



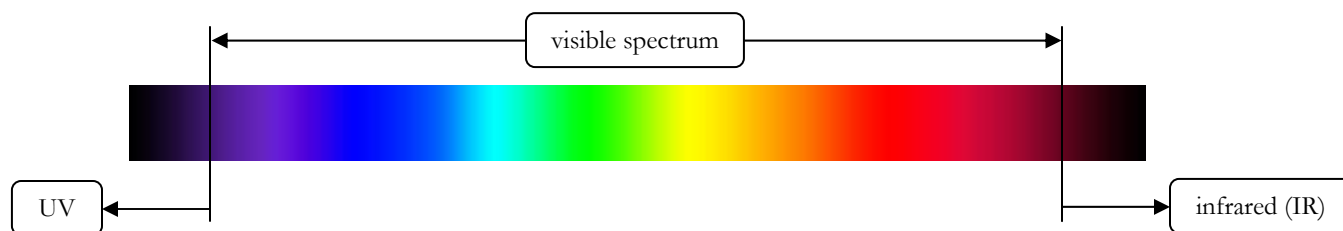
Application Note #2

How to use a white target to identify UV-enhanced paper

1. Introduction

1.1. What is Ultra-Violet?

Ultra-Violet light (UV) is a range of wavelengths that extends from the deep blue (violet) towards the X-Rays. UV light is not directly visible to the human eye but its shorter, more energetic wavelength, is readily absorbed by organic materials, with human skin first coming to mind. But while not being directly viewable we can still visibly detect its presence in certain situations. Beside being the “light” that causes sunburns, anyone who has been in a room filled with “black lights”, usually a fluorescent light with a dim violet look but which emits a lot of invisible UV, knows that certain materials, in particular white fabrics made of man-made materials (polymers, or “plastics” to be more specific), are seen as bright light-blue.



Is the perception a result of UV reflection? No, since that, even reflected, UV light remains invisible to the human eye. What happens is that the UV light is not directly reflected by the fabric but is first absorbed by the fabric molecules and dyes. After a very small, unperceivable, delay, the energized molecules re-emit the energy. However, because of the molecule structure, this re-emission does not give back the energy of the initial wave; some part of it is lost in heat. Since the re-emitted wave is of lower energy, its wavelength is longer, and thus toward the visible spectrum. This re-emission, the fluorescence, is generally in the blue part of the spectrum, not too far from the UV.

