Colour size effect

G. Kutas, K. Gócza, P. Bodrogi, J. Schanda
Colour and Multimedia Laboratory of the University of Veszprém
H-8200 Veszprém (HUNGARY)
Corresponding author: G. Kutas (kutasg@vision.vein.hu)

ABSTRACT

In this paper, the colour perception of fully immersive self-luminous colour stimuli is investigated. 16 colours were presented on a large-screen plasma monitor placed in an observing chamber with mirror walls to achieve full visual immersion to the colour stimulus. By the aid of two methods, experimental data were collected to learn more about the "size effect". Immersive stimuli appeared to be lighter in all cases but chroma shifts were not so systematic. Results were compared to those of recent literature.

1. INTRODUCTION

Besides illumination, weather, surrounding stimuli, the colour perception of a colour stimulus is also affected by the viewing angle under which the stimulus appears. This may be explained by a physiological reason i.e. the spatial distribution of the S, M and L cones but this effect takes place also in those retinal regions where the ratio of the number of cones is uniform. CIE recommended the usage of two standardised colorimetric observers (CIE 1931 and 1964). CIE 1931 standard colorimetric observer is to describe colour stimuli subtending a visual field less than 4° and the CIE 1964 observer to represent colour stimuli larger than that. In industrial practice, it is a common finding that the small colour sample used to select the covering paint for interior and exterior surfaces does not exactly predict the colour perception of the finished large surface. The reason for this is that the CIE observers cannot describe colours appearing at larger than 20° of visual angle. Experiments related to this effect were performed in recent times including large visual angles[1,2] and outdoor observations[3].

More complex colour appearance models (CIECAM97s and CIECAM02), assessing the colour perception relative to a well-defined viewing situation, are also derived from a dataset of small field observations. Hence, when observing an extremely large homogenous field, almost fully immersive, they also fail to describe the colour perception correctly. For such a large stimulus, the background around the stimulus and the adapting field is the same as the colour element considered, and there is no reference white in the field of view.

Virtual reality systems and also large screen monitors and televisions made possible the observation of large self-luminous stimuli under laboratory conditions, too, besides reflective patches and wall colours. These stimuli were examined in a previous study systematically[4] where chroma decrease was detected when the visual angle increased from 10° to 130° contrary to previous studies[1,2]. Similar to e.g. large wall surfaces, the retinal image corresponding to the approximately uniform colour stimulus is large.

Authors of the present work believe that, by observing a large homogenous colour field totally immersed, adaptation is only of secondary importance. Most critical is the instantaneous colour impact, which is the essence of the phenomenon. In real-life situations, when the finished paintwork and the small sample of the same dye in the catalogue do not match, it is the "sudden impression" of viewing the large surface that is dominant. There is no need to adapt to the situation - the two perceptions, small and large, differ instantly.

The aim of the present work was to continue our self-luminous colour size effect investigations by the aid of a refined experimental methodology. Uniform self-luminant images were presented on a large-screen plasma display panel (PDP monitor) placed in an observing chamber. The observer's task was to quantify these colour perceptions using CRT colour matching technique and employing the *method of adjustments* (AM) and the method of *constant stimuli* (CS). Though both displays were well-characterized, in the evaluation only in-situ measured values of the observer's answers were considered, using a well-calibrated PhotoReserach™ 705 spectroradiometer.

2. EXPERIMENTAL SET-UP

In the experiments, a 21 in. HP CRT display and a 42 in. Panasonic high-definition plasma display panel were employed[5]. The set-up of the experiments is depicted in Figure 1. As can be seen from this top view image, the two displays were positioned next to each other and there was a separator between the two displays that excluded the other display from the visual field of the subject observing either screen. A cardboard covered by black paper was employed for this purpose and it also helped the observers to achieve desired viewing distances (designated by 1 and 2 in Figure 1). The PDP was actually placed behind a wooden booth painted black. Into the interior of the booth four panes of mirror were mounted. The depth of the cabinet was 50 cm. To blur the pixel texture of the PDP, observable due to the close viewing distance, a neutral diffusion filter was attached to the screen of the device. The two monitors were driven by two separate PCs with an S3 Trio and an ATI Rage 128 graphical controller.

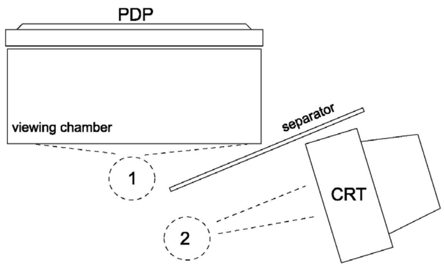

Figure 1: Top-view of the experimental set-up

Four well-trained young female colour normal observers participated in the experiments. They observed 16 colour stimuli (15 in the CS experiment) on the PDP, plotted in CIELAB *a**-*b** in Figure 2 referred to as "original colours". On the CRT, stimuli were represented under two different visual angles in both CS and AM experiments, namely 2° and 10°. Observations were performed in a dark room. Stimuli were displayed by the aid of two computers.

