Background Influences on Color Appearance

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Abstract

The aim of this study is explore how complex spatial backgrounds influence color appearance in mesopic vision. To reach this aim we have run psychophysical experiments based on the magnitude estimation technique. Factors had been considered in this study: the lightness, the colorfulness, and the hue of background patches, the distance between background patches and test patch, the size of background patches and the colorfulness of background. Results showed that spatial background produced large and selective shifts on color appearance. Likewise, results showed that these shifts were higher when a complex (natural) image was seen than when color patches were seen. The image dependence was especially noticeable in lightness direction.

Introduction

The aim of this study is to analyze the influence of scene content (color patches and spatially-varying images) and of background types (a simple chart with a few number of color patches, complex spatial backgrounds and spatially-varying backgrounds) in color appearance judgment. To reach this aim we have run psychophysical experiments based on the magnitude estimation technique. The main objective of this study is to investigate various visual phenomena, such as brightness adaptation, chromatic spatial adaptation, contrast effect due to sizes and colored backgrounds, display field sizes, dynamic range in the scene.

Previous work was done by Webster [1], the motivation of this work was to examine changes in color perception resulting from adaptation or induction to color contrast in spatially-varying backgrounds. Our motivation is quite different; our aim is to examine background influences on color appearance to define new specific viewing parameters consistent with color perception. Another work was also done by Fairchild [2], who proposed an image appearance model referred to as iCAM. The iCAM model has a sound theoretical background; however, it is based on empirical modeling of viewing parameters relative to image content, background and surround rather than a standardized color appearance model such as CIECAM02 and some parts are still not fully implemented. Moreover filters implemented are only spatial and cannot contribute to color rendering improvement for mesopic conditions with high contrast ratios and a large viewing field. The main objective of this paper is to better define what the background of a scene is and how it influences color perception.

Experiments based on magnitude estimation method

In this study, we have considered the case of study for which the observer saw projected images on a white screen in a darkened room (Figure 1). The average luminance of the screen (i.e. the surround) was lesser than 10 cd/m^2, as for cinematographic viewing conditions, for which the human visual system is functioning in the mesopic range rather than in the typical photopic range [3].

The projector was calibrated daily and a MURATest (color wheel video-colorimeter) was used to control the non-uniformity of projection. Each color patch projected on the screen was measured to compare color attributes assessed by observers to color data displayed.

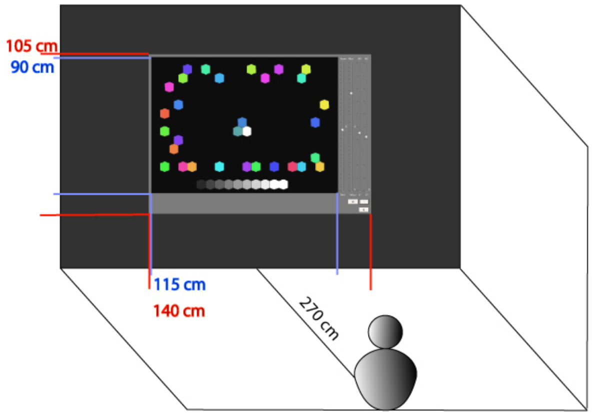


Figure 1. Viewing geometry.

The viewing angle for each image was about 24°, which correspond to a perifoveal vision. The size of images was 90 by 115 cm^2. The images were partitioned in hexagonal cells of constant size. For most of experiments the viewing angle for each patch (cell) was about 1.5°, which corresponds to a foveal vision. Before the experiment started, observers were asked to look a grey image for one minute for adaptation. Then they were asked to estimate the lightness, colorfulness and hue of a test patch displayed (e.g. see Figure 3). Reference stimuli are presented too to allow better relative estimation. Test patch and reference patch was centered in the image. The assessments were realized with the magnitude estimation technique. There results were recorded by pressing 4 buttons on the screen for the answers of Green/Red, Blue/Yellow, lightness and colorfulness, respectively (Figure 2).

