Evaluation and modelization of chromatic discrimination. Effects on image palette

M.C. García-Domene*, M.D. de Fez*, V. Viqueira*, M. J. Luque**

****Departamento de Óptica, Farmacología y Anatomía. Universidad de Alicante***
Carretera de San Vicente del Raspeig s/n.
03690 Alicante (Alicante, Spain)

*****Department. d'Óptica. Facultat de Física. Universitat de Valencia***
Dr. Moliner, 50.
46100 Burjassot (Valencia, Spain)

Abstract

From a reduced set of experimental measurements, we have developed an algorithm that generates a mosaic of color discrimination ellipses, densely covering the region of the chromaticity diagram defined by the phosphors of a CRT monitor, with minimum overlapping between ellipses and leaving the minimum uncovered space. To test how well this mosaic covers color space, a set of digital color images has been filtered with it and the resulting palette reduction analyzed.

Key words: Chromatic discrimination, digital image filtering, palette quantization

Introduction and Objectives

Chromatic discrimination may change due to adaptation conditions and to the presence of abnormalities in the visual system of the observer [1,2,3,4].

We aim to model the effect of such changes on the appearance of color images. At present, we are on the preliminary stage of the project, measuring chromatic thresholds around different colors and under a range of adaptation conditions. Once a complete set of experimental data is obtained, we intend to introduce a stage simulating thresholds in an existing color vision model (ATD95 in particular [5]).

At the present stage, color palette reductions due to altered chromatic discrimination may be simulated by means of an algorithm that allows the shape of the discrimination ellipse around any point of chromatic space to be estimated by interpolation of experimental data.

Since MacAdam's classic work [6], different studies have determined discrimination thresholds concluding that the results could be fit to an ellipse in different colour spaces (see [1] for an example). This means that the colors that fall inside an ellipse are perceived by the observer as equal to the centre color, whereas a color outside the ellipse is perceived as different. Numerous later studies have completed this original work, and are amply referenced in the literature.

Experimental method

We have measured color discrimination thresholds, defined as the minimum color difference that allows the observer to correctly locate the position of the gap in a Landolt ring on a given background, using the CRT test (Fig. 1)[7].

To ensure that only color acts as a clue, luminance changes randomly in each point in the scene. The stimulus is constructed so that other clues, such as edges, cannot serve to detect the gap.

The present paper is centred in the study of the average normal observer. For each background color, threshold is the mean from five different observers. But with the purpose of being able to study the influence of adaptation on discrimination thresholds, we have included also preliminary measurements with colored filters (Gray, Brown, Green and Green-Gray Physiotint, provided by Essilor®), obtained from a single observer.

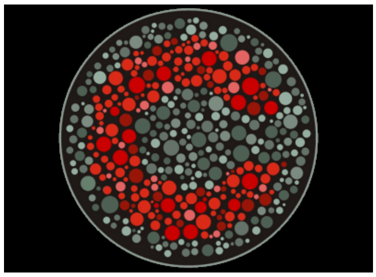


Figure 1. *Experimental session, showing the stimulus.*

Background colors were chosen from a grid uniformly covering the region determined by the screen phosphors in the first-stage opponent space ATD95 (fig3-a).

In order to carry out the study, a Matlab® routine has been developed to obtain a dense pattern of minimally overlapping discrimination ellipses covering the ATD95 space, from interpolation of the empirical data.

This program has been developed as part of the collaboration between the Vision and Color Group of the University of Alicante and the Vision Group of the University of Valencia.

