The latter has led to a technological limitation in the ability to model the emission profile that best matches the RSRC M2. The compromise has been to the coincidence between the profiles of reflectance and emission as many points as it has been possible. Fig 7 shows a scale representation of M2 RSRC in relationship with each lamp spectral distribution.

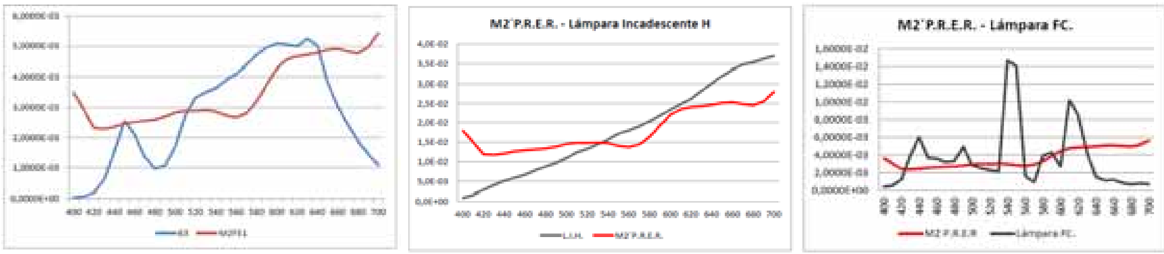

Fig. 7: RSRC of M2 compared with three different lamps

(Left: LEDs' lamp illuminator; Centre: Incandescent lamp; Right: Compact Fluorescent Lamp)

The plot in Figure 7 illustrates the relationship of only partial overlap between the Representative Spectral Reflectance Curve (RSRC) of M2, the sample selected for the pilot phase measurements, the spectral profile of the source emission in this case the LED Illuminator was designed by regulating the emission of its 5 LED lamps, and most points of agreement reached with the RSRC Reference M2 (Fig 7). Likewise, it has not been possible at all points of the range of the spectrum to have the emission value of the source to be less than the value given by the spectral reflectance curve of M2. Therefore we assumed in advance a certain value of deteriorating factor that can be calculated and evaluated after exposure, according to the color change produced in the exposed area, measured in terms of displacement field in the L * a *b.

The second lamp used in the experimental stage is enhanced by halide, incandescent 111 mm. in diameter mounted on a sliding bracket. It is the most widely lamp used in museum lighting in our region, reasons are related with its high performance color rendering with CRI 99 and with its pleasant color temperature. The profile of the spectral emission and comparison with the representative spectral reflectance curve (RSRC) shows the M2 exhibit are presented in Figure 7

The third lamp used in the experimental stage is the compact fluorescent one. Its use in museum lighting is almost ruled out, except for basic lighting and maximum CRI possible and a color temperature equivalent to those achieved by the incandescent lamps.

The exposure conditions of the reproductions of the sample, for the three cases are as follows: a. They have performed measurements in a cabin built for that purpose.

b. Measurements of the Representative spectral reflectance curves (RSRC) for each reproduction were made at the beginning and end of the exposure period. Moreover, colorimetric measurements were taken of chromaticity coordinates CIEL * a * b *, prior to and after exposure areas.

c. Exposure of the three samples was carried out with reference to the Total Annualized Exposure in conservation policy in Europe and North America. This regulates the limits of exhibition of artwork in museums and estimates a maximum tolerable exposure of 100 lux for 10 hours a day and 180 days per year, resulting in 180 kLux.hy