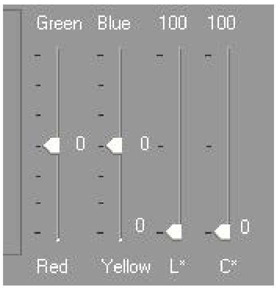


***Figure 2.** Magnitude estimation of hue (Red/Green and Blue/Yellow), lightness and colorfulness of a test patch.*

We have considered three sets of tests: - one set of nine tests (Test N°1 to test N°9) compound of three color patches (one test patch and two reference patches) and of a few number of color patches in the background (e.g. see Figure 3). For all these tests, the size of patches was constant. - One set of three tests (Test N°10 to test N°12) compound of three color patches (one test patch and two reference patches) and of a few number of color patches in the background. For each test, the size of patches was different of those of other tests. - One set of three tests (Test N°13 to test N°21) compound of one test patch and of a large number of color patches in the background. For each test, the size and the number of patches are different of these of other tests (e.g. see Figure 5). Three sets of background corresponding to three complex (natural) images segmented in regions of equal size had been considered. For each test, the shape (hexagonal) and the size of test stimulus, reference stimuli and background stimuli is constant

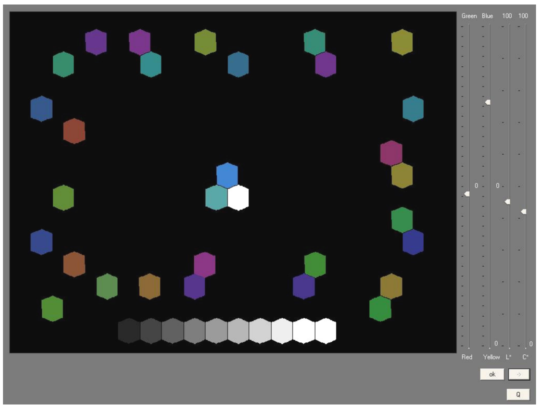
For each test, the white point was always displayed onto the image or measurable onto the white screen. The luminance of the white point was set to 200 cd/m^2. The luminance of the dark wall surrounding the white screen was set to 1 cd/m^2. The luminance of the background of images (black patches) was approximately equal to 0.8 cd/m^2.

The procedure used for Test N°1 to Test N°9 consists to present two color stimuli to the observer; a reference patch and a test patch. A few number of color patches was also randomly distributed in the periphery of the image (see Figure 3). For all these tests, the viewing angle for each patch was about 1.5°, which corresponds to a foveal vision.

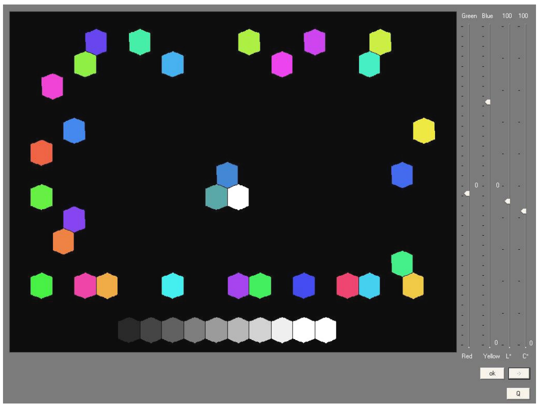
The observer was asked to estimate the difference of hue, lightness and colorfulness between the test patch and the reference one. Reference stimuli were presented too to allow better relative estimation. Lightness attribute was estimated relatively to a reference white scale. On this scale, the lightness of white point was set to 100, and the lightness of black point was set to 0. Ten lightness patches was presented from black (L=0) to white (L=100). For each run the cursor of the lightness scale was set to the lightness value of the reference patch. A reference white patch was also presented at right under the test patch. Hue attribute was estimated relatively to two hue scales; a Red/Green scale and a Blue/Yellow scale (respectively a* and b* axes of the L*a*b* color space). For each run the cursors of the hue scales were set to the hue values of the reference patch. Colorfulness attribute was estimated relatively to a colorfulness scale. Two reference values had been used to shorten the colorfulness scale; the value 0 (achromatic color) and the value 100 (in our experiments colorfulness of color patches was always under 100). These reference values were used in order to reduce variations between observers and to adjust all colorfulness visual results onto the same visual scale. For each run the cursor of the colorfulness scale was set to the colorfulness value of the reference patch.

Four colors had been used for reference patches. Ten colors had been estimated for each reference patch. Thus, 40 magnitude estimations had been done in each experiment. The test patches were chosen to cover a large color gamut and luminance range. They were also defined in order to equidistant in CIELAB. For each test, 28 color patches were also displayed in the background (e.g. see Figure 4). These patches were randomly distributed in the periphery of the image. The color of these background patches was (randomly) chosen to cover a large color gamut.