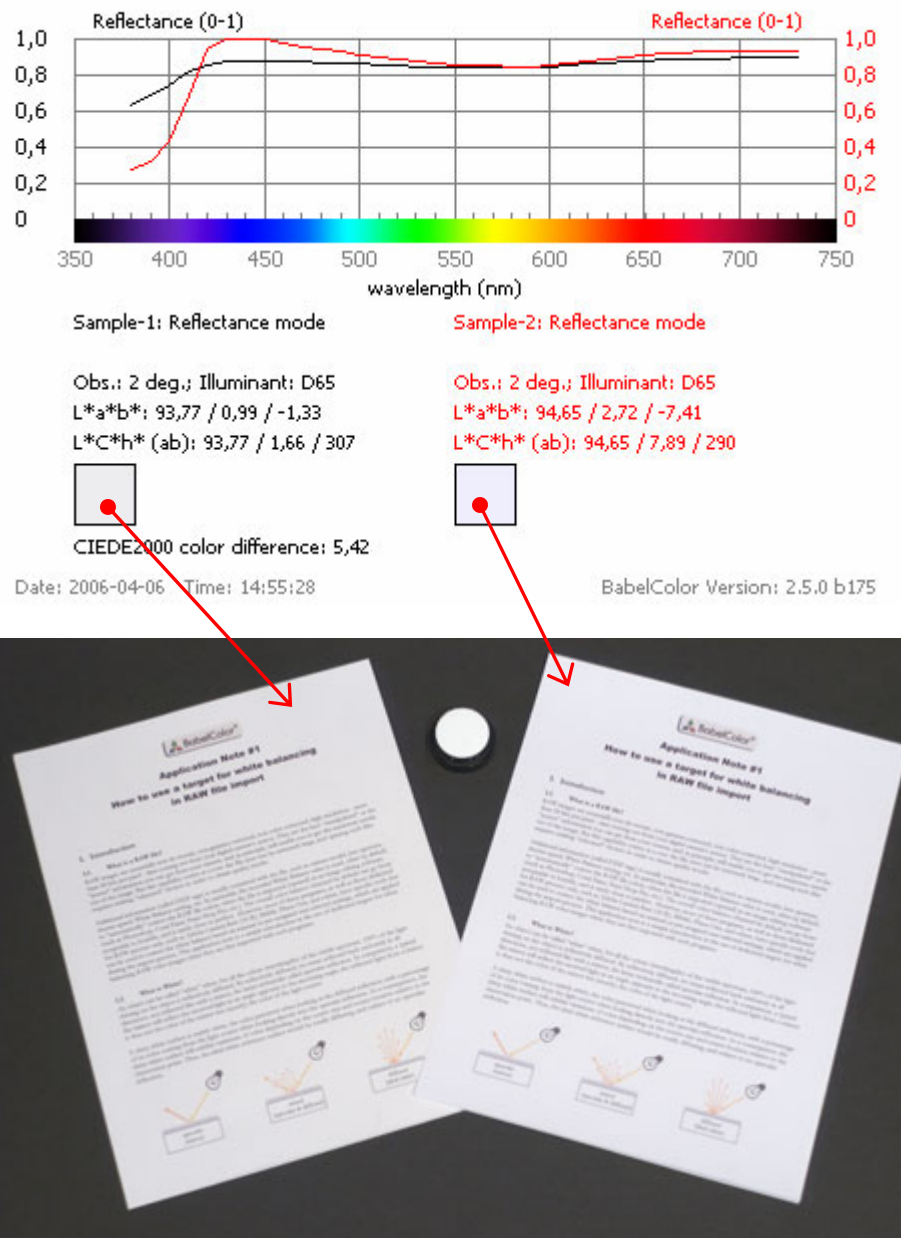
When the only illumination source is a black light, we essentially see only the fluorescent materials, and we see them in a color corresponding only to the fluorescence light; the non-fluorescent materials of various colors are seen as black. When UV light is mixed with white illumination, which is the case for normal sunlight and most artificial white light sources, our eye combines the visible reflection, the object’s “true” color, with the bluish light from fluorescence, if present. In such an environment, a white object which is subject to fluorescence will look somewhat bluer than another white object which is not fluorescent, and our brain may judge that the fluorescent sample is “whiter”. This “trick” of fooling the brain is used by most detergent manufacturer which mix blue dyes and fluorescent additives in their products so that washed clothes look whiter than they are.

The same trick is used by paper manufacturers which offer products with an ISO brightness of 108 or more. This 108 essentially means that 108% percent of the incoming light is reflected back! Since the paper is not an energy source (unless it is radioactive!), the only explanation is fluorescence. Since some of the UV energy is re-emitted in the visible spectrum; if you compute the brightness as the ratio of reflected VISIBLE light to the incoming VISIBLE light, the extra contribution from fluorescence will improve the ratio in all cases, and may even make it go over 100%.

It is quite straightforward to identify UV-enhancement with a spectrophotometer or a colorimeter, as we will see in the next paragraphs. Without such (costly) instruments, we can only surmise of its presence. However, there are alternatives; Section 2 shows how to use a simple white target and our eyes, or a camera, to make an informed assessment.