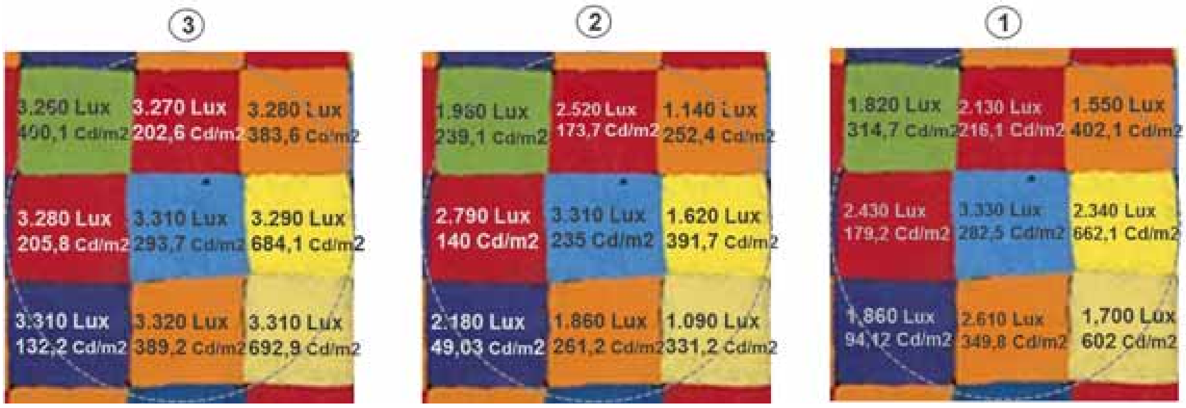

Fig. 8: Characterization of exhibition areas. Illuminances and luminances (Right to Left:1 LEDs' Illuminant; 2 Halogen Incandescent Lamp; 3 Compact Flourescent Lamp)

The characterization of the regions of the views of M2, which were exposed to the lighting of the three types of sources (Fig.8) shows that in the light of the three samples was performed with the criterion of equal illuminance maximum in the center square - blue sky - the three exposed areas

Uniformity of illuminance of different sources is very different, as revealed in the characterization of the exposed samples. By averaging the measured illuminances in nine color spaces in areas exposed to three different sources, it shows a significant difference in the average of each of them. Between the highest average illuminance obtained, compact fluorescent lamps (3,290 lux) and the lowest average illuminance obtained for the sample M2 exposed under the illumination of a lamp Incandescent Halogen (2,052 lux) there is a difference of 37.75%.

Due to differences of homogeneousness among the three sources and the consequent differences in average illuminance used to calculate Total Annualized exposure of each of the samples and, since the exposure is performed over 24 hours in all cases, the adjustment variable to achieve correspondence in Total Annualized Exposure (TAE) of the three views, has been the number of days during each of the samples was exposed.

The experimental phase of this work involves exposure of the three reproductions of M2 with different light sources such that the resulting exposure is equivalent to a certain number of years of Total Annualized exposure (TAE). For our experimental stage represents the equivalent of nine years exposure.

The total annualized exposure value (TAE) in the three core areas of blue color was achieved after 20 days of exposure. After the exposure period measurement values of colorimetry in each of the central squares of the three samples exposed, ie measurements of L * a * b * and the chromaticity coordinates (x, z) were performed (CIE 2006 ; CIE, 2007; CIE, 2009; CIE, 2011; CIE, 2014).

With the values obtained in the measurements of both L * a * b * color coordinates and the displacement in the CIEL * a * b * 2 and 10 degrees field observers, blue sky located in calculated the center of the exposed area measured after exposure, compared to the same color measured prior to exposure. (CIE, 2006; CIE, 2007; CIE, 2009; CIE, 2011; CIE, 2014).

We proceeded in this way because the first sign of deterioration or damage is the photochemical fading or discoloration (Thomson, 2008), which in some cases is even visible to the naked eye in the case of our exposed samples (Fig. 9).