Three factors of study had been considered for Tests 1 to 9: the lightness, the colorfulness, and the hue of background patches.



(a) The saturation of color patches of background is lower than those of the two stimuli studied.



(b) The saturation of color patches of background is higher than those of the two stimuli studied.

Figure 3. *Magnitude estimation of hue difference (Red/Green & Blue/Yellow), lightness difference, and colorfulness difference between the test patch and the reference patch. The test patch is at the center of the image. The reference patch is presented at left just under the test patch and a white patch is also presented at right just under the test patch. The two color stimuli presented in (a) and (b) have the same color but their backgrounds are different. Whatever the background, all background patches had the same luminance level.*

The procedure used for Test N°10 to Test N°12 consists to present two color stimuli to the observer; a reference patch and a test patch. As for previous experiments, a few number of color patches was also randomly distributed in the periphery of the image. For Tests N°10 and 11, the viewing angle for each patch was about 1.5°, which corresponds to a foveal vision. For Test N°12, the viewing angle for each patch was about 12°, which corresponds to a perifoveal vision.

For Test N°10, 28 color patches were displayed in the background at a distance of 45 cm (i.e. 8°) in average from the test patch. For Test N°11, 26 color patches were displayed in the background at a distance of 20 cm (i.e. 4°) in average from the test patch. For Test N°12, 14 color patches were displayed in the background at a distance of 35 cm (i.e. 7°) in average from the test patch. Background patches were randomly distributed in the periphery of the image. The color of these background patches was (randomly) chosen to cover a large color gamut.

The observer was asked to estimate the difference of hue, lightness and colorfulness between the test patch and the reference one. Reference stimuli were presented too to allow better relative estimation.

Two factors of study had been considered for Tests 10 to 12: the distance between background patches and test patch, and the size of background patches.

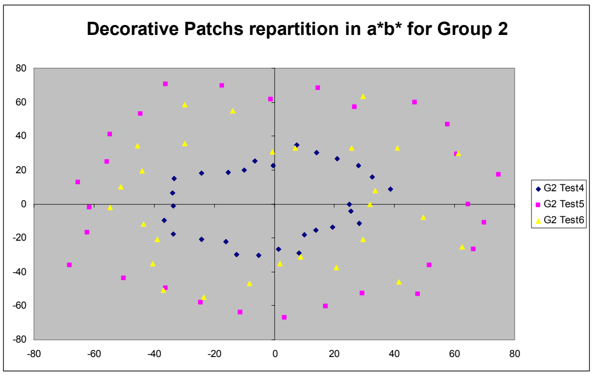


Figure 4 Sets of color patches belonging to the background (Tests 4 to 6).

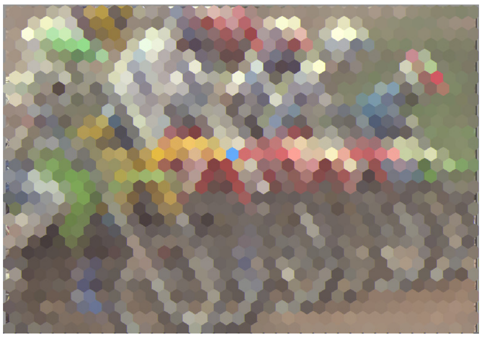
The procedure used for Test N°13 to Test N°21 consists to present only one color stimulus to the observer; the test patch. The background is compound of natural images segmented in regions of equal shape and equal size (see Figure 5).

For three of these tests the viewing angle for each patch (region) was about 1.5°, which corresponds to a foveal vision. At this resolution high frequencies (details) are visible in the segmented image. For three other tests the viewing angle for each patch was about 5°, which corresponds to a perifoveal vision. At this resolution only small areas homogeneous in color (low frequencies) are recognizable in the segmented image. For other tests the viewing angle for each patch was about 12°, which corresponds to a peripheral vision. At this resolution only large areas homogeneous in color (very low frequencies) are detectable in the segmented image.