The figure below shows the spectrums of two white papers, one non-UV-enhanced (Sample 1, in black), and the other one UV-enhanced (Sample 2, in red). Three sheets of paper were superimposed for each measurement, in order to minimize any background influence. We can see a little bump in the blue region of the spectrum for the UV-enhanced paper; the reflectance goes up to 100% around 430 nm, in fact 104% (clipped in the illustration), and its b^* coordinate clearly indicates a strong blue content ($b^* = -7,41$). Such a well defined bump is not present in the non-UV-enhanced paper and its $L^*a^*b^*$ and b^* coordinates are much more neutral.

We printed a typical report page on each paper. When looked side-by-side under a typical halogen desk lamp, as shown in the image below, the UV-enhanced paper is usually preferred over the non-enhanced one, but let's not get to a conclusion too fast here, as color accuracy is seldom the selection criteria here.



1.2. Why should I be concerned?

Using a UV-enhanced paper in a report, a business letter, a CV, and many other document types will usually enhance the presentation, even if there are color charts and figures. In some circumstances, the use of a UV-enhanced paper will even give good results with images, but here starts a grey zone.

Firstly, you should be aware that light sources have varying UV contents. Sunlight has significant UV content when directly exposed to it, i.e. outside; its UV content goes down dramatically when viewed through a window (it is quite hard to get a suntan behind a window!). In comparison, tungsten lights have low UV content, while halogen lamps, because of their quartz envelope, can emit more UV, but not as much as sunlight. As for fluorescent lights, their UV content varies significantly from one tube type to the other. When looking at a UV-enhanced sheet of paper under these various lights and conditions, the effect of fluorescence will be different. Similar effects will also be seen if you measure a color patch on such a paper using a spectrometer or colorimeter with either a tungsten or a xenon (flash-type) lamp, with the xenon lamp closer in spectrum to sunlight, or with an instrument fitted or not with a UV filter.

Secondly, not all UV-enhanced papers react the same way since the chemicals and their proportions vary by manufacturer, and by batch.

Imagine that you just made an ICC printer profile using color patches printed on UV-enhanced paper, and measured with a spectrometer fitted with a tungsten source and a UV filter, and that an image printed with this profile is viewed under a D50 light booth. Because of the light booth normal UV content, the paper will fluoresce and show more blue than what was measured, a simple consequence of using a UV-filtered spectrometer, which prevented UV light from reaching the sample. This blue-shift will be quite visible and create a color imbalance which will vary from one image to the other, depending on their color content.

Now let's say that we used an instrument with no UV filter, and that all measurements were thus done with a certain dose of UV content typical of what is found in tungsten sources used in color measuring instruments. Images corrected with a profile measured in such conditions should look better under the D50 light booth than for our previous example, but since the UV content of D50 is higher than the UV content of the tungsten source, the resulting images should also be subjected to a slight blue shift.

You may think from the above that the solution is to use a xenon lamp, without a UV filter, or a xenon or tungsten light with D50 or D65 filters, which would ensure a better match between the measuring instrument light and the viewing booth, and you would be right, up to a point. First you need to consider that, except for controlling color in a print shop, most images are not seen under a D50 booth by the final user. Magazines are usually seen under a halogen or tungsten lamp while exhibition images can be seen under daylight and halogen lights.

In addition, filtered color instrument lamps may correct the visible part of the spectrum but will not enhance the UV content, if not already present. Finally, not all D50 light booths are created equal as they are often judged on their visible specification alone with little importance placed on their actual UV content, which can vary between models and manufacturers.

As you can see, the combinations of paper type (and batch), instrument light source, instrument filter (UV, D50, D65, or no filter), and viewing light sources set the stage for a nightmarish play. One general consensus is that you should not select an instrument with a built-in fixed UV filter; without the filter, you have at least a chance of taking into account some of the fluorescence effects. Also, some high end profiling software packages offer tools for tweaking the effect of UV fluorescence with a "ratio" type control (essentially a trial by error approach).

