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THE INFLUENCE OF SPATIAL ARRANGEMENT OF A SCENE IN THE STABILITY OF COLOR APPEARANCE UNDER DIFFERENT LIGHTS

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Abstract
Color rendering is defined as the "effect of an illuminant on the color appearance of objects by conscious or subconscious comparison with their color appearance under a reference illuminant"[1]. A Color Rendering Index (CRI) aims to indicate through one or more values the range of the color variation of an object after changes in the illumination of the scene. In other words, it tries to quantify to what extent the chromatic appearance of an object is preserved under a given light source with reference to a standard illuminant. Goal of a CRI is to evaluate the quality of a light source given that a "good" illuminant should keep color appearance as much unchanged as possible. With the arrival of novel LED based light sources, classic CRI proved not to be a measure in line with the human visual color sensation. As a follow up, a series of new methods and algorithms to compute alternative CRIs have been devised and tested, but no one has emerged as the definitive one. This paper aims at suggesting a potential weakness of all CRIs;: they get as input just the spectral power distribution (SPD) of the light source and implement a Color Adaptation Transform (CAT) as a simplification of the Human Vision System (HVS), ignoring its spatial mechanisms. In everyday life, perceptive characteristics of objects are strongly dependent on the context in which they are placed since we rarely see colors in isolation, as well as on the quality and SPD of light radiation[2]. Classic examples in which the spatial distribution of a scene plays an important role in the color appearance are the optical illusions. We aim to study if the spatial arrangement of a scene may influence the final appearance under different illuminants[3,4] and thus if it should consider it in its computation.

Keywords: *Color Rendering index; Color Sensation; Color appearance*.

INTRODUCTION

The Color Rendering Index (CRI) of a light source is the measure of how *natural* appears the colors of the objects illuminated it. In other words, it is a quantitative measure of the ability of a light source to reveal the colors of various objects faithfully in comparison with an ideal or natural light source.

The CRI is determined by the light source spectrum and numerically, the maximum CRI possible value is 100 and would only be given to a source identical to standardized daylight or a black body.

The main weakness of CRIs is the consideration of a color just as the result of its characteristic spectrum of reflected and absorbed wavelengths generated by the interaction of an illuminant with a definite spectrum. In this assertion the Human Vision System (HVS) is not considered. From this problem, usually a Color Adaptation Transform (CAT) is used as simplification of the HSV, but doing that, the spatial mechanism of HSV are ignored. In everyday life, perceptive characteristics of objects are strongly dependent on the context in which they are placed since we rarely see colors in isolation, as well as on the quality and SPD of light radiation[2]. In this study we will demonstrate how the spatial arrangement of a scene may influence the color signals' formation, like in optical illusions, under different illuminants.

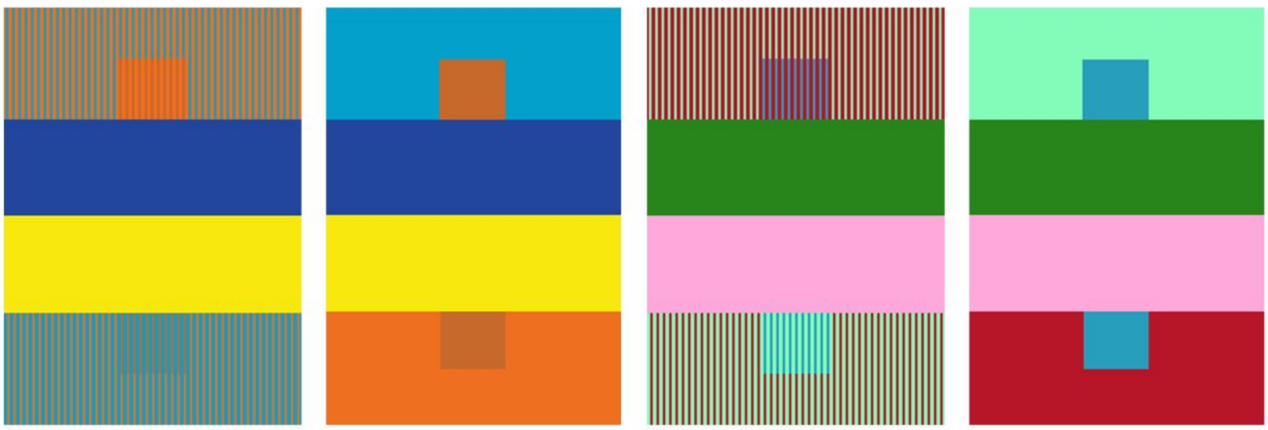

Figure 1. Patches used in this experiment. Patches 1A and 2A Assimilation effect; Patches 1B and 2B Simultaneous contrast effect.

