Does an expert use memory colors to adjust images?

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Abstract

In a previous experiment, we have studied the preference judgement of pictorial images with image experts and naive observers. We asked image experts to improve pictorial images the way they preferred. Then we showed those images to naive observers and asked them for their preferred image. We learned that, to enhance an image, an expert divides it into large zones of interest, which mainly correspond to natural colors, and that, to assess their preference judgments, naive observers principally focus on natural colors like sky, skin or grass when present.

In the present work, we want to extract information about expert's behavior in enhancement and naive observers preference, directly from the digital files produced by one of the experts. We show that the segmentation process used by the expert permits to apply different correction on different objects. We use the previous work on memory colors made by Yendrikhovskij [4] to correlate our images data with the theory of memory colors. We show that, to enhance an image, an expert moves the pixel colors toward areas of memory colors corresponding to the modified object. The expert also follows some rules while enhancing one segmented part. The corrections must be plausible inside one segment and for the whole image. The images are accepted by observers in relation with the presence of memory colors and when the treatment of the whole image seems coherent.

Introduction

Image quality may be influenced by many factors. In order to be able to optimize image treatments before printing, we need to evaluate and to quantify the importance of those factors from an observer's point of view. We are studying the factors influencing color image quality and preference of printed images. In a previous paper, we described an experiment with image experts. The aim was to learn from their behavior in image's enhancement. We asked image experts to improve eight pictorial images the way they preferred, and to save each intermediate version of enhancement. We showed images produced by one expert to naive observers and asked them "which image do you prefer?". We learned that, to enhance an image, an expert divides it into large zones of interest, which mainly correspond to natural colors. We validated the procedure with naive observers in a psychophysical experiment. The observers gave us their preference judgement on the images produced by the expert. Likewise, when judging an image for preference, naive observers principally focus on natural colors like sky, skin or grass when present. We now have an image database associated with preference judgements. Could we now extract some more information from the digital image files? The aim of the present work is to better understand the factors underlying the expert's behavior in enhancements and the preference of images.

Previous experiment with image expert and naive observers

This article follows the experiment described in the previous article : "Color Correction Judgements of Digital Images by Experts and Naive Observers"[1]. The aim of this work was to learn improvement recipes from the behavior of experts in image enhancement, and to have the correction procedure validated by a panel of naive observers. This paragraph briefly recalls those previous experiments.

We gave eight digital pictorial images with unknown colorimetry to an image expert from a pre-press company. In this company, the expert is in charge of scanning and enhancing digital images for several magazines that will be printed on traditional presses. We asked the expert to improve the images the way she wanted in order to produce the image she would prefer. She had to save each intermediate version of the enhanced images, each time she thought it was an important step of quality improvement. It provided several versions of the same image, between two and five versions. The expert was also asked to produce a few alternative versions of enhancement in order to increase the number of possible versions of the same image. Thus, the expert first treated the images the way she would prefer and the alternative versions usually corresponded to alternate interpretations of images. We printed all the images on an Epson Stylus Pro 7600 ink jet printer, with the size 17 cm x 26 cm.

Figure 1. Example of four images upon eight used in the previous experiment and their segmentations made by the expert

The prints were presented to ten observers who were naive to the experiment and to color image processing. We showed six versions of each image selected among the original and the five to eight versions produced by the expert. We used a pair comparison procedure where all the possible pairs were presented. Screening was made in a D50 color booth. The question asked to the observers was "Which image do you prefer?".

We learned from those previous experiments that an expert first segments an image into zones of interest in order to enhance it. The zones mainly correspond to natural colors. The expert corrects every zone sequentially. Figure 1 shows four examples of images and the zones made by the expert : Baby, Hand, Lighthouse and Garden. When we look at the images preferred by naive observers versus the corrections made by expert, we see that naive observers validate the expert's enhancements. The naive observers preferred five corrected images with segmentation out of eight. In three images, naive observers preferred the final expert's correction obtained after segmentation. In three cases, the corrections were not chosen by naive observers and the preferred image was the original one. In the last two cases, naive observers preferred an intermediate version of enhancement with segmentation. It seems that to judge an image for preference, naive observers principally focus on natural colors like sky, skin tones or grass when presented. Neither expert nor naives focus on parts if no memory colors are associated with them.

In order to further understand the work of the expert and the preference choices of the naive observers, we need now a quantitative evaluation of those data.

