Instrumental and Visual Correlation between a Multiangle Spectrophotometer and a Directional Lighting booth

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ABSTRACT

Colour differences between what we see and what we measure entail a very complex topic. In this work, we deal with this issue for the case of special effect pigments. With this purpose, the instrumental and simulated visual results obtained for the same pairs of samples were compared. Instrumental evaluation was performed by the BYK-Gardner's multiangle spectrophotometer, BYK-Mac, and simulated visual evaluation was simulated with a gonio-spectrophotometric system composed by the tele-spectroradiometer PR-650 from Photo Research, Inc. and the directional lighting booth, Byko-spectra effect from BYK-Gardner. The set of samples were constituted by 13 pairs of three different kinds of pigment: solid, metallic and pearlescent. They were analysed at six geometries: 45as-15, 45as15, 45as25, 45as45, 45as75 and 45as110. The colour differences between samples of the same pair were quantified by means of AUDI2000 colour difference formula. In general, both devices behave very similar, although the set formed by the tele-spectroradiometer and the lighting booth shows higher colour differences and in some cases unacceptable from an industrial point of view. Despite the observed similarity, these two instruments do not show any firm correlation. Therefore, more goniochromatic samples must be analysed in order to strengthen the tendencies revealed by this study.

1. INTRODUCTION

Several devices are designed for colorimetric analysis of materials, either spectrophotometers or colorimeters, but the final decision is visually taken. This statement affects the whole colour science; however, this work is focused on goniochromatism. Materials that contain special effect pigments need more complex evaluations than solid pigments due to their lightness variations (metallic materials), hue and chroma (pearlescent materials) as a function of illumination/observation angle (Maile et al. 2005, Pfaff 2008).

Therefore, this study consists of finding the correlation between instrumental and simulated visual assessments of special effect and solid pigments. By this way, we will be able to know and quantify how much closer or further these techniques are.

2. METHOD

Both evaluations, visual and instrumental, were performed by means of two different gonio-spectrophotometric systems. In instrumental evaluation, the BYK-Gardner's gonio-spectrophotometer, BYK-Mac (Figure 1, left), was used to measure the samples. On the other hand, simulated visual evaluation was carried through the system composed by the PR-650 tele-spectroradiometer of Photo Research, Inc. and the BYK-Gardner's directional lighting booth Byko-spectra effect (Figure 1, right). The goal of this second gonio-spectrophotometric device consists of simulating a typical visual evaluation by placing inside a booth a couple of coloured samples and measuring them at each geometry.

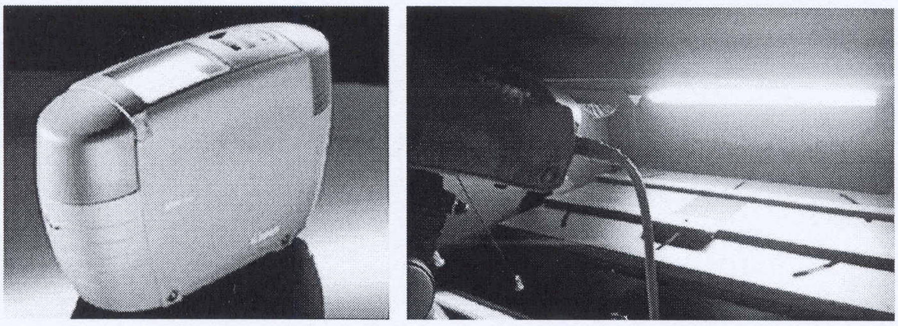

Figure 1: Left: gonio-spectrophotometer BYK-Mac; Right: Gonio-spectrophotometric system formed by the PR-650 tele-spectroradiometer and the Byko-spectra effect lighting booth.

The set of samples included 13 pairs of three different kinds of pigments: solid, metallic and pearlescent. Every pair was composed by samples of the same colour but different batches; due to that fact, colour differences were very small. Regarding measuring geometries, they were fixed by the gonio-spectrophotometer and the lighting booth: 45as-15, 45as15, 45as25, 45as45, 45as75 and 45as110.

Colour differences between samples of the same pair were calculated by means of AUDI2000 colour difference formula (Dauser 2012). It was especially designed for goniochromatic materials, in other words, it takes into account the colorimetric variations that these materials show as a function of illumination/observation angle.

$$\Delta E_{AUDI2000} = \sqrt{\left(\frac{dL^*_\gamma}{k_{dL}S_{dL_\gamma}}\right)^2 + \left(\frac{dC^*_\gamma}{k_{dC}S_{dC_\gamma}}\right)^2 + \left(\frac{dH^*_\gamma}{k_{dH}S_{dH_\gamma}}\right)^2} \qquad \text{(Eq. 1)}$$

where dL^*_γ, dC^*_γ and dH^*_γ are lightness, chroma and hue differences, respectively. In the denominator, lightness (S_{dL_γ}), chroma (S_{dC_γ}) and hue (S_{dH_γ}) weighting functions and also lightness (k_{dL}), chroma (k_{dC}) and hue (k_{dH}) parametrical factors can be found. These last factors do not depend on the observation angle because this dependency is considered by the weighting functions.