Figure 2. ΔE values for each candidate and each illuminant for configurations; a) ΔE 1A and 1B top b) ΔE 1A and 1B bottom c) ΔE 2A and 2B top d) ΔE 2A and 2B bottom.

EXPOSITION

To validate the idea that variations in the spatial arrangement of a scene may influence the stability of color rendition we arranged a matching experiment involving human observers. Goal of the experiment is to investigate if color appearance's shift due to optical illusions changes while changing the illumination of the scene.

We created 4 colored Patches and printed them on 4 A4 sheets, Figure 1. Each patch has 2 targets (top and bottom), having a specific spatial configuration designed to produce an optical illusion for simultaneous contrast (Patches B) and assimilation (Patches A). These patches have been printed in the same moment with the same printer after a set of warm up prints. Patch 1B reports Albers' visual illusion in which two identical browns targets placed respectively on a blue background and on an orange background have a different color appearance due to simultaneous contrast effect. Patch 1A features the same colors which have been arranged to create an assimilations effects. In the latter, the two brown targets have a different color appearance in accordance with another spatial mechanism of the HVS. Similarly, in patch 2A and 2B we create an illusion by assimilation and one by simultaneous contrast using different colors.

Under a certain illuminant the visuals illusions configuration produces a measurable color appearance shift between correspondent test patches. In the experiment, the scene was uniformly lighted by light sources under test.

Changing the light source produces a uniform global change in the light distribution of the scene. This means that there are two possibilities which are under test: 1) change in the appearance of the targets are stable regardless of the context in which they appear 2) the appearance of the patches varies in different way varying light source. The following illuminants have been tested: D65 (6500K), CWF (4150 K), U30TL84 (3500 K) and A (2856 K). During the experiment, we have asked to a group of volunteers to choose from a set of reference samples the one with the appearance closest to the target. Colored swatch taken from "The Munsell Book of Color" were used as reference samples to assess the patches appearance. This book is composed of over 1600 removable color samples on 40 detachable constant-hue pages ordered in Munsell Color Systems which specifies surface color in 3 dimensions: Hue, Value and Chroma. Hue is notated by a number between 0 and 10 with a prefix. Value is a number between 0 (black) and 10 (white) aim to indicate how light or dark a color is. Chroma starts at 0 (grey) and increases as color becomes more saturated than a grey of the same Munsell Hue and Value. Hue pages 2.5YR, 5YR and 7.5YR were chosen as reference for Patches 1A and 1B. For Patches 2A and 2B Hue pages 5B, 7.5B and 10B were used. During one step of the experiment the candidate is settled in front of the lighting box. One by one the patches were put in the box after turning on the light for several minutes.