Analysis methods

The purpose of this manuscript is to understand the color processes that underlie the color adjustment and the color preference of images. For this goal, we plan to extract color information directly from the digital files of the images.

Color transformations from CMYK to Lab

The images produced by the experts are digital files in CMYK. Because the images were printed in order to be judged by observers, the images finally perceived by the observers depend upon the printing process and the viewing conditions. In order to analyze the results in a color space closer to perception, we transformed the CMYK files in L*a*b* values that correspond to printed colors. To convert CMYK images into L*a*b* images, we used the ICC profile of our printer. We made this ICC profile using the IT8 characterization chart printed with our printer and we measured every patch with a spectrophotometer under the D50 illuminant. Interpolations between the colors of the patches were made using the color management module in Photoshop. Thus we are now working on digital images specified in the L*a*b* color space which represents the color prints presented to the observers.

Representation of color changes in images

To understand the transformations made by the expert, we reported the color of every pixel of each image in L*a*b* and u'v' color spaces. We plotted the pixels on two-dimension maps that are L*a*, L*b* and u'v' color planes. As we saw that the expert treated the image by dividing it in large zones in order to modify each part sequentially, we plotted on separated maps the pixels that belong only to one zone. The color transformations made by the expert could be illustrated as the move of pixel colors in a color plane. Precisely the shift of the pixels between one image and its enhanced version is characterized by arrows linking the coordinates of the original pixel (beginning of the arrow) to the coordinates of the pixels in the corrected image (head of the arrow).

Memory colors

We have already mentioned that both expert and observers focused on natural colors like skin tones, grass or tree colors and sky color. These pieces of information seemed to be very important for the corrections as for the judgement of images. Such choices could be related to the theory of memory colors. Memory colors describe those colors that are recalled in association with familiar objects. We analyzed the data included in the images selected by the observers within the frame of the memory colors. We used the previous works made by Yendrikhovkij[2,3,4] and colleagues and by Janssen[5] about memory colors.

Yendrikhovkij did psychophysical experiments to locate areas of memory colors for skin, grass and sky in a u'v' plane. His digital images were displayed on screen. In the procedure, the colors were systematically varied in the u'v' plane. Observers were asked how natural the color looked and they were invited to quantify their judgements by grading the naturalness from 0 to 10. Ratings were normalized from 0 to 1. Ellipses of memory colors were constructed so as the center of the ellipse had a score of 1 and the other points followed a gaussian profile.

We decided to compare the ellipses of memory colors found by Yendrikhovskij with the data of our experiment. In his experiment, Yendrikhovskij used a D65 calibrated

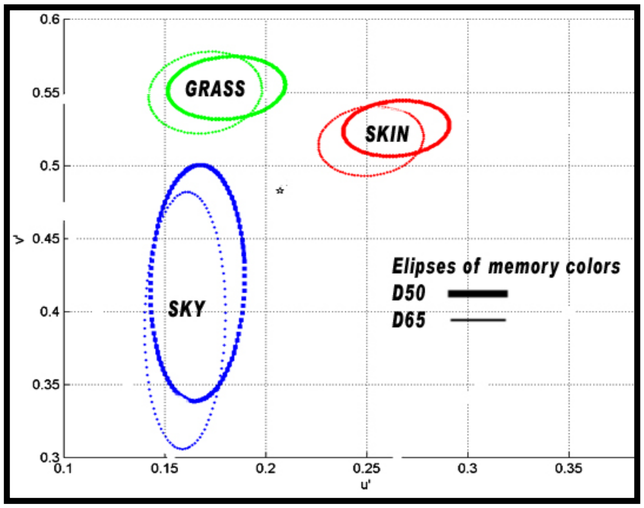

Figure 2. Ellipses of memory color areas in D50 and D65.

screen. Because we did our experiments under a D50 illuminant, we used the Bradford chromatic adaptation[8] transform to calculate the ellipses of memory colors from D65 to D50 illuminant. We also transformed the coordinates of our images from L*a*b* to u'v' space using colorimetric formulas. Thus we were able to compare the D50 transformed ellipses with our images. In order to identify the relationship between our images and memory colors areas, we plotted together the pixels of our images with the ellipses of memory colors. This allowed us to show which pixels located on image belong to a memory color ellipse.

