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Case Study #1
Evaluating the Influence of Media on Inkjet Tone And Color Reproduction With the I* Metric

by

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Introduction

The impact of paper choice on inkjet print quality is well known to experienced printmakers, but novices have to contend with many new variables that may not be familiar to them. Media and printer driver settings interact such that the media response cannot be fully isolated from the contributory role of the driver settings. Many end-users are also confused about the benefits and limitations of ICC profiles when trying to achieve a reasonable monitor-to-print appearance match. Under appropriate printing and viewing conditions glossy photo prints can produce a satisfactory "match" for many consumers. However, the inherent color and tone limitations of most reflection print media make the expectation of a close match between monitor and print rather futile without resorting to professional level software and a "softproofing" workflow. How can we rate the quality of the colors and tones obtained on any given print paper so that we may better predict the degree of difficulty that will be encountered when trying to make a great looking print? The I* metric is well suited to this purpose and has been described in previous papers.[1, 2] It scores color and tone reproduction accuracy on a percentile ranking scale. This case study applies the I* metric to the evaluation of print reproduction quality for three different paper types when printed on the same photo inkjet printer and ink set. Optimum printer driver settings were also carefully chosen for each kind of media. The selected media were printed on an Epson R1800 photo inkjet printer using one batch of Epson inks specified for use in the R1800. A digital image with full tonal range but somewhat limited color range (e.g., vivid blues and cyans are not present) was chosen for the study and is shown in figure 2a. Although not an "all purpose" test image, it nevertheless illustrates the concept of media dependent results quite well.

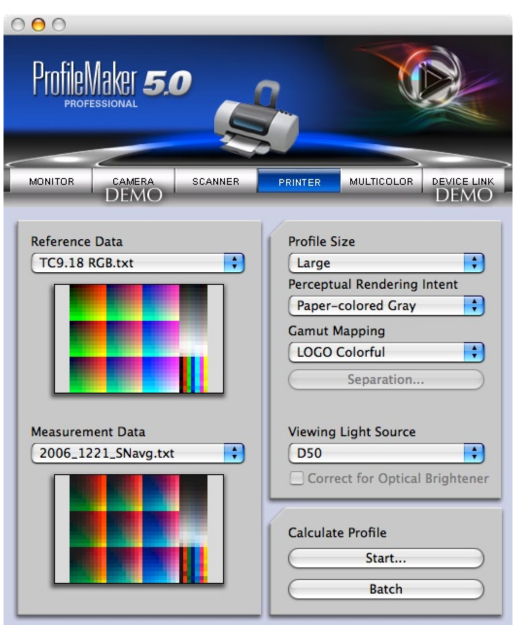
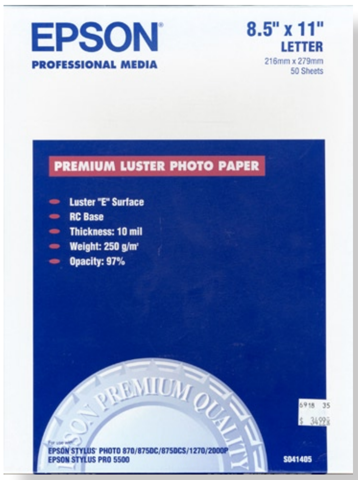


Figure 1

Experimental:

The three different media types selected for this study are representative of the broad choice of papers that can be used with inkjet printers. The group included a plain paper product with a paper sizing optimized for inkjet printers, a cast coated product with matte finish coating, and a premium grade microporous inkjet photo paper with luster finish. A GretagMacbeth TC9.18 RGB target was printed on each paper using the settings listed on page 2 of this report, and a custom ICC profile was made for each paper. GretagMacbeth Profilemaker 5.0.7 software and the settings shown in figure 1 were used for all three profiles in order to produce a consistent "flavor" of perceptual rendering intent.

Using standard I* methodology, the reference image shown in figure 2a was downsampled and resized to make a printer target with 805 color patches as shown in figure 3. The target and reference image were then printed by direct conversion (i.e., no additional image edits) through the custom ICC profile for each media type using perceptual rendering intent. The printed target patches were measured on a GretagMacbeth Spectroscan with UV cut-off filter. The spectral data were converted to D50 LAB data and then compared to the reference image's LAB data extracted from the target file of figure 3. The reference values are extracted by converting the target image to LAB mode in Photoshop, saving the file in tiff format, and then exporting the values to text format for analysis by the I* metric. Note that the RGB data of the reference image is converted through the image profile (in this case, sRGB IEC61966-2.1) via Bradford transform to D50 LAB image data in Adobe Photoshop. The D50 condition is also how the data conversion to the printer is executed since the custom printer profile also conforms to the D50 illuminant. Hence, the I* metric is comparing D50 LAB data for the reference image to D50 LAB data for the comparison print as measured by the Spectroscan. Paper and Driver settings were as follows:



Printer: Epson R1800 with Epson OEM inks
Paper: Epson Premium Luster Photo Paper

Driver Settings: Media type = "Premium Luster Photo Paper", Mode: Advanced, Print Quality = "Best Photo", (high speed, mirror image, finest detail unchecked), Gloss Optimizer = "On" Color management = "Off (no color adjustment)"

Custom Profile: AaI_R1800_Epprlus(2).icc
Applied Rendering Intent = Perceptual (PM5.0.7 "LOGO Colorful")

Printer: Epson R1800 with Epson OEM inks
Paper: Epson Matte Paper Heavyweight

Driver Settings: Media type = "Matte Paper – Heavyweight", Mode: Advanced, Print Quality = "Best Photo", (high speed, mirror image, finest detail unchecked), Gloss Optimizer = "Off" Color management = "Off (no color adjustment)"

Custom Profile: AaI_R1800_Epmatthvwt(1).icc
Applied Rendering Intent = Perceptual (PM5.0.7 "LOGO Colorful")

Printer: Epson R1800 with Epson OEM inks
Paper: HammerMill Ultra Premium Inkjet

Driver Settings: Media type = "Plain Paper", Mode: Advanced, Print Quality = "Photo", (high speed, mirror image, finest detail unchecked), Gloss Optimizer = "Off" Color management = "Off (no color adjustment)"

Custom Profile: AaI_R1800_HamUltPrPlain(1).icc
Applied Rendering Intent = Perceptual (PM5.0.7 "LOGO Colorful")

Figure 2

sRGB Reference Image:

If rendered on high quality calibrated display

I* Score - estimated
>90 tone / >90 color

2a

Luster Print:

Softproof Simulation of Print on Epson Premium Luster Photo Paper

Average I* Score
80.7 tone / 82.9 color

2b

Matte Print:

Softproof Simulation of Print on Epson Matte Paper Heavyweight

Average I* Score
70.8 tone / 72.9 color

2c

Plain Paper Print:

Softproof Simulation of Print on HammerMill Ultra Premium Inkjet paper

Average I* Score
56.6 tone / 58.5 color

2d

Results:

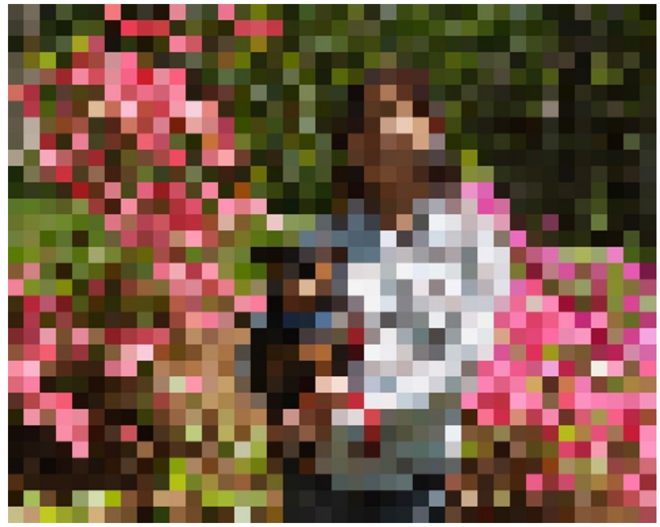


Figure 3. I* Reference image data - e.g., 805 color samples and corresponding L*a*b* values extracted from the reference image at 4dpi sampling frequency.

Looking at the actual R1800 prints under controlled lighting is, of course, the best way to compare the I* results with what we observe visually in the three print reproductions. However, in lieu of your presence in my studio, figure 2 shows softproof simulations of the prints that were made. The simulations were derived from the ICC profile characterization of the LAB data output rather than by scanning the actual prints because a scanning approach was likely to cause greater reproduction errors not attributable to the prints themselves. Some caveats are still required when you look at these simulations. Figure 2a is the reference digital data encoded in sRGB colorspace and now rendered to your display. The reproduction in figure 2a underscores one fundamental property of digital images; they must reproduced on some output device in order to view them. The primary output device of choice for most photographers is the computer monitor on their desktop, not a printer that makes reflection prints. Understandably, most photographers consider the image displayed on their monitor as the reference or "gold standard" for what the image should look like when reproduced on other devices. However, a computer and monitor setup is subject to the same reproduction issues of calibration and characterization of the data as is any other output device. The I* metric can indeed be used to evaluate real monitor color accuracy, but it takes special instrumentation and software to collect the data. Monitor-acquired data could have served as the reference image data in this study, and then the I* scores for the prints would have been scaled relative to the specific monitor's image reproduction. A sensible alternative and more precisely defined standard is to bypass monitor reproduction quality issues and to compare the reflection print reproductions directly to the color data in the digital file itself. The scores listed in Table I (also noted in figures 2b-d) were calculated using this methodology. In this case, the "gold standard" is the digital image file itself, expressed in CIELAB colorimetric terms. I have included an estimate of the I* score for the figure 2a image reproduced on a high quality display in order to remind the you that you are undoubtedly not viewing a perfect reproduction of the original file data on your monitor.