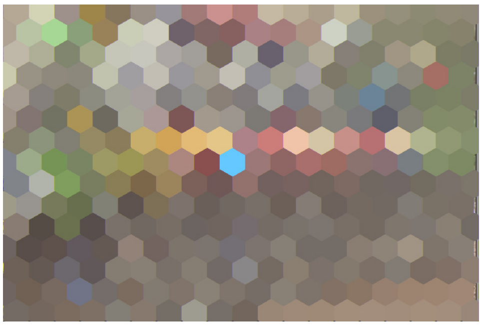
For all these tests the background was compound of a large number of color patches, respectively 1050 patches, 300 patches and 60 patches. Three kinds of complex (natural) images were used for these tests: one achromatic, one chromatic with low spatial frequencies and one chromatic with low spatial frequencies.

The observer was asked to estimate the difference of hue, lightness and colorfulness between the test patch and the color of the background. Neither reference stimulus nor grey scale was used in this set of experiments. For each run the cursor was set to the lightness, hue and colorfulness values of the mean lightness, mean hue and mean colorfulness values of the background, respectively. Two factors of study had been considered in this group of experiments: the size of background patches and the colorfulness of background.

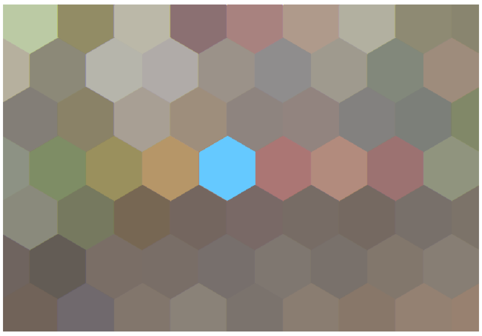
To assess the influences of chromatic adaptation and chromatic induction, the color of the background was controlled before and after each test.



(a) Small patches



(b) Standard patches



(c) Large patches

Figure 5. Examples of segmentation used for Tests13 to 21. The test patch is at the center of the segmented image.

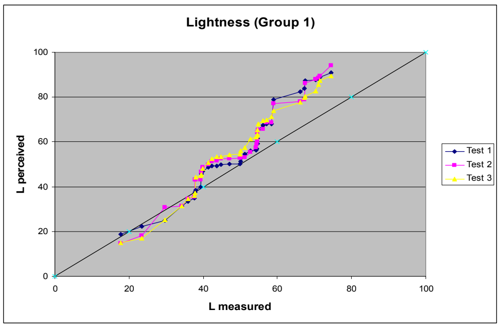
Experimental results

Ten observers participated in this experiment. They were students in computer vision. All had a normal color vision according to Ishihara test. Half of them had experience in attending psychophysical experiments.

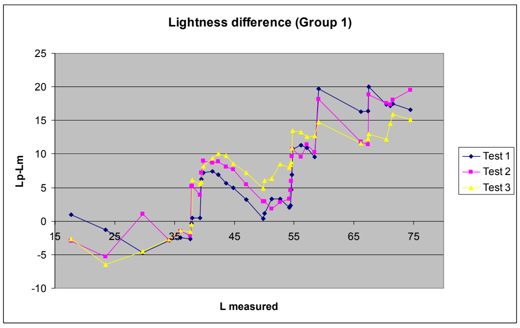
In total, 800 judgments (20 tests x 40 experiments) per observers were made. The whole assessment was divided into 7 sessions (3 experiments by session) with each lasting approximately 40 minutes to avoid observer fatigue.

Results showed that spatial background produced large and selective shifts on color appearance (see Figures 6 to 9).

Likewise, results showed that these shifts were higher when a complex (natural) image was seen than when color patches were seen (see Figures 8 to 9). The image dependence was especially noticeable in hue direction (see Figures 8 and 9).



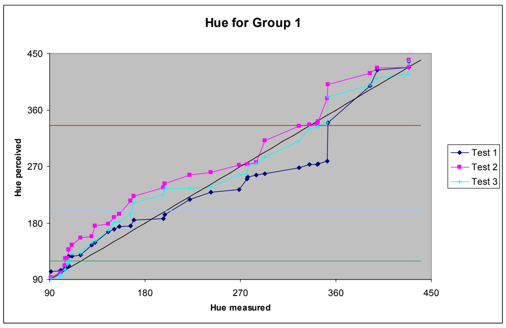
(a) Perceived lightness plotted as a function of measured lightness.