Analysis of expert's work and naive's preference

Expert's work and memory colors

We learned in the previous experiment that an expert firstly segments an image in a few zones in order to enhance it. Those zones correspond mainly to natural objects, like skin tones, grass or sky colors. The expert changes each zone separately, and sequentially. When we plot the images corrected by the expert in u'v' plane together with memory color ellipses, we see that the number of pixels belonging to memory color ellipses increases as the expert enhance the image. Each time the expert worked on an object that could be associated with one of the three memory color zones, the pixels have moved toward the ellipses. In other words, after enhancement by the expert, more pixels constituting the skin tones of the image belong to the ellipse of the skin memory color defined by Yendrikhovskij.

We show here two examples. The first example is from the image Lighthouse (see figure 1). The expert used the software Adobe Photoshop to enhance the images and used four steps to produce the image she would prefer. In the first step, the expert changed the white point of the image. This step changed all the colors of the image. Then, the expert only changed the color of the sky area to produce step 2. For step 3, she changed the contrast of the whole image. This image obtained the highest Z score which means that it is preferred by observers. At last, she changed the color of the lighthouse (step 4). Table 1 summarize the modifications made by the expert and the preferences of naive observers characterized by Z score and rank of images.

Table 1 Lighthouse image : expert's enhancements and observers' preferences (rank and Z-scores)

	Expert's changes	Rank	Z score
Original	-	Not shown	-
Step1	Change white point of image	4	0,11
Step 2	Change sky color	2	0,67
Step 3	Change global contrast	1	0,7
Step 4	Change lighthouse color	3	0,2

In figure 3, we plot the pixels from prints of the lighthouse in the u'v' plane. We only plot here the pixels belonging to the segmented area of the sky as defined by the expert (see figure 1, zone 1 of the segmented image lighthouse). When we study the group of pixels representing the sky in u'v' (figure 3), we see that this group is moving into the memory color ellipse of the sky. The expert made a translation and

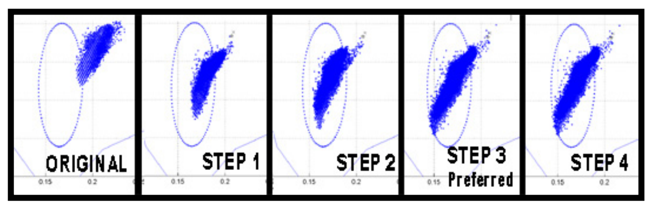

Figure 3. Pixels of the sky from image Lighthouse plotted in u'v' with the ellipse of memory color of the sky

Figure 4. Pixels that are inside the ellipse of memory color of the sky

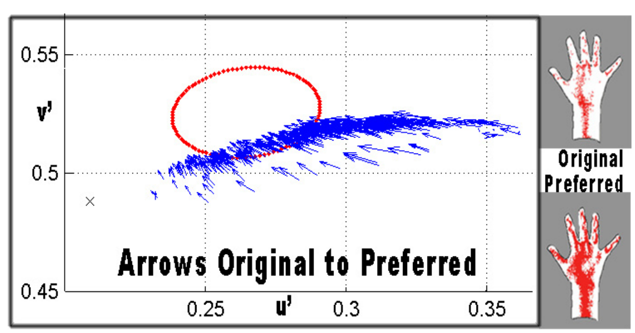

Figure 5. Hand image : original and preferred

an expansion on the group of pixels to obtain the preferred image : the sky pixels now cover the whole memory color ellipse. As in other images containing a sky part, the expert has kept the direction of the group constant. Ultimately, the sky pixels spread between the white point of the image to the most saturated point on the ellipse.

In figure 4, we have plotted in blue which pixels are inside the ellipse. The original image had almost no pixels from the sky recognized as memory color of the sky, but this image presented an obvious red color cast. The first step which consisted of removing the unwanted red has increased a lot the number of pixels inside the ellipse.

Between steps 3 and 4 of the enhancement, the pixels from sky are not significantly moving. Nevertheless, the observers preferred the third step of correction better than the last step. Those two images have obtained different preference scores, which indicates that the memory colors are not the only parameter influencing preference.