If you find yourself uneasy after reading the preceding paragraphs, than you are perfectly normal, and you will not be shocked if we say that for critical and reproducible color printing, the use of UV-enhanced paper should be proscribed! What should shock you however is that many photo papers by major printer companies ARE UV-enhanced. For instance, the Canon "Matte Photo Paper" and Epson "Enhanced Matte Paper", with an ISO brightness of 108 and 104 respectively, are obviously treated in such a way. You will also find that many glossy and semi-glossy high-end photo paper are also UV-enhanced, but at a lesser degree than the papers just mentioned; the effect is more subtle, but can be noticed.

Using papers which are strongly UV-enhanced is like standing on moving sands; every attempt to improve the situation usually results in a more desperate arrangement. What makes the situation even more dangerous is that UV-enhancement, like moving sands, is not always obvious (well, except when you see a 100+ brightness spec!). Therefore, the sooner you are aware of its presence, the better, and because you may not always have a spectrophotometer at hand, this is where the use of an “almost perfectly white” target can be helpful.

2. Identifying UV-enhanced papers with a white target

2.1. Characteristics of the white target

As we have seen in the first part of this document, UV-enhanced white objects exhibit more brightness and more blue content than non-UV-enhanced whites. The two main characteristics of a white target to be used to identify UV-enhanced paper are then:

The target should not be fluorescent!

This one is obvious. You do not want your reference to be subjected to the variable enhancement from the changing UV content of various sources. If your target is placed near a fluorescent paper, it will look less blue, in fact yellowish, since your eye will adapt to the larger sheet of fluorescent paper.

The target should be the whitest possible

By being sure (99% sure!) that any other white object is not as white, you will rapidly identify any paper that is brighter than the target as being UV-enhanced. One could argue that, ideally, the target should be of the same reflectance as the unknown paper, but this parameter is often not known when we are placed in presence of the paper in question.

It will not be a surprise if we mention that the BabelColor White Balance target has both these properties!

2.2. How to use the target (for paper identification!)

The following recommendations apply only to this particular application, which is to identify UV-enhanced papers. Please consult “Application Note #1: How to use a target for white balancing in RAW file import” for instructions on the use of the target for general photography.