Figures 4, 5, and 6 plot the L* tone reproduction curves for the three papers using all sample data, a subset of nominal "skintone" colors (i.e., tan and brown values), and lastly, a subset of low chroma samples which are

Table I: I* test scores for three papers printed with Epson R1800 Printer and OEM inks

		I*Tone Accuracy			I* Color Accuracy		
Image Sample	**Number of samples**	**Average**	**Worst 10%**	**≤ QC limit(1)**	**Average**	**Worst 10%**	**≤ QC limit(2)**
Reference Image compared to itself	805	100	100	0	100	100	0
Epson Premium Luster Photo Paper	805	80.7	65.1	0	82.9	51.2	0
Epson Matte Heavyweight Paper	805	70.8	52.6	0	72.9	27.9	0
HammerMill Ultra Premium Inkjet Paper	805	56.6	28.5	1.9	58.5	22.8	0

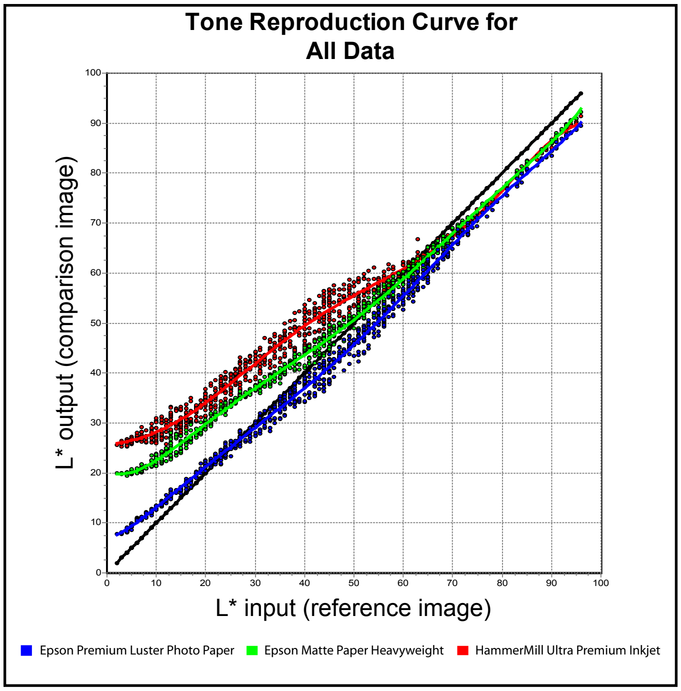


Figure 4

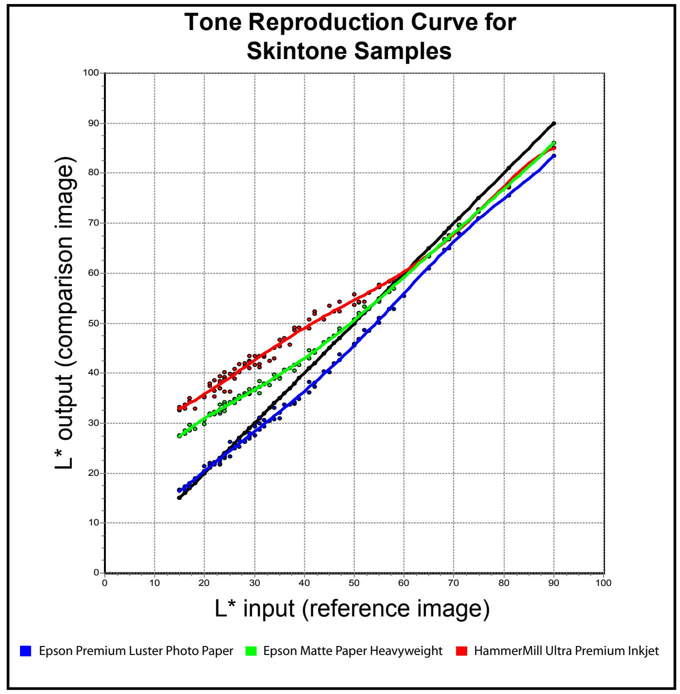


Figure 5

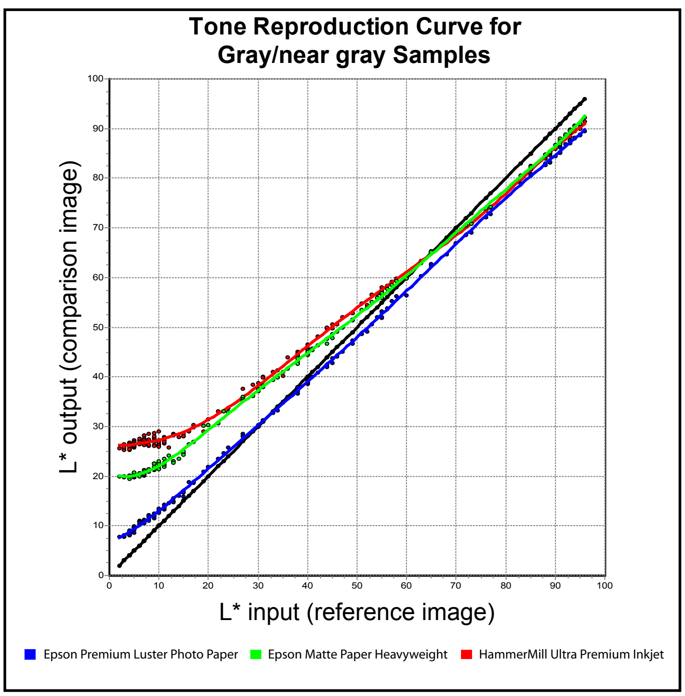


Figure 6

gray and near gray in color appearance. The curves in figure 4 plot the average system tonal response using the complete data set [805 samples]. A perfect tonal response would have placed all sample points on the black line which means a one-to-one match (slope=1) between the reference image L* values and the printed output L* values. The large amount of apparent scatter in the data is not caused totally by random deviations from the aimpoint. Rather, subsets of color are being rendered along different tone curves as can be seen by examining figures 5 and 6. In figure 6, the nominal "skintone" color samples [83 samples] have been sorted from the total population. In figure 6, the low chroma colors that the I* metric classifies as gray and near-gray colors [161 samples] have been plotted. It can be seen that the subset color ranges plot with less scatter but along significantly different curves. This result is a fundamental aspect of the gamut compression being implemented by the ICC profiles in order to translate the larger color and tone range of the reference image into the reduced color and tone range of the printer-ink-paper system. Note that the highlight reproduction of all three papers is similar and roughly parallel to and below the black line. This result indicates that the perceptual rendering intent of the ICC profiles is mapping the output L* values relative to the media white