The second example is from the image Hand (see Figure1). In figure 5, we plotted the arrows going from the original Hand image (beginning of the arrow) to the preferred one (head of the arrow) in u'v' plane. The preferred image is the second and last step of enhancement made by the expert and is in head of the arrow. We used the mask drawn by the expert to isolate the skin tones so we only show the pixels representing the skin tones of the image. Between those images, the expert first changed the color of the paper around the hand. Then, on step 2 of enhancement, she changed only the color of the skin tone. She used the curve menu of Photoshop to adjust the skin tone color by adding some yellow on the whole hand. The move of the skin pixels in u'v' is characterized by the direction and the magnitude of the arrows. The arrows do not have a random behavior but have a main magnitude and direction. The magnitudes are almost the same here for all pixels. The directions are quite uniform as the group is moving toward the ellipse. This is not exactly a translation as the directions are slightly concentrated on one point, this leads to a compression of the group of pixels in the preferred image. The expert changed the colors by attracting them to the ellipse of skin memory color. The points here do not completely enter the ellipse as we will explain in next chapter but the principle is confirmed. Corrections increase the number of points that belong to the ellipse of memory color. The location of the pixels inside the ellipse of skin memory color are represented for the original image (right up in Figure 5) and the preferred one (right down). Pixels in red are inside the ellipse, pixels in white are outside. Pixels in gray delimit the mask of skin tones.

The relationship between the corrections made by the expert and the move of pixel to memory colors areas is verified on most images. Furthermore, as those images were preferred by naive observers, they validated the memory colors hypothesis.

Directions of corrections in color plane

When we plot the arrows representing the color shifts between two steps for the whole images in u'v' plane, no single direction appears for all the pixels. The points move with different directions and magnitudes. For example, Figure 6 shows the move of pixels for the whole image Lighthouse between the original image and the step one of enhancement. Nevertheless, when we study the shift of a group of pixels belonging to a segmented area drawn by the expert, the direction of this group of points becomes obvious. All the pixels of this group generally share a common direction in the u'v' plane, and a uniform magnitude. The move of groups of pixels could be a translation, an expansion, or a compression and they are usually applied to all the pixels belonging to one object. This comforts that the expert needs the segmentation process to correct each object in its own way. The expert knows the destination color she wants to achieve for a group of pixels representing a natural element. This is coherent with the idea that we keep in mind a color associated with well-known natural objects like sky, skin, grass.

Corrections in Lightness planes

The interpretation of the shifts of pixels in the u'v' color plane is often not sufficient as the expert also changes the lightness attribute while enhancing images. The first step of correction made by the expert is often a correction of the white point of the image, especially if there is a color cast. This step changes the color and / or the lightness value of the whitest point of the image (including reflects highlights). Photoshop permits to change color and lightness in the same time with one tool. This step allows the user to adjust the dynamics of the image and to remove the color cast. In Figure 7, we show all the pixels of the image Lighthouse in u'v', L*a* and L*b* planes. Original image is in the upper line and the first step of correction is plotted in the bottom line. The continuous blue line on each diagram represents the gamut of our printer. The modifications achieved by the first step of correction and their interpretation are more obvious in lightness planes than in the u'v' color plane. We see in L*a* plane that the expert moves the whitest point of the original image to the whitest point reproducible by the printer, with all the other points following. This constricts all neutral colors on the neutral