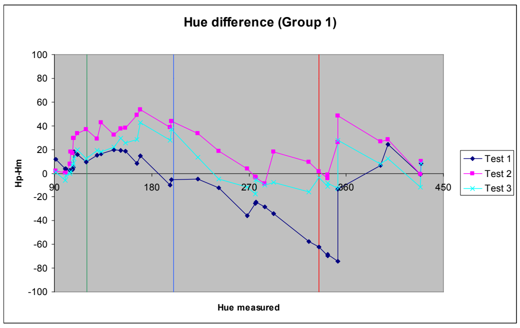
(b) Difference between perceived lightness and measured lightness versus measured lightness.

Figure 6: These results correspond to mean values computed for 10 obser-vers and to different levels of lightness for background patches (Tests 1 to 3).

Results showed also that high lightness shifts induced high colorfulness shifts. These results showed that chroma shifts were less noticeable than hue and lightness shifts, which doesn't agree with other studies [5].

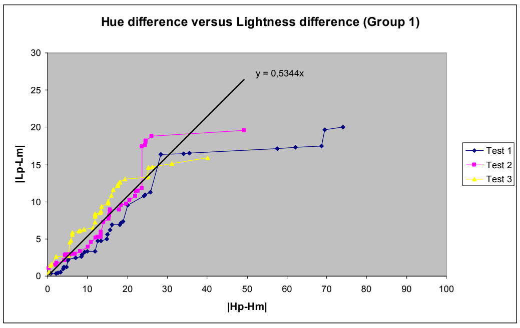


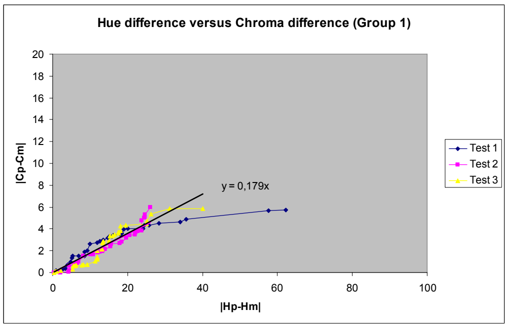
(a) Perceived hue plotted as a function of t hue.



(b) Difference between perceived hue and measured hue versus measured hue.

Figure 7: These results correspond to mean values computed for 10 obser-vers and to different levels of lightness for background patches (Tests 1 to 3).





(a) For different levels of lightness for background patches (Tests 1 to 3).

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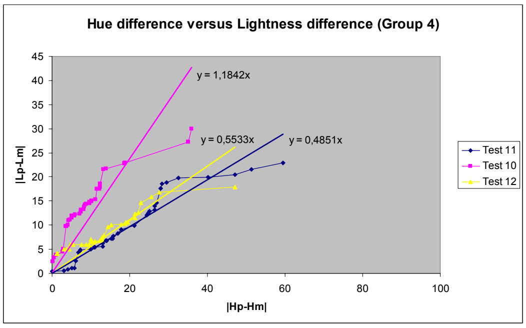

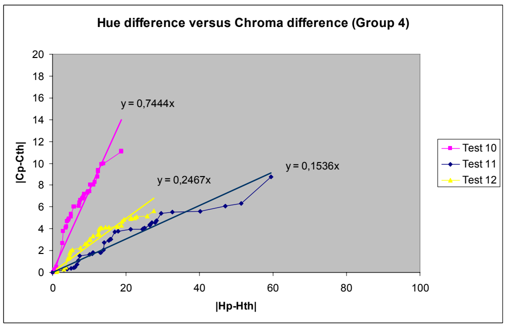

(b) For different spatial configurations for background patches (Tests 10 to 12).