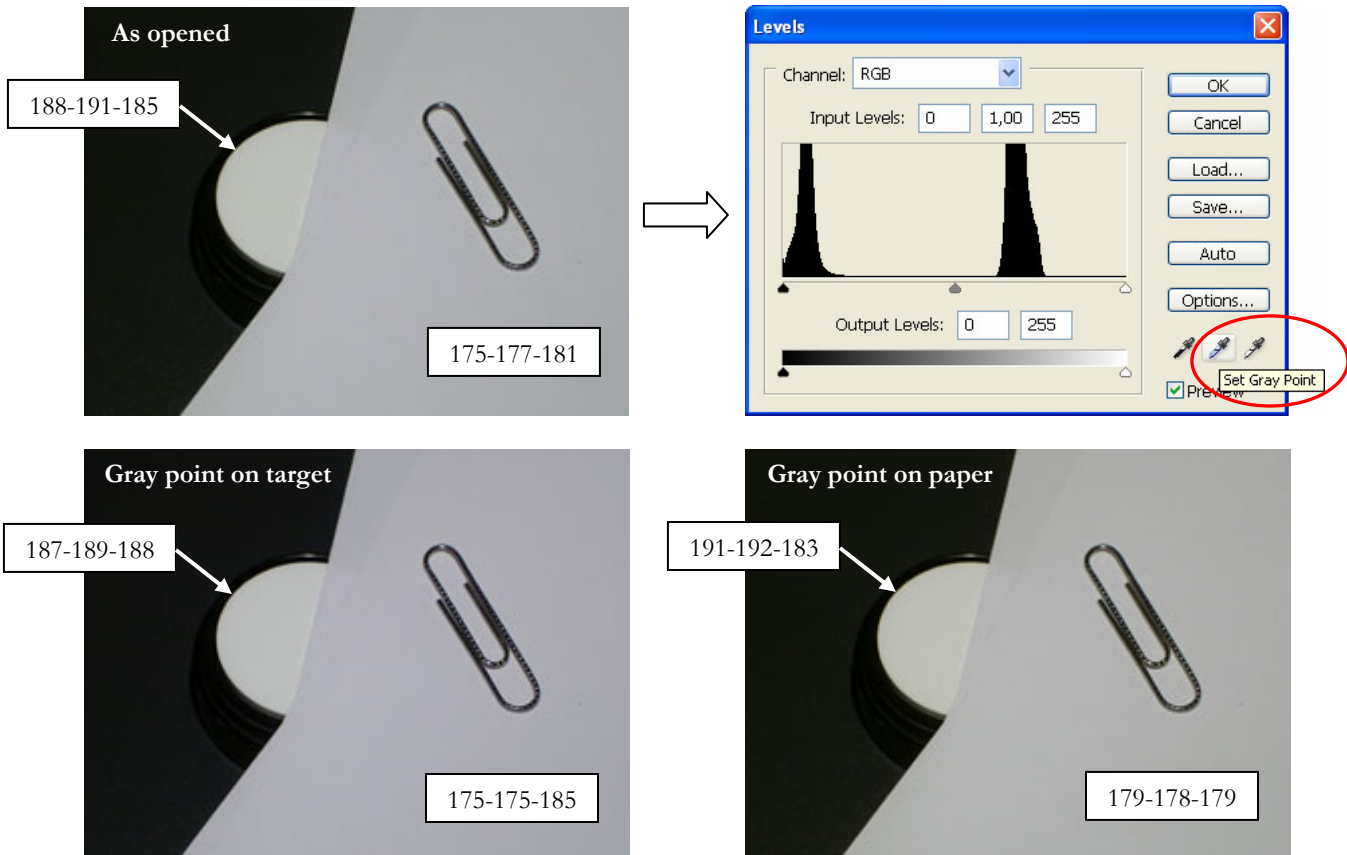
- i- For illumination, if you have a choice, select a source which has the most UV content. We are not talking of a black light here, but of a normal white source; for example, select a D50 booth instead of a standard halogen desk lamp.
- ii- Try not to mix lighting from different sources as the illumination may change with the relative paper to viewer position. The illumination level should be on the high side, such as a 50 cm away from a 50 W halogen lamp for example.
- iii- Do not place the paper at an angle where you can see the light source like in a mirror; this is particularly applicable to glossy and semi-glossy papers.
- iv- Place your sheet of paper on a neutral grey background (preferably dark grey). Remove all other sheets of paper from your immediate field of view as well as all brightly colored objects which could affect the illumination.
- v- Wait a few seconds to let your eyes adapt to the illumination, then simply place the white target beside your unknown sheet of paper.

A few situations could be witnessed at this point:

- a- The paper looks whiter and brighter than the target: The target will most likely look yellowish, which is normal since your brain has adapted its perception on the larger paper sheet which “it knows is white”, or so it assumes. In such a case, you clearly see the effects of UV-enhanced paper and how badly it could affect your colors if you print on such a paper.
- b- The paper looks whiter than the target but not brighter: The paper may look grayish blue, because of the additional UV-induced blue content, but the additional light is not sufficient to make the brightness go over the 99% reflectance of the white target. To be further convinced of seeing a blue shift, look at the reverse side of your paper sheet; very often the back of these sheets are more neutral than the front face.
- c- The paper looks grayer than the target but as neutral: This case will happen whenever your paper is not UV-enhanced but neutral white. Under tungsten light, both the target and paper may look of the same yellowish tint. Remember that essentially no paper has a reflectance over 96%, so the target will always look brighter.
- d- The paper looks yellower than the target: This case will happen for many standard non-UV-enhanced papers which are not neutral white. In particular, many art type papers will have this appearance.

If you are not sure of your analysis, simply take a picture of the target against the paper. For thin papers, we recommend using a stack of three sheets. Set your camera’s White Balance (WB) setting to the custom setting which best matches the illuminating conditions. We recommend saving the picture in JPG as no fancy image correction is required. The following examples were made using Adobe Photoshop.