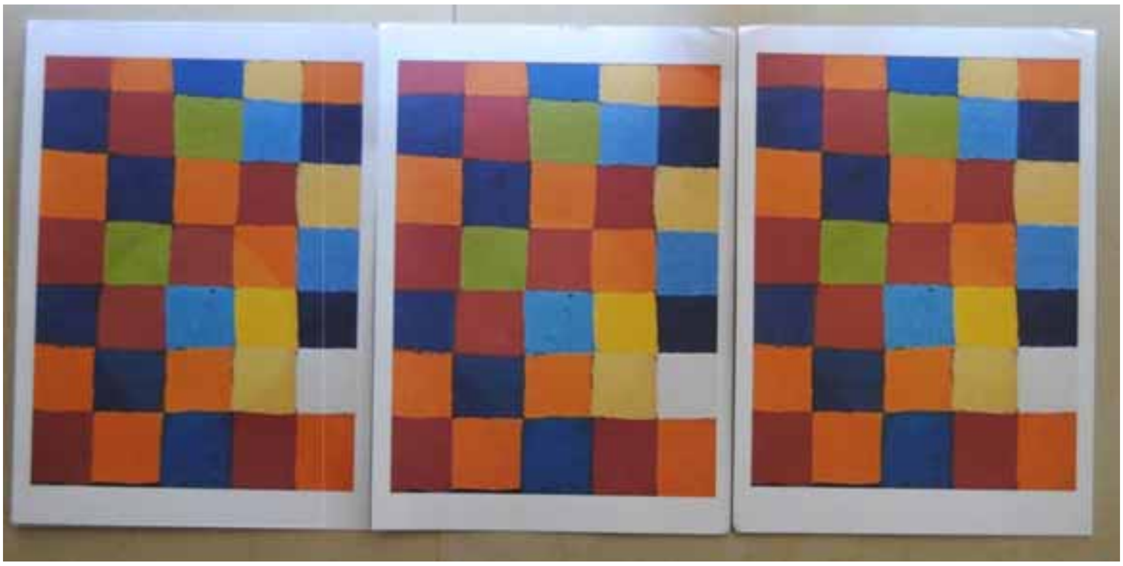

Fig. 9: Samples of M2 after the exposure to emissions (Right to Left: LEDs' Illuminant; Halogen Incandescent Lamp; Compact Fluorescent Lamp)

In principle the figures in the displacement L * a * b * for the LEDs' Illuminator and the halogen incandescent lamp are very similar and both lower than the figures of displacement in the color field obtained by the fluorescent compact lamp.

Between the figures obtained by the LEDs' illuminator and the halogen incandescent lamp there is a very small margin of displacement in the field of color in favor, a shorter distance obtained in dark blue colors for observer 2 ° is observed and the green for 10 ° observer.

Additionally, it is important to note that the results of damage for the LEDs' Illuminator are obtained with significantly less energy than incandescent lamp. A comparison of energy efficiency between LED lamps and incandescent lamps clearly favors the first to consume a smaller fraction to 30% of the energy of traditional in its improved version.

Based on analysis of the results of color change measured in the samples used in the experimental stage, we believe that an equal performance is confirmed for the improved incandescent lamp and the LEDs' illuminator with regulated Profile, in both cases a better result than those obtained by the compact fluorescent lamp.

5. Conclusions

A new methodology has been developed in order to characterize the RSRC of an artwork and then used to select and later design a light spectral source distribution for use in Museums to properly exhibit and preserve artwork. The methodology has been tested in a sample of artwork reproduction, for presentation and preservation. On presentation, L*a*b* colour difference results, both calculated and experimental fall mostly under 3 C.I.E. L*a*b*(1976) units. On preservation, C.I.E. illuminants and sample-designed illuminants have been evaluated and ranked according to a deterioration factor originated in the gap between each R.S.R.C. and the given illuminant.

Curves of spectral information can be used in a described manner in a lighting system capable of regulating its spectral emission to be used in museum lighting. To achieve a controlled between spectral information from the illuminated object and the visible radiation emitted by a source, would imply an important advance in the precision with an object deterioration is managed, along with an adequate fulfilment of the presentation aspect of the museum mission. Advanced Lighting technology as LEDs proved to work positively in terms of preservation, presentation and efficiency as it can produce less deterioration due fading than other sources with a significant difference in energy consumption. Further studies may include experimenting with human observers and other assessments to corroborate results in the preservation mission of the museum.

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