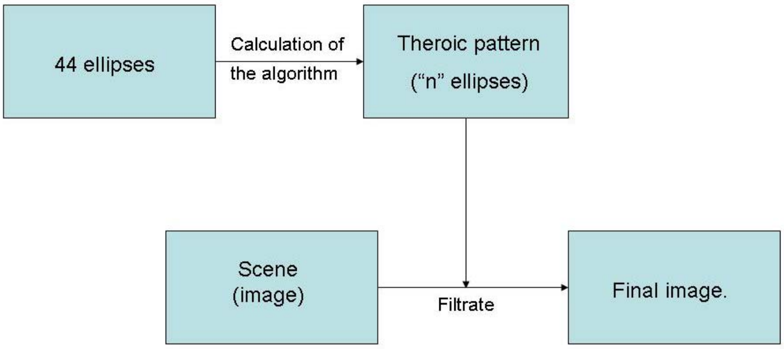


Figure 2: *Representative scheme of the routines implemented in Matlab.*

The theoretical set of ellipses can be used to reduce the color palette of an image: the routine assigns to all colors laying within a given ellipse the chromaticity of its centre. Colors belonging to the intersection of several ellipses or lying in an uncovered region are assigned the chromaticity of the nearest centre.

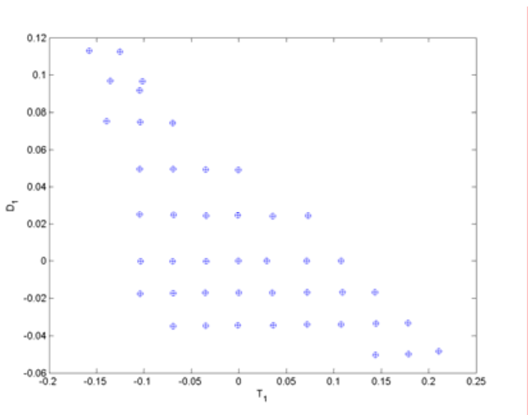
Note that we just show which colors would appear as equal, but we do not really answer the question "equal to what?". This must be kept in mind particularly when the observer whose perception we are simulating has a vision defect or when studying the effect of filters or a change in the illuminant [8].

Results

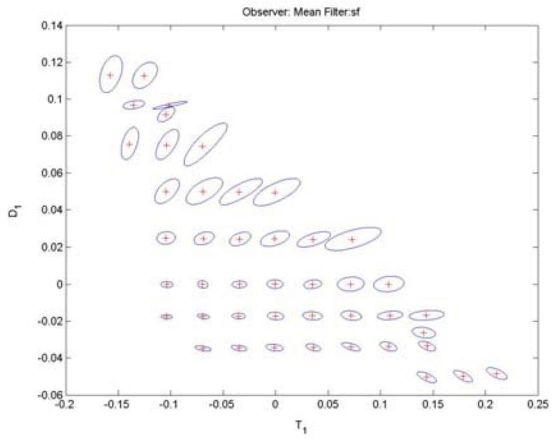
We can see in the figure 3-a the colours selected uniformity in the ATD95 space to be the ellipse centres.

Figure 3-b shows the 44 ellipses measured for the mean observer in what we will call "the naked eye condition", to distinguish it from situations where the observer is adapted to colored lights or wears a filter.

a)



b)



c)

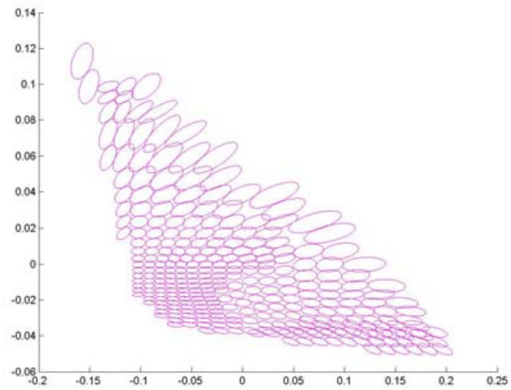


Figure 3: *First-stage opponent space in ATD95, showing A) the grid of background colors, (B) the discrimination ellipses for the mean normal observer (naked eye condition) and (C) and the predicted pattern of the ellipses of color discrimination.*

The theoretical pattern obtained by interpolation of experimental results is shown in fig 3-c. For the Gray, Brown, Green and Green-Gray filters, we have followed the same procedure.