3. RESULTS AND DISCUSSION

Table 1 shows the maximum and mean colour differences calculated by AUDI2000 colour difference formula of each pair and for the six geometries and sorted according to the instrument. Samples that present higher maximum and mean values belong to the pearlescent group, as *Dark grey* and *Gold*. The results obtained through the system formed by the tele-spectroradiometer and the lighting booth reveal higher colour differences for solid and metallic colours. However, colour differences related to pearlescent samples are higher for gonio-spectrophotometic measurements.

Table 1. Maximum and mean ΔEAUDI2000 values of each sample for the six geometries and as a function of the instrument.

Sample	BYK-Mac		PR-650 + Byko-spectra effect	
	Maximun $\Delta E_{AUDI2000}$	Mean $\Delta E_{AUDI2000}$	Maximun $\Delta E_{AUDI2000}$	Mean $\Delta E_{AUDI2000}$
Red	1.33	0.97	2.12	1.17
Yellow	1.32	0.84	3.47	2.02
White	3.41	2.62	8.57	6.78
Cream	0.98	0.76	2.57	1.98
Green B	6.91	6.11	5.87	4.65
Violet	1.36	0.81	2.22	1.39
Green	1.3	0.82	2	1.24
Grey	2.48	1.58	3.91	2.27
Blue	1.15	0.85	4.8	3.82
Dark grey	3.63	2.92	3.5	2.81
Light blue	6.86	3.16	4.66	3.08
Gold	4.89	4.22	5.24	4.73
Light grey	14.5	4.35	8.83	3.53

On the other hand, Figure 2 shows three plots which represent each kind of pigment; they are the most representative examples of each one.

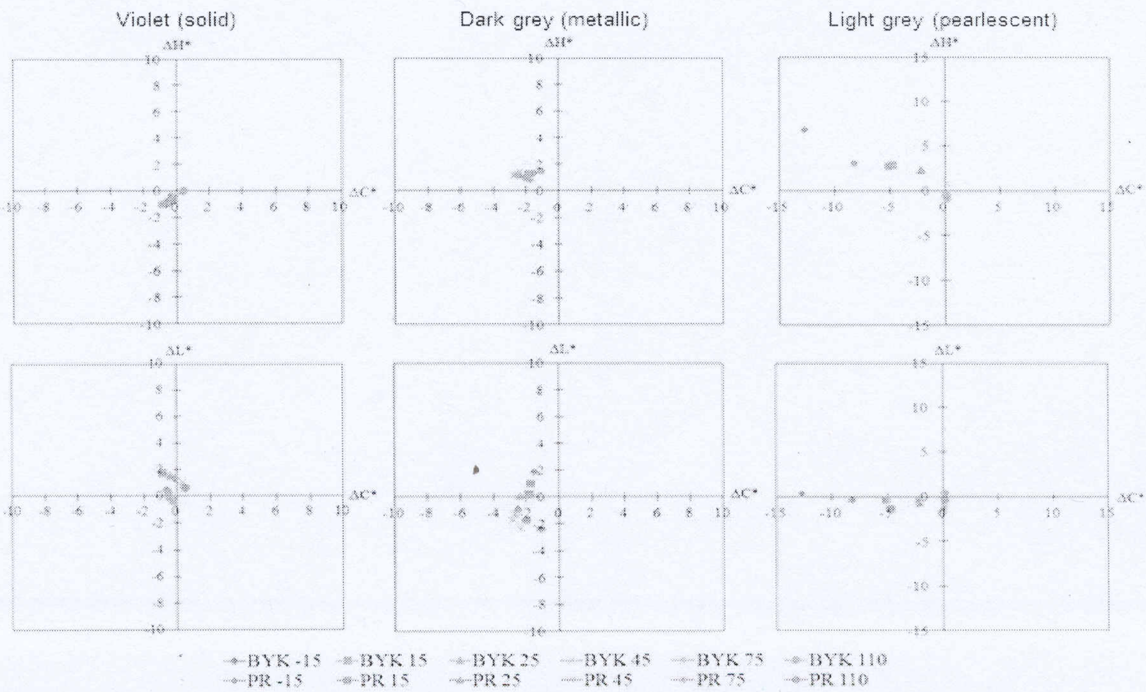

Figure 2: Partial colour differences of one solid pair, one metallic pair and one pearlescent pair.

As the results show, both systems present similar behaviour for solid colours and colour differences are very small, closer to zero in some pairs. Regarding metallic samples, they exhibit higher lightness differences, mainly in 45as-15 and 45as110 geometries for the

BYK-Mac. Nevertheless, in the case of PR-650 plus booth, the higher the aspecular angle, the higher the colour differences. Finally, hue and chroma differences shown by pearlescent pairs are higher for angles closer to specular reflection. In this case, colour differences calculated by means of gonio-spectrophotometric results are higher than the ones obtained by the tele-spectroradiometer plus lighting booth set.

4. CONCLUSIONS

Summing up, both devices behave in a similar way but there is no strong correlation between colour differences calculated by AUDI2000 colour difference formula. Solid pigments clearly correlates but effect pigments show more differences between samples. Future work will be focused on analysing a larger set of goniochromatic samples, deeply studying the different behaviour of each sort of pigment related to each measurement system and the light source of each device.

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