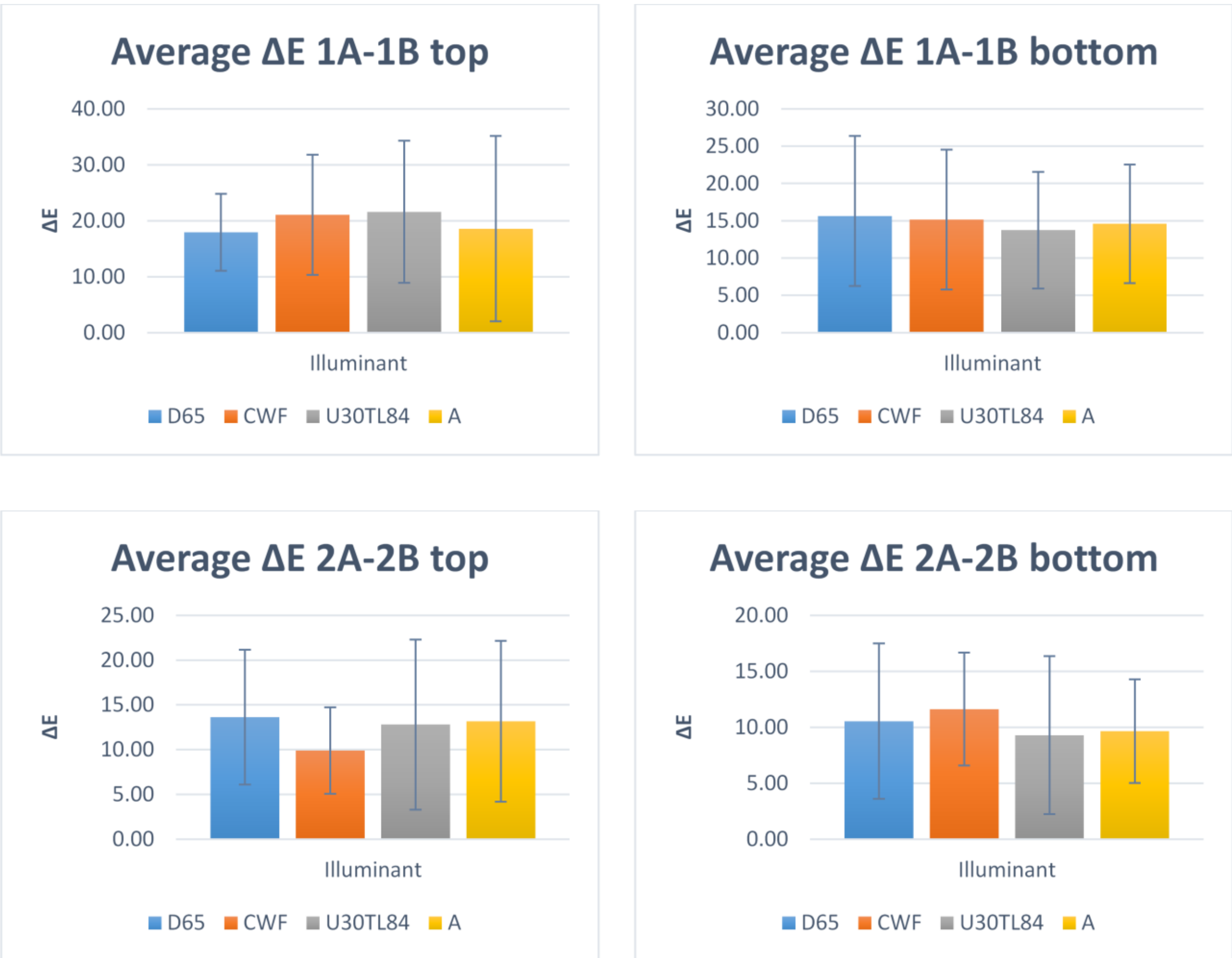

Figure 3. Average ΔE values for targets a) 1A and 1B top b) 1A and 1B bottom c) 2A and 2B top d) 2A and 2B bottom.