Figure 4 shows, as an example, an image filtered using data from the naked eye condition. If we keep in mind that we aim to determine which colors appear as equal, and not which is the real appearance of those colors, it can be seen that in this case the algorithm, as expected, does not introduce large appearance changes, the only effect being a reduction of palette size.

On the other hand, preliminary results with colored filters (Figure 5) show a more marked reduction of the color palette than in the case of the naked eye condition.

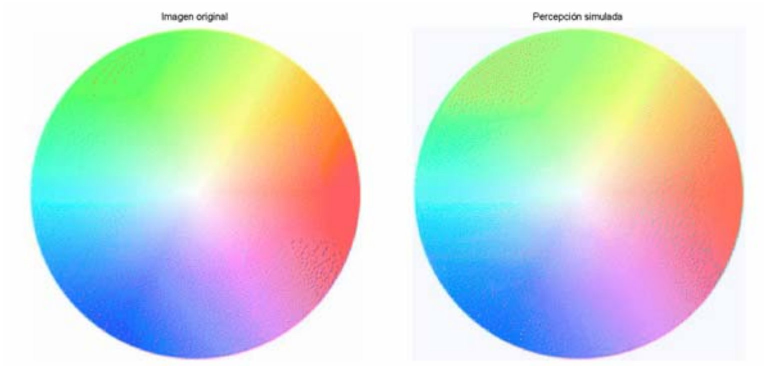


Figure 4: *Comparison of the original Image and the Image Naked eye.*

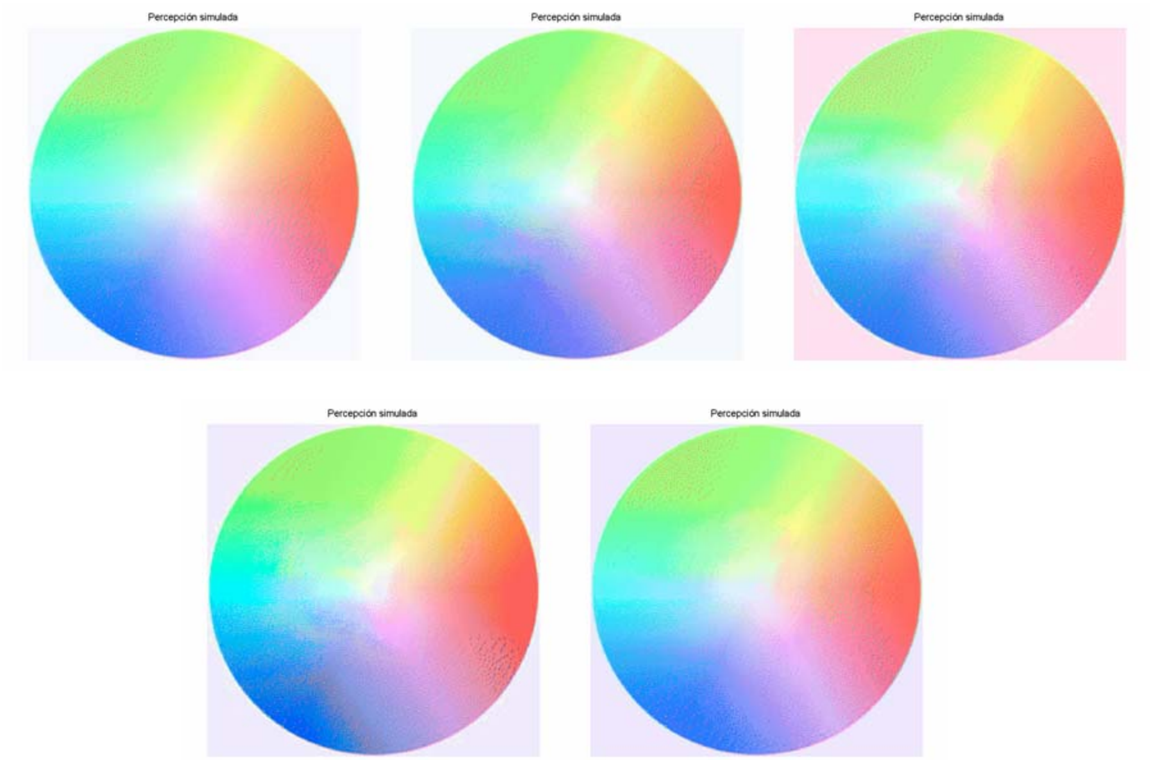


Figure 5: *Images compared under the naked eye condition and with filters b) Gray, c) Brown, d) Green and e) Green-Gray.*