In the "*constant stimuli" experiment*, subjects were presented one of the original colours and a set of 13 fixed stimuli generated around the original colour within a radius of 8 CIELAB-units at constant *L** level. This means that only the chroma and the hue deviated from the original colour. These 13 colour stimuli were displayed on the CRT device, each of them separately, to compare them with the original colour presented on the PDP. The question asked the observers was: "Do these two stimuli on the two monitors have the same perceived colour?" The immersive stimulus on the PDP emerged for only a limited duration (2 seconds) repeatedly, and, between two appearances the observer changed head position, to observe the comparison stimulus on the CRT (see Figure 3). The observer was permitted to look back and forth between the stimuli before she gave her final yes/no judgement. A mid-grey background surrounded all stimuli on the CRT and the same grey was displayed on the PDP between the 2 second intervals when the immersive stimulus appeared. The 16 original colours times 13 comparison stimuli were shown three times to each observer in random order. Stimuli of 2 or 3 "matching" answers were measured after the experiments for further evaluation, using the spectroradiometer.

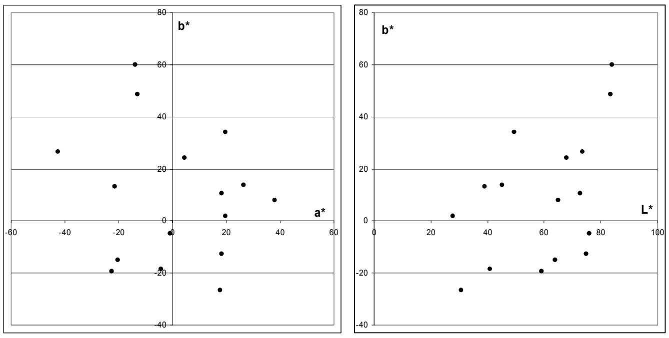

Figure 2: 16 Original colours of the experiment plotted in CIELAB a^*-b^* plane and their L^* values

The AM technique involved colour matching via *adjustments*. Using the same set-up with the CRT and the PDP, observers were shown the original stimuli for 2 seconds, again, repeatedly in the viewing chamber. By observing the immersive stimulus, observers were requested to assess their perception. Then they turned to the CRT and used hue, saturation and value (HSV system) "sliders" in the user interface of the program running on the computer. They had to set a colour stimulus on the CRT with a matching perception, on mid-grey background. For this case, subjects had unlimited time to look back to the PDP and to achieve the matching stimulus on the CRT. Adjusted colours were measured at the end of the observations and spectral data were saved for evaluation.

Figure 3: Observing an original colour in the viewing chamber and a comparison colour on the CRT

3. RESULTS AND DISCUSSION

From the measured spectral data, CIE *XYZ* values were determined and transformed into CIELAB (L^*, a^*, b^*) using the white of the PDP as reference white. Results of the two methods for both the 2° and the 10° comparison stimuli are plotted in Figure 4. Circles show the original colours, open markers are for the CS method and filled ones for the AM method. Triangles show 2° results and squares stand for 10° comparisons, respectively. This sort of visualization shows changes in the a^*-b^* plane only, as, for the CS technique, only this is applicable. Unfortunately, at the end of the CS experiment some original stimuli turned out to have no 'yes' answers at all, from either observers (consider the missing marks in Figure 4). This made the evaluation of the size effect impossible in this case. Observers seemed to give always 'not matching' judgements to the six darkest original colours, out of 15. Our idea was that the *simultaneous contrast* of the luminance of the unchanged mid-grey background and the comparison colour on the CRT affected the experiments and amplified the size effect. The magnitude of this "simultaneous contrast" effect is greater for dark comparison colours. Observers may perceive the "immersive" original colour to have different lightness from the comparison colours shown, and this is obvious from the AM results, see below. Since no luminance deviation was allowed within the 15 sets of comparison stimuli of the CS experiment, and their luminance values were equal to the measured luminance of the corresponding original colour, observers found no colour matching with the original.

Since, in the AM experiment, the task was to mix a colour of the same perception as that of the original stimulus, observers had a wider range of possibilities. It is clearly seen in the results of this method that the measured colorimetric properties of the stimulus perceived to be the same in the small and immersive fields, differ more remarkably, compared to the results of the CS experiment. The mean difference between the 16 original colours and the adjusted small patches were determined (for 10° and 2°). The overall average of these differences was 15.7 (max: 30.4, STD: 5.3) for 10° and 17.3 (max: 32.1, STD: 5.3) for 2°, in terms of ΔE^*_{ab} colour difference.

