Parametric factors for colour differences of samples with simulated texture

R. Huertas, M. Melgosa and E. Hita
Departamento de Óptica, Facultad de Ciencias, Universidad de Granada. 18071-Granada (SPAIN)
Corresponding author: R. Huertas (rhuertas@ugr.es)

ABSTRACT

We have studied the way in which simulated textures, made of random dots, influence visual suprathreshold colour tolerances. The experimental tolerances were determined from a pair-comparison test displayed in a CRT colour monitor. In order to achieve systematic change of textures, we considered different variables controlling the simulated texture. Combinations of these variables generated 33 different simulated textures for each of the 5 CIE centres studied. A panel of 5 experienced observers with normal colour vision performed a total of 7706 visual assessments. Finally, we fitted the parametric factors for CIE94 and CIEDE2000 colour-difference formulas, considering the tolerances of each of the textures that statistically differed from homogeneous samples. In agreement with previous findings, our results show that texture increases tolerances, mainly lightness tolerances. But it is not simple to provide a unique set of parametric factors for all the potential textures.

1. INTRODUCTION

The latest colour-difference formulas proposed by the International Commission on Illumination (CIE), CIE94[1], and CIEDE2000[2] contain parametric factors related to illuminating and viewing conditions. Among other parameters, the sample surface structure (texture) significantly influences colour perception and thus has far-reaching industrial relevance. Homogeneous samples are included in the reference conditions[3], for which all the parametric factors are equal to 1.0. For non-homogeneous surfaces, there are few results, most referring to textile samples. Specifically for textile samples, the CIE has recommended[1,2] the use of k_L=2, k_C=1,and k_H=1. However, the accuracy of this recommendation is not yet well understood and additional research has been called for[4,5]. In addition, some recent publications have shown the strong effect of texture in perceived colour differences [6,7,8,9].

We have analysed the effect of a simulated texture over the visual suprathreshold[10] colour tolerances, separately analysing the lightness, chroma and hue tolerances for the 5 CIE centres recommended in 1978[4] with 33 different simulated textures. The visual data have been compiled using a CRT colour monitor, by the anchor-pair method. The resulting 7706 tolerances have been statistically analysed. Finally, only for the textures which led to statistical significant differences with respect to homogeneous samples, we have fitted the corresponding parametric factors for CIE94 and CIEDE2000 colour-difference formulas.

2. METHOD

The experiment was managed by specific software that we have developed. This software displays the test in a calibrated Samsung SyncMaster 900p CRT colour monitor, connected to a graphics card NVIDIA RIVA TNT2 Model 64 Pro 32 MB in a compatible-IBM PC. The visual experiment consists basically of a pair-comparison test in which the test pair is made of textured colour samples and the anchor pair is made of homogeneous grey samples. Figure 1 shows an example of the test employed. The anchor pair has a fixed colour difference of 1.6 CIELAB units. Both pairs were displayed over a neutral background (x_{10}=0.284, y_{10}=0.303, Y_{10}=24.78 cd/m2, equivalent to L^*_{10}=50.96) and a white surround (x_{10}=0.284, y_{10}=0.304, Y_{10}=126.90 cd/m2) subtending 1º and used as reference white for transformations to CIELAB. The software controlled all the variables of the texture, recorded the observer's response and the time spent in each observation, and also allowed the colorimetric calibration of the CRT monitor.