With the Gray filter (Figure 5a) the most important effect is that bluish purple colors become confused with blues at high colourfulness and even with cyan at low, whereas the differences between reddish purples and reds (oranges at low colourfulness).

In the image filtered with Brown pattern (figure 5c) we verify that the frontiers between hues are smeared, showing colour discrimination losses, especially for purples. The change in image background colour shows that differences between achromatic and magentas are reduced.

With Green filter (figure 5d) the blue and purple zone appears less saturated and they look like the achromatic stimulus. The yellow gamut is extended to red and green colors, indicating discrimination losses for these colours. Reds, however, increase their distance from the achromatic stimulus (seem more colourful), whereas the achromatic itself shifts towards blue.

The Green-Gray filter (Figure 5e) has degraded yellow colors that now are more green-yellowish. Cyan has spread to greens and chromatic color bands appears in the purple colors.

Conclusions

We have developed an algorithm to simulate the effects of human chromatic threshold on the appearance of an image, which does not require to measure thresholds for a very large number of colors.

The image simulating the naked eye condition does not appreciably differ from the original image, although the number of colors of the palette is reduced, as expected. This reduction is more marked in the case of colored filters.

Some of the possible applications of this algorithm could be: situations in which there is desirable a reduction of the image size, since one can reduce the palette bearing in mind the chromatic discrimination of the final user, optometric applications like in detection of defective chromatic vision and pathologies (DMAE, glaucoma...), in which the color palette is determinant for correct diagnosis, calculation of ranges of reproducible colors for different devices, artificial vision, colorimetry, nanoscience...

In future work, we will modify the algorithm to extrapolate thresholds outside from the triangle of monitor primaries, which is necessary when, as in the image we have chosen as an example, we are dealing with quite saturated colors. Besides we mean to work in the ATD95 perceptual space, which would deal with the problem of simulating the appearance of the stimuli, particularly when using filters, instead of simply signalling which stimuli would appear as equal.

References

[1] Krauskopf J, Gegenfurtner K. Color discrimination and adaptation.Vis Res 32:2165–75, 1992.

[2] Yeh, T.; Pokorny J.; Smith, V.C.; Chromatic discrimination with variation in chromaticity and luminance: Data and Theory. Vis Res 33:1835–45, 1993.

[3] Hubel, D. H.; Eye. Brain and Vision; Nueva York: Scientific American; 1988.

[4] Capilla, P.; Artigas, J.M.; Puyol, J.; Fundamentos de colorimetría; Universidad de Valencia, 2002

[5] Wyszescki-Stiles; *Colour science, concepts and methods, quantitative data and formulae;* John Wiley & Sons, 1982

[6] MacAdam, D.L., Visual sensitivities to color differences in daylight, J. Opt. Soc. Am., 32, 247, 1942.

[7] Mollon, J.D.; Regan, B.C.; Cambridge colour test (handbook); Cambridge University, 1999.

[8] Gómez López, D.; Domingo Luna, E.; Sánchez Cerdán, A.; de Fez Saiz, M:D:; Estudio clínico de la aceptación de filtros fisiológicos en pacientes de cirugía refractiva; Ver y Oir, 2003, 54-64, 2006.

Author Biography

Mª Carmen García-Domene received her degree in Optometry from the University of Alicante (2004). Since then she has worked in the Vision and Colour Group (Department of Optics), at the University of Alicante, and is a student of the Advanced Optometry and Vision Science Master.