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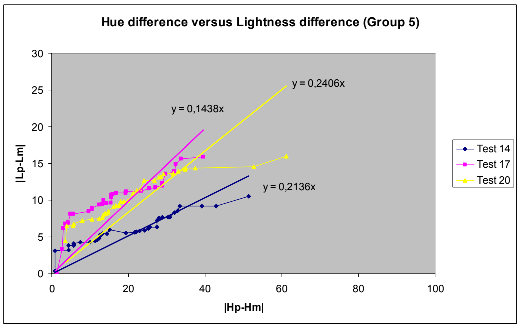
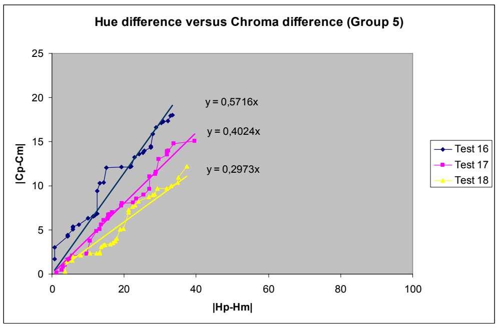
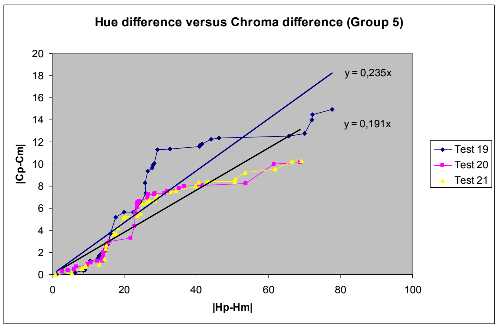




(c) For different types of complex images (Tests 14, 17 and 20).

Figure 8: *Lightness difference (between perceived lightness and measured lightness) versus hue difference (between perceived hue and measured hue). These results correspond to mean values computed for 10 observers..*

(c) For different types of complex images (Tests 16 to 18).



(d) For different types of complex images (Tests 19 to 21).

Figure 9: Chroma difference (between perceived chroma and measured chroma) versus hue difference (between perceived hue and measured hue). These results correspond to mean values computed for 10 observers.

These results show that the more the content of a scene is complex the more the observer's judgment is biased by the color of the background. This confirm the Webster's hypothesis suggested in [1], according with "color perception in different environments may be systematically biased by distributions of colors in those environments". Likewise they confirm that these bias result from both spatial contrast adaptation and spatial contrast induction in viewing background.

Discussion

We have noted that resulting scores were significantly impacted by the duration of experiments. Such observation was already done in previous studies. For example, Wichmann had shown in [4] that, contrary to contrast, color plays a major role on long term visual memory (e.g. for display duration longer than 500ms).

We have noted also that the sequence of tests influences assessment estimations due to human memory effect. In a general way, such a question had not been extensively studied. To what extent the question was: is the viewer's current impression (for test T+1) of the experiment dependent upon previous assessment (for test T)? Yes. That was the reason why in this study our tests were carried out in a random order. More generally, we have noted that human memory effect biased the assessment estimation when the background of the image did not vary in the time from one test to the following one, and when the test duration was higher than at least 5 seconds.

We have also noted that viewers were quick and less accurate to assess high changes from one test patch to the following one (between tests T and T+1) but slow and accurate to assess low changes (between test T and T+1). Considering that differences in viewer's reaction times to background changes may reduce assessment's accuracy, the assessment time was therefore limited to 5s.

Four continuous grading scales was used in this study with ten-grade assessment values linearly spaced in order to help the viewer in his judgment. Even if it has been established that there is no direct psychophysical correspondence between a continuous scale and a rating scale, we have noted a good correlation when the color difference between the test patch and the reference patch was low or moderate. Nevertheless, when the color difference was high correlation was lower.

Results show also that visual judgment was less accurate when the color difference between the test patch and the reference patch was high (e.g. see Figure 8 (a): under a difference of lightness of 40 the correlation between lightness difference and hue difference is correct, but above 40 the correspondence is bad).

Perspective

The next task of our study will address the problem of defining the specific viewing parameters which best define image content, background and surround. The motivation of this study will be to use these viewing parameters as inputs to color appearance models. That means calculating new color appearance attributes into measurable objective mathematical entities. As for this first study, an image analyzer will be used to capture reference target images under all the viewing conditions studied. These images will be analyzed so as to accurately describe viewing parameters such as illuminant, background and surround.

References

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Rafaël Nicolas received his Bachelor's degree in Computer Science in 2002 from the Université Jean Monnet, and a Master's degree in Image, Vision and Signal in 2003 from Ecole Nationale Supérieure des Mines of Saint-Etienne, France. He works under the direction of Pr. Alain Trémeau and his current research focuses on color appearance model and contextual colorimetry. He's also teaching assistant in Computer Science at Université Jean Monnet since 2004.