Once the file is opened, select the *Image/Adjustments/Levels...* menu command. Click on the “Set Gray Point” eyedropper tool; this is the middle eyedropper of the “Levels” window. In your image, click either on the white target or on the paper; this action will “neutralize”, i.e. set to a neutral gray, the selected object. The image obtained with both options are shown below; RGB values are relative to the sRGB space..



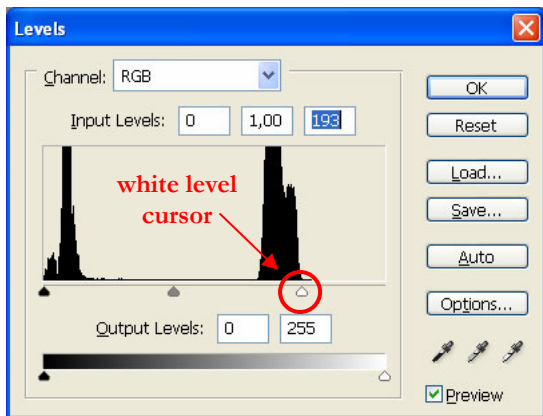
Hint: In Photoshop, before opening the “Levels” window, select the “Eyedropper Tool” and set its “Sample Size” to either a 3x3 or a 5x5 average. This setting will also be used by the “Levels” window eyedroppers.

We could adjust the brightness and get a more realistic appearance but we already have our answer here. By clicking on the target, as shown in the “Gray point on target” image, we effectively obtained a neutral gray; in comparison, the paper has a definite blue cast, as confirmed by its RGB coordinates (175-175-185). Similarly, by clicking on the paper, as shown in the “Gray point on paper” image, we obtained a neutral gray for it, and the target is clearly yellow (RGB: 191-192-183).

Do you wonder why we did not select the “Set White Point” eyedropper instead of the gray point one? Simply because clicking on any pixel with this tool will bring its value to 255 (255 is the default value, and even though it can be changed by the user, the chances are that it is near 255). So, if we click on the lower brightness paper using the “Set White Point” eyedropper, the white target will likely get clipped, and its tint will not be visible.

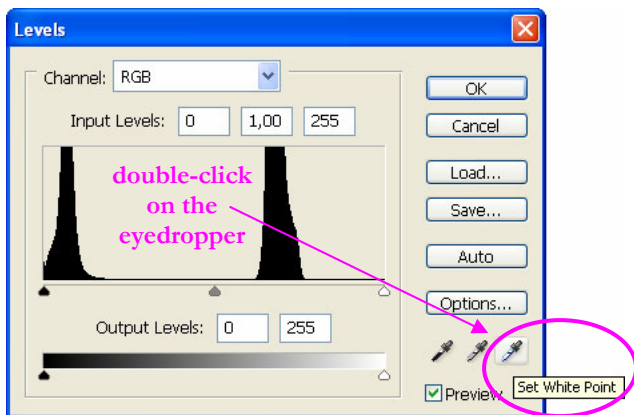
Because we know that the target is neutral and not fluorescent, the physical “reality” is the image where the gray point was set on the target. This is not what we perceive if we are adapted to the paper, but this is nonetheless an absolute confirmation that this paper is UV-enhanced. This is why, when we set the gray point on the paper, the target looks yellow. It is difficult to judge this from the image “As opened” since the white balance is somewhere between the target and the paper.

Similar results could have been obtained starting with RAW files and using RAW import programs such as *Adobe Camera Raw* (ACR), part of Photoshop CS2 (<http://www.adobe.com>) and *Bibble* (<http://www.bibblelabs.com>), a stand-alone RAW file importer. However, instead of using the “Set Gray Point” tool, the “White Balance Tool” of ACR and the “Click White Cursor” tool of Bibble would be recommended. By “similar”, we do not mean “identical”, and the “Set Gray Point” tool of the “Levels” window does not correct images in the same way, or as well, as the white balance tools of Bibble and ACR. In other words, the “Set Gray Point” tool should not be considered as a white balance tool (it was designed to correct color casts).