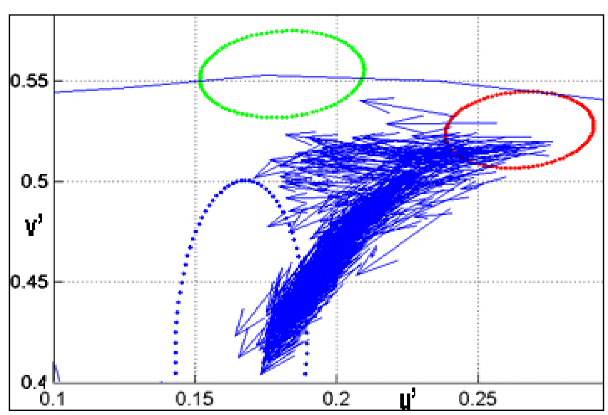

Figure 6. Lighthouse image, changes between original and step one

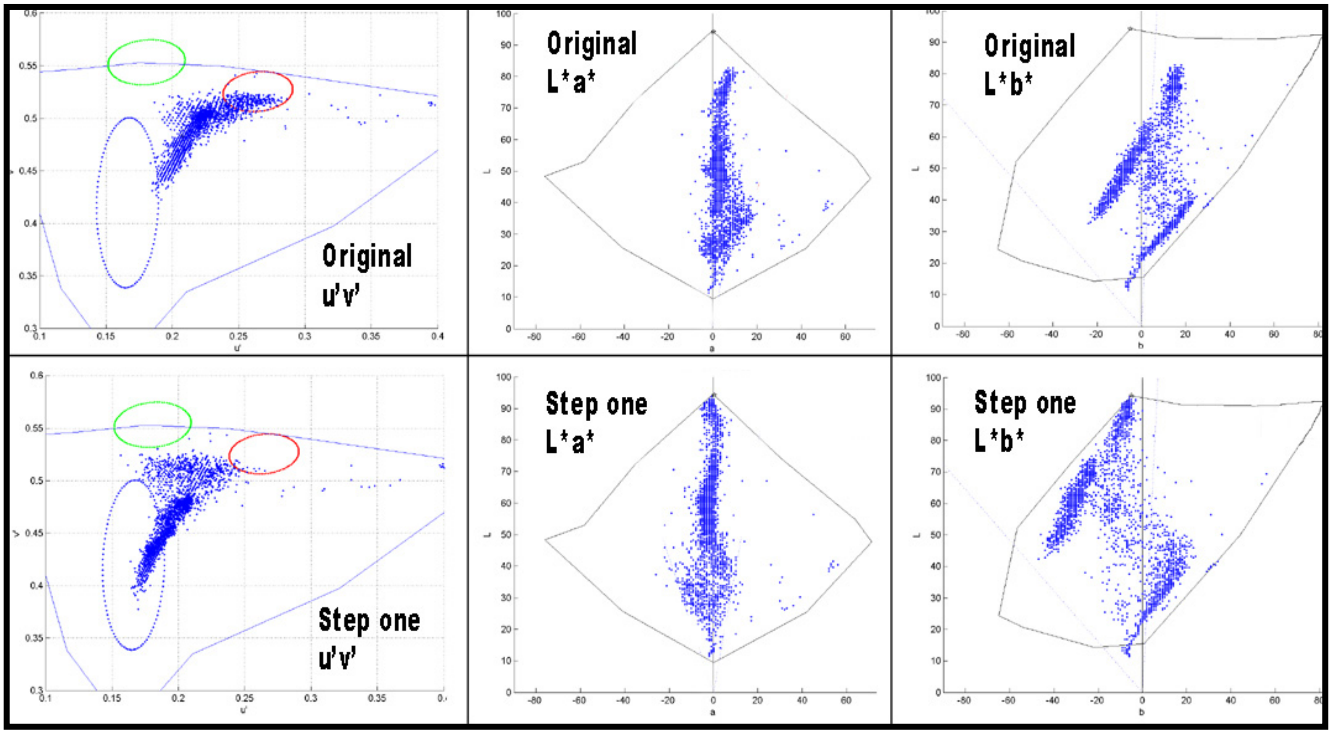

*Figure 7. Original lighthouse image's pixels in u'v', L*a* and L*b* and the first step of correction on bottom*
The continuous line delimits the gamut of our printer

axis. The original image had an obvious color cast which is removed during this first step of correction. In the L*b* plane, this correction leads to enhance saturation of objects as groups of pixels are moving away from neutral axis and to enhance contrast as groups of pixels are moving away from each other. The pixels are now distributed to occupy the whole gamut available.

Discussion

Location of the ellipses

As the points of the corrected images do not seem to exactly fall inside the ellipses of Yendrikhovskij, we have examined our data and constructed the ellipses that could have been used by the expert. For this, we isolated the areas corresponding to memory colors modified by the expert and we used images that were chosen by naive observers. We isolated the pixels of skin tones and the pixels of sky from four images and the pixels of greenery from two images. Then, we calculated the average pixel in u'v' coordinates for skin, sky and greenery areas. Those points became the center of our new ellipses. New ellipses were constructed using the same standard deviation and covariance as Yendrikhovskij's ellipses. The newly derived ellipses could be seen as memory color areas in the mind of the expert working to enhance printed image seen under D50. Memory color ellipses from expert are plotted in Figure 8. In the u'v' plane, the areas that characterize memory colors of grass and sky for the expert have common regions. But, in a 3D space, those memory colors have distinct scales in lightness, so they do not share L*a*b* volume.