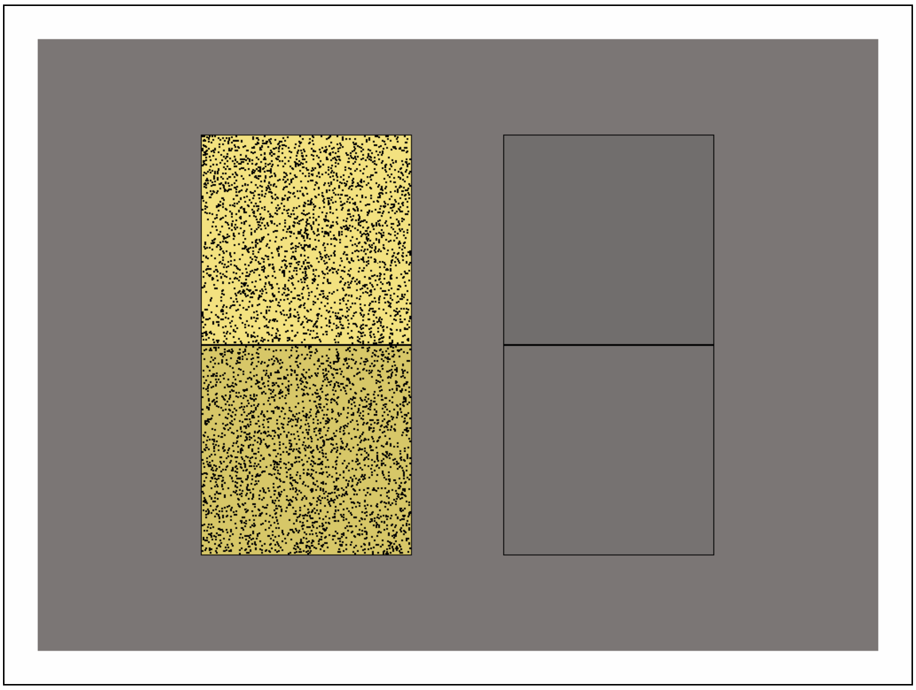

Figure 1: Example of an experimental observation with the pair test (left) and anchor pair (right).

The observer's task was to establish a colour difference, which would be suprathreshold, on the test pair just above the one perceived in the anchor pair, which was suprathreshold. The observer achieved this by changing gradually the colour of one of the samples of the test pair. The software randomly selected the sample (up or down) and the only coordinate (lightness, chroma or hue) to be changed in each experimental observation. The observations were preceded by 2 min of darkness adaptation. No more than 5 assessments were realized in one session, and before each visual assessment the observers were adapted for another 2 min to the background and the surround. A panel of 5 experienced observers (3 females and 2 males) with normal colour vision participated in the experiment.

With respect to the texture, two main aspects have in general been considered: colour difference between texture and sample and percentage of sample covered by texture. The simulated textures used were made of random distributed dots over a homogeneous sample displayed in a CRT colour monitor. We investigated the way in which a systematic change of textures influences the perceived colour differences. Thus, we considered different variables that characterize the texture, such as the size of the dots, the difference of colour between dots and sample, and the percentage of the surface covered by dots. Specifically the simulated texture was made up of dots with a size of 1 or 4 pixels, and of 5 different types: dots with lightness 10 CIELAB units more (type B) or less (type C) than the homogeneous samples, dots with chroma 15 CIELAB units more (type D) or less (type E) than the homogeneous samples, and black dots (type F). Type F is called "absolute" texture, while the others types (B, C, D, E) are termed "relative" textures because the colour of the dots are relative to the colour of the homogeneous sample. Texture type A, which corresponded to homogeneous colour samples without any texture, was used to establish reference tolerances. Depending on dot size, different percentages of surface coverage was possible by changing the number of dots. Specifically, we considered the cases of 5%, 20%, and 50% sample coverage. Only in the case of absolute textures, also 80% of the surface covered by the dots was considered, because for the relative texture a percentage greater than 50% was meaningless. These three variables considered in the texture (size, colour and covered surface) were systematically modified and combined, obtaining 33 different textures for each CIE centre. The combination of centre, texture and coordinate of the tolerance (lightness, chroma or hue) were randomly scheduled within the different experimental sessions.

Overall, 7706 suprathreshold visual tolerances were recorded, with at least 3 replicates per observer for each case.

As mentioned above, the tolerances referred only to lightness, chroma or hue for each one of the centres. First, we statistically analysed all the tolerances as a function of the dependent variables considered. We worked out the textures with statistically significant differences with respect to the homogeneous samples. For each of these textures, we have compiled a set of values of the parametric factors. The parametric factors were computed minimizing the difference between the tolerances corresponding to homogeneous and textured samples. This difference has been computed for each texture as the average difference of all the centres and observers. In this way, the parametric factors take into account the influence of the textures on the perceived colour differences.

3. RESULTS

Although there were statistically significant differences between some observers and also between some centres, the main trend over the different textures was the same for all observers and for all centres, because there were no interactions between these variables and texture. This important result allows us to disregard the variables observer and centre, increasing the number of tolerances for each texture. As expected, the tolerances invariably increased with the percentage of covered surface, in particular for absolute textures. The two dots sizes (1 and 4 pixels) did not statistically differ, and thus this variable was not further considered. The case of texture covering only 5% of the surface of the sample statistically did not differ from homogeneous samples. The differences between homogeneous and textured samples were greater when dot differentiation was in lightness (type B) or chroma (type D) over the sample. The parametric factors (Figure 2), were fitted, by averaging centres, observers and sizes only for the textures with statistically significant differences with regard to homogeneous ones.