The images on the next page show similar tests done with a variety of papers, and where the gray point was set on the target. In addition, for these images, we have increased the brightness by sliding the **white level cursor** to the left until the target white was around 250. Results are shown on the next page.

In fact, because we made the brightness adjustment using only the white target, we could also have used a faster procedure by setting the target highlight value in Photoshop. This is done by double-clicking on the white eyedropper of the “Levels” window, the **“Set White Point”** tool discussed above, and shown on the bottom of this page. This action opens the color picker where we can set any value for the white point; for this example, we would set all RGB values to 250. An alternate method to set the white point is to click on the “Options...” button and then click on the color patch of the “Highlights” setting.



Once the white point is set in such a way, we can neutralize the white target color and bring its intensity to 250 in a single click, instead of the two steps required when using the “Set Gray Point” + white level cursor method. Also, for general image correction, the white point method will give better results in terms of improving the overall white balance.



The target white is set to about 250-250-250 (sRGB) in all three images. The RGB value shown on each image is a typical measure taken on the tested paper.



The top image on the preceding page is in fact the same picture as the one used on page 5. The paper is Epson Premium Bright, a general purpose paper for "...vivid colorful images", as written on its package; it has an ISO brightness of 108+ and can be used on both sides, which is not common. Three sheets of paper were stacked for the test; they are fanned slightly to see the effect of thickness. We can see the target through the paper where there is only a single sheet. This paper is heavily UV-enhanced and is not recommended for accurate image reproduction, although it does make nice reports!

The middle image is taken with a single sheet of Canon Photo Pro paper, a high-end paper dedicated to photographic reproduction. Its quoted ISO brightness is 88. While being slightly UV-enhanced, as we can see from the non-neutral RGB reading, which we confirmed by looking at its reflectance spectrum, it is quite a nice paper. However, its UV sensitivity may make it unpredictable in illumination setups with strong UV content, and a visual check would be recommended in such instances.

The bottom image is a test with three sheets of paper from the *Digital Graphics* magazine, a trade magazine for the large-size ink-jet printing industry (billboards, vehicle wrap, trade-shows graphics). Because of their readership, we expected that the magazine editors had some concerns for color fidelity in the magazine itself, and we were not deceived! Although the paper brightness is on the low side, it is as neutral as you could expect.

By setting the target white to the same value in all pictures, our visual **qualitative** analysis has become **quantitative** and we can compare the papers on a common basis.

3. Conclusion

Being able to rapidly judge a paper's characteristics can save you time and money when selecting a paper for a given job or trying to solve an issue with a press output. We have seen how a simple visual check with a (almost!) perfectly white target can inform us on the UV properties of a paper. We have also seen that an even more precise assessment can be obtained by taking a picture of the target against the paper and that a spectrometer is essentially not required.

Should you reject all UV-enhanced paper papers? For archival and art gallery type images, I would say a “strong yes”, which is not an “absolute yes”; for instance, papers which show a small UV-enhancement can certainly find a place for some specific uses. However, papers with strong UV-enhancement should be discarded without remorse for these applications, and I would hesitate strongly to use them for any applications where color accuracy is expected under various illumination conditions (a framed picture for instance).

Using a white target is a simple way to look into the complex environment in which color images are produced, and it can help better understand how we perceive and judge colors.



The BabelColor Company

Founded in 2003, *The BabelColor Company* is dedicated to the development and sale of specialized color translation software and color tools. It also provides color consulting services for the professional and industrial markets.

target@BabelColor.com

<http://www.BabelColor.com>

BabelColor is a registered trademark, and the BabelColor logo is a trademark of Danny Pascale and The BabelColor Company. All other product and company names may be trademarks of their respective owners.

© 2006 Danny Pascale and The BabelColor Company