The vast majority of the average differences result from lightness differences: ΔL^*=14.4 for the 10° and 15.7 for the 2° comparison. The immersive stimulus was perceived to exhibit more lightness in all 16 cases. This corresponds to the results of the previous study[2], namely, by increasing its visual angle, the same colour stimulus is perceived to be lighter. The magnitude of the parameter K_L of the fitting curve $L^{*\prime}=100+K_L(L^*-100)$ is 0.6 here, which coincides with the results of comparing a 2° and a 50° field in the work of Xiao et al[2] (K_L=0.59). $L^{*\prime}$ is the lightness of the small sample and L^* is the measured lightness of the immersive stimulus, see Figure 5 where perceptual lightness differences are plotted between the small (2°) and the immersive field together with the best fitting curve of the above equation for 16 colours (with STD error bars at the measurement points).

The results of the detected chroma shifts do not seem to entirely agree with the results of the previous study[2]. In this study, chroma shifts were not systematic; the shift direction strongly depended on the observed colour. In case of the greenish and yellowish tones, chroma perception increased, but it decreased for certain pink tones. Again, 2 out of 3 bluish tones seemed to neglect any chroma shift, and their perceptions changed only in lightness with the increase of size. This was also found in another paper of the authors[6]. The average chroma shift of the 16 colours was 3.5 (max: 9.7, STD: 3.3) for 10°and 4.1 (max: 14.6, STD: 3.4) for 2° matching. Hue changes were hardly detected but some shifts towards bluish shades were observed for the case of pink tones.

The influence of the simultaneous contrast on the results is considerable. But it should be noted that, regardless of the original stimuli being darker or lighter than the used mid-grey background, observers perceived the immersive field to exhibit more lightness than it actually did. We have already started a new series of experiments using the *same luminance background* as the observed colours, thus eliminating the influence of simultaneous contrast.

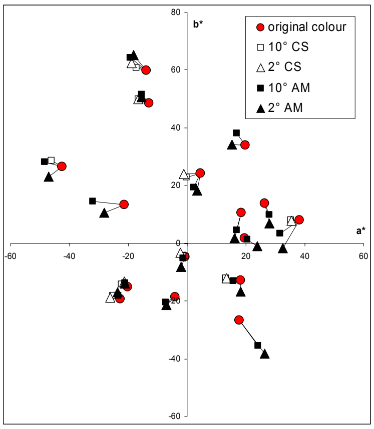

Figure 4: Results of the experiments AM and CS for both the 2° and the 10° comparison stimuli on the CRT

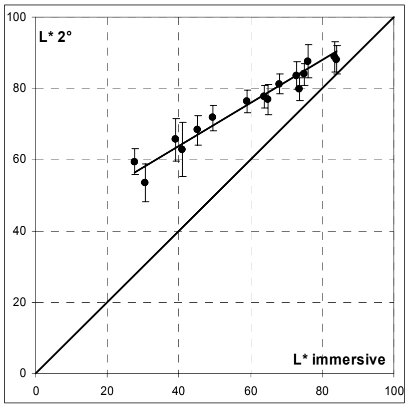

Figure 5: Relation between the lightness of the perceptually matching small (2°) and the immersive stimulus

References

1. J. S. Lee, "A Quantitative Study of the Area Effect of Colours," in Proceedings of AIC Meeting Seoul 2000, p. 236.
2. K. Xiao, C. J. Lee, R. M. Luo, C. Taylor, "Colour Appearance for Dissimilar Sizes," in Proceedings of The Second European Conference on Color in Graphics Imaging and Vision (Soc of IS&T), 2004, pp. 12-16.
3. K. F. Anter, "What colour is the red house? Perceived colour of painted facades." Doctoral thesis. Stockholm, 2000.
4. G. Kutas, K. Gócza, P. Bodrogi, J. Schanda, "Colour Size Effect," in Proceedings of The Second European Conference on Color in Graphics Imaging and Vision (Soc of IS&T), 2004, pp. 70-73.
5. G. Kutas, P. Bodrogi, "Colorimetric Characterisation of a HD-PDP Device," in Proceedings of The Second European Conference on Color in Graphics Imaging and Vision (Soc of IS&T), 2004. pp. 65-69.
6. G. Kutas, P. Bodrogi, J. Schanda, Effect of the lateral size of the colour stimulus on colour perception, CIE Expert Symposium on temporal and spatial aspects of light and colour perception and measurement, Veszprém, Hungary, 2002.