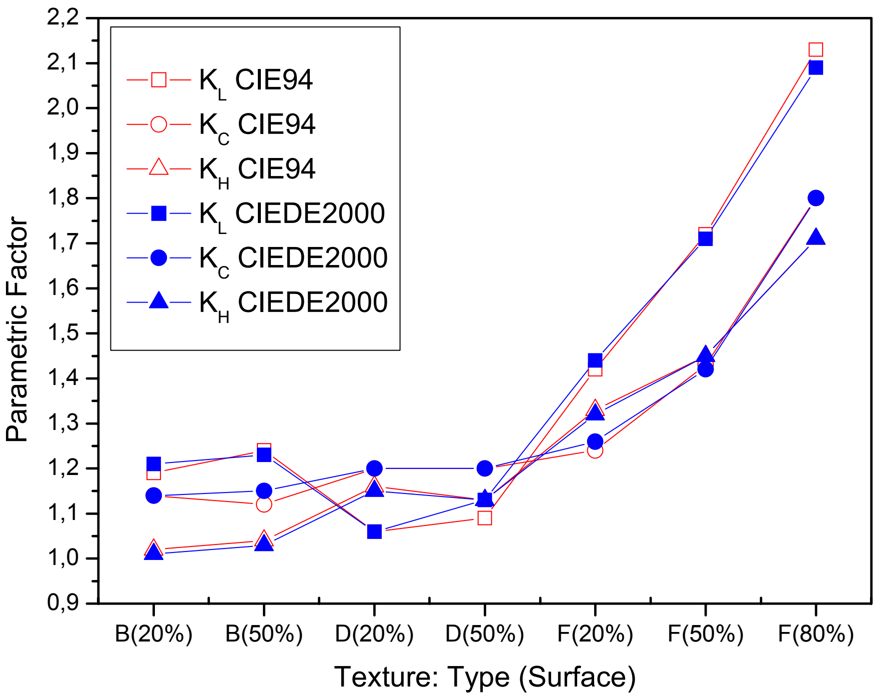

Figure 2: Fitted parametric factors for the CIE94 and CIEDE2000 colour-difference formulas, corresponding to the textures with statistically significant differences respect to homogeneous samples.

Minor differences, depending on the centre, were found between the parametric factors for CIE94 and CIEDE2000. As in the recommendation for textile samples, k_L increased up to 2.1 in the case of texture type F (absolute). The other factors, k_C and k_H, were also sometimes higher than 1.0, indicating that texture affects not only lightness tolerances but chroma and hue tolerances, too. The texture consistently increased the tolerances or equivalently reduced the perceived colour differences.

The absolute texture (type F) proved to be the strongest, as expected, and had the highest values of parametric factors. The value of the parametric factors increased with the amount of texture, considering the percentage of covered surface as a measurement of the quantity of texture.

4. CONCLUSIONS

Although the effect of texture on colour differences has important implications, it is not possible to supply a simple set of parametric factors for all potential textures available in industrial applications. Rather, each texture should be studied separately. In general, simulated textures increase the tolerances on lightness, chroma and hue each in different way. For example, lightness tolerances are increased more than chroma and hue ones. In the case of real texture, similar results could be expected, but additional research is necessary.

Acknowledgment
Research Project FIS2004-05537, Ministerio de Educación y Ciencia, Spain.

References

1. CIE Publication 116, Industrial colour-difference evaluation (CIE Central Bureau, Vienna, 1995).
2. CIE Publication 142, Improvement to industrial colour-difference evaluation (CIE Central Bureau, Vienna, 2001).
3. CIE Publication 101, Parametric effects in color-difference evaluation (CIE Central Bureau, Vienna, 1993).
4. A. R. Robertson, “CIE Guidelines for Coordinated Research on Colour-Difference Evaluation,” Color Research and Application, 3, 149-151 (1978).
5. K. Witt, “CIE Guidelines for Coordinated Future Work on Industrial Colour-Difference Evaluation,” Color Research and Application, 20, 399-403 (1995).
6. E. D. Montag and R. S. Berns, “Lightness dependencies and the effect of texture on suprathreshold lightness tolerances,” Color Research and Application, 25, 241-249 (2000).
7. B. Han, C. W. Cui and M. R. Luo, “Texture effect on evaluation of colour difference,” in *Color Communication and Management (AIC 2003 Interim Meeting)*, Bangkok (2003).
8. J. H. Xin, C. C. Lam, and M. R. Luo, “Investigation of texture effect on crt color difference evaluation,” in *Color Communication and Management (AIC 2003 Interim Meeting)*, Bangkok (2003).
9. R. Huertas, M. J. Rivas, A. Yebra, M. M. Perez, M. Melgosa and E. Hita, “Investigation of simulated texture effect on perceived color differences,” in *Book of abstracts of Color and Paints (AIC 2004 Interim Meeting)*, p. 46. Porto Alegre (2004).
10. M. Melgosa, E. Hita, A. J. Poza, D. H. Alman and R. S. Berns,“Suprathreshold color-difference ellipsoids for surface colors,” Color Research and Application, 22, 148-155 (1997).