Questions arise about the origin of the difference between Yendrikhovskij's ellipses and our expert's ellipses. Let us recall that Yendrikhovskij did his experiment on a display with D65 white point. We used printed images viewed under D50 illuminant. The white point and the level of adaptation between the two experiments are notably different. This could explain the difference in the location of ellipses of memory colors, as studied by Hunt [6]. Furthermore, the gamut of our printer is limited and can not reproduce all colors : the ellipse of grass from Yendrikhovskij is half out of the colors reproducible by our printer (see Figure 7).

Impact of lightness enhancements

An expert modifies lightness attributes in the same time as color attributes. It seems that the expert tends to use the whole dynamic and gamut available for enhancing the images. Those changes surely depend on the physical characteristics of the final receptor of the image (screen, printed paper) and the conditions of illumination during observations. Lighting environment influences adaptation and has an impact on image optimization. More studies should be directed to the influence of those factors in our experiment.

We studied images enhancements by experts in relation with memory colors areas in the u'v' color plane. However, memory colors areas of skin, sky, grass have a typical range of lightness. Further analysis should be done on our images in a three dimension color space including the lightness parameter of memory colors.

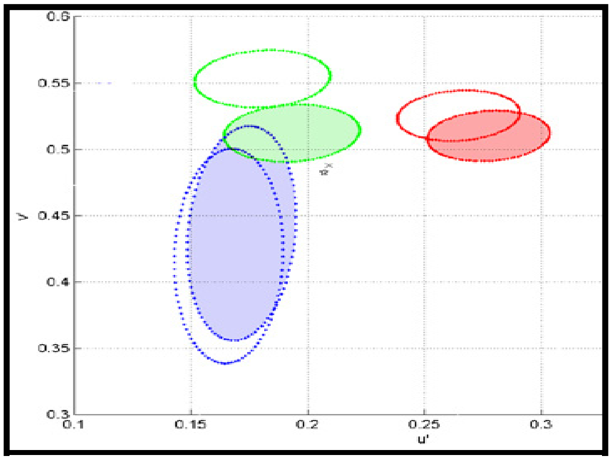

Figure 8. Ellipses used by the expert (full color) and ellipses from Yendrikhovskij

Physical plausibility of image appearance

If the association between preferred images and memory colors is clear, it is not the only criteria used by observers. Some rejected images have a high percentage of memory colors (like Lighthouse step 4). We suggest that one important element to judge an image is the coherence of the whole color distribution which should make the whole scene at least natural or plausible. A real world scene typically contains a single dominant lightsource (e.g. sun) that constrains the appearance of the objects on this scene. Observers are able to judge the coherence and plausibility of one scene [7].

We saw that the segmentation process made by the expert permits to correct appearance of the objects present in the scene in their own way. Different color and lightness corrections are applied to each segmented parts. The corrections represented by the transformations on groups of pixels in u'v' are not anarchic and follow certain rules. For example, the whitest point of the segmented part should stay the whitest point of the group in order to keep the object plausible. For sky corrections, the expert usually changes the orientation of the group of sky pixels in order to follow the direction characterized by the image's white point, the center of the sky ellipse and the most saturated point of the ellipse. All these transformations maintain the plausibility of each segmented part and permit to correct the whole image with coherence to an illuminant. More research is needed to explore the relationship between the various enhancements of segmented parts of the images with respect to the coherent representation of the scene.

Conclusion

In a previous experiment, we showed that the expert segments images in order to be able to enhance each object in its own way. Here we find that an image is preferred if the colors of the elements in the scene match the colors we have stored in our memory. While enhancing an image, an expert is changing the colors of the natural elements like skin tones, grass or sky color to make them match the color he recalls from his memory. Likewise, naive observers clearly use memory colors to judge an image for preference. Both expert and observers learned memory colors from elements they saw in the past, from their experience. Further we show that the transformations respect the plausibility of each segmented part with respect to the whole image. As the presence of memory colors is decisive for preference, the whole image must be coherent to be accepted.

Acknowledgements

The authors would like to thank the expert, Mme Marie Raymond-Bertrand and all the observers for their participation. We would like to thank too M. Ruud Janssen for his help and advice.

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Biography

Clotilde Boust received her engineering degree in photography from the Ecole Nationale Supérieure Louis Lumière, France in 1998. After working for two years as color consultant in the press industry and one year as researcher in the Vision laboratory of the Museum National d'Histoire Naturelle, she began a Ph.D. in image quality with Océ Print Logic Technologies and Paris VI University.