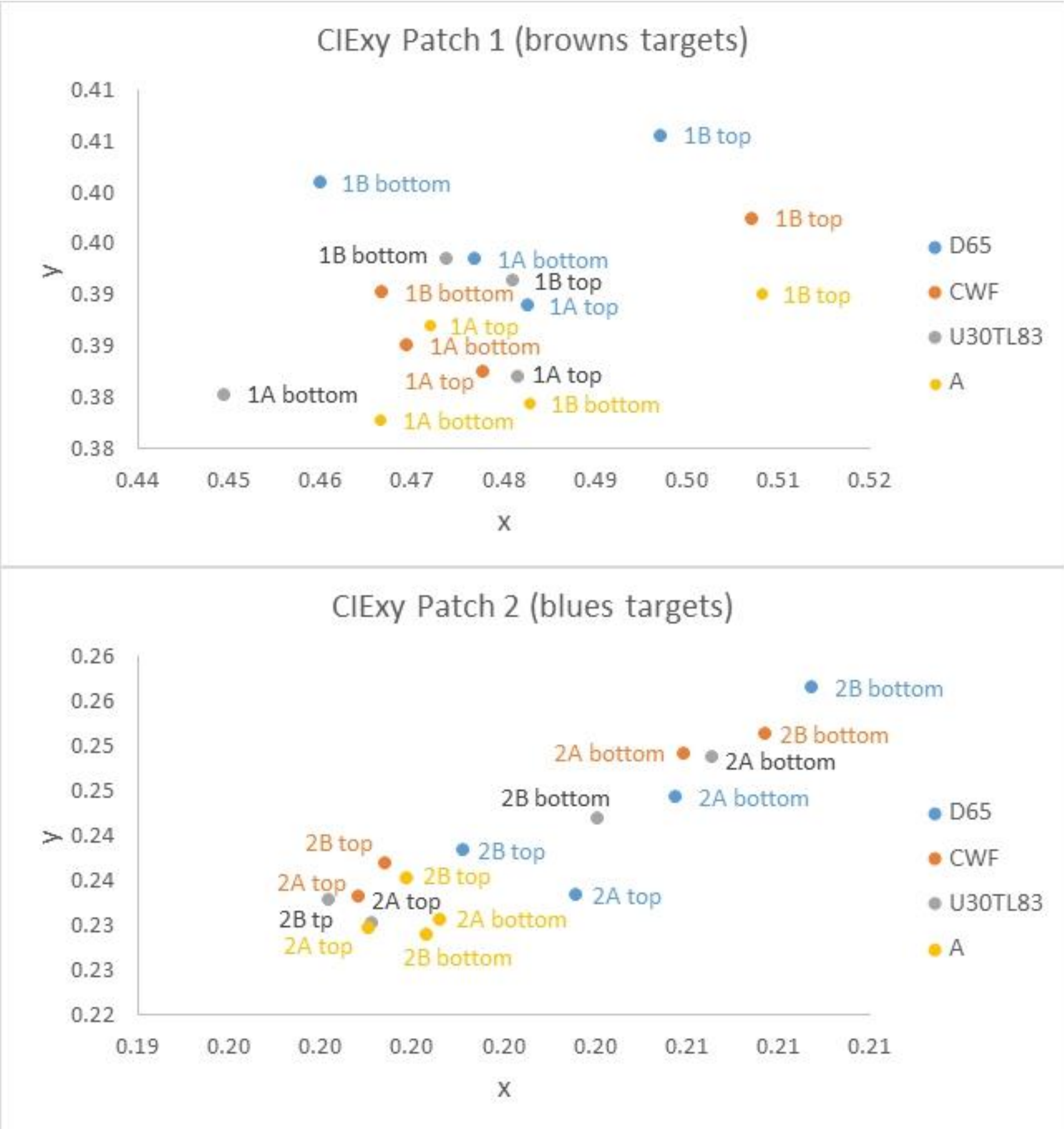

Figure 4. Average colour appearance of all the targets under the different light sources in the chromaticity diagram.

The candidate can move itself and the reference samples but cannot touch the patch which is inside the lighting box. For each target on each Patch observers choose HVC reference values with closest appearance. The experiment is repeated using all the light sources previously described. Between two consecutive rounds of the experiment the lights were settled off for 2 minutes. The experiment involved 18 volunteers, 6 females and 12 males, aged between 26 and 46, with an average age of 26.17. None of them reported color deficiencies. Approximately, for each candidate, the experiment took 40 minutes. In order to compare the effect of the changing in the illumination between two patches with different spatial context the Euclidean vector chromatic difference (ΔE) was calculated for each couple of targets having the same colors but different configurations (1A-1B top; 1A-1B bottom; 2A-2B top; 2A-2B bottom). It is important to remind that all the 4 brown targets have the same color and so the other 4. ΔE calculations are computed in the MLab isotropic color space[5]. Results are reported in Figure 2. Mean values (μ) and standard deviations (σ) of ΔE are reported in Figure 3. We note that the results are very heterogeneous in terms of degree of perceived color difference among candidates and between targets appearance for each candidate.

Globally the targets have a different color appearance and this is not surprising due to visual illusions effects. Indeed, in the 11.5% of the cases ΔE=0 and the two colors appear identical, whereas in the 88.5% (ΔE >5) observer notices two different colors[6]. The point of this work is to investigate how this perceived difference varies while changing the light source because this could have an important effect on the rendition of colors predicted by CRI. One should expect a similar stable change in appearance varying the light source of the scene, and so a stable change in the perceived color difference between two targets, if it only depends on the SPD. On the contrary a combined effect of visual illusion and spectral composition of light would produce a different degree of color shift. In figure 6 and 7 the average ΔE values are plotted. We can notice that for each different configuration the average values are quite similar but never identical whereas among all the configurations the difference is noticeable. To understand if the similarity between the average values for one configuration is to be attributed to the spectral power distribution of the illuminant or to the characteristic spatial configuration, we have placed the average color perceived of each target in the CIExy chromaticity diagram, shown in Figure 4. In these diagrams, each point represents the mean between the x and y values indicated by each candidate for each target. The conversion from the HVC to Yxy was achieved using spreadsheets distributed by Paul Centore[7]. Based on our assumption if the colors would be clustered in the chromaticity diagram according to the type of illuminant then the substantially constant difference in the color perception of the targets due to the optical illusions can be imputed to the change of the spectral components of the lights. However, as seen in Figure 4, the color points are quite spread and do not form evident clusters. For each light source the different chromatic appearance caused by simultaneous contrast and assimilation's effects is evident. We can note a trend: color point representing a specific target (for example 1A top) in the chromaticity diagram tend to be quite near under the majority of light sources. This means that the context has an important role in the generation of the appearance. Thus, even the targets have the same colors, the visual illusions configurations produce an evident shift in colors appearance. The perceived color shift between two targets in a different spatial context is negligible varying the light sources but noticeable among the different configurations considered. Implying that the global variation of color rendition due to the light change depends also on the spatial distribution of colors in a scene.

CONCLUSION

Results demonstrate that the color appearance depends on both spectral content of the light source and spatial configuration of the observed scene. In accordance with our results spatial configuration plays an important role in the formation of color signal, even while changing the light source. In conclusion, visual context impact on the rendition of colors across different light sources is noticeable and this evidence should be considered in the computation of color rendering indexes.

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