point as one would expect rather than being scaled from the 100 L* value of the sRGB colorspace whitepoint. At the midtone level, the curves are then forced to begin flattening in contrast in order to preserve shadow detail with respect to the higher blackpoint limits of the papers. This deviation in contrast from the slope = 1 condition accounts for the majority of the I* tone score.

Conclusions:

Knowledgeable printmakers will find that the softproof simulations of the prints made in this case study are consistent with their own practical experiences on different media. The I* metric provides an objective way to quantify the visual results. The I* metric easily differentiated between the three papers and returned values that have significant point spread on the 0-100% I* scale. The color and tone reproduction superiority of the microporous luster surface over the matte paper surface, and the matte paper surface over the plain paper sizing is decisive, but to maintain perspective one must also factor in the cost per page. The luster photo paper cost $0.70 per US letter-size page, the matte paper cost $0.29 per page, and the plain paper was $0.015 per page. Advanced inkjet paper coating technologies make a big difference in image quality, but they also come at a price.

For amateur printers who are not fully aware of the benefits and limitations of ICC profiles, the results of this case study may be a little surprising. Some mistakenly assume that custom ICC profiles will closely match the color and tone reproduction outcome across different printers and papers and especially in the situation where only one printer and ink combination is being used. That impression is logical if one imagines the inks, especially pigmented inks like those used in the R1800 printer, to be laid down opaquely at the very top of the media surface. However, inkjet prints are a subtractive color process where the brightest white is dictated by the paper color not by ink deposition. More importantly, there is significant interaction between the inks and the material properties and physical surface of the paper. In reality, the media and attendant coatings interact strongly with the inks such that radically different color purities and tonal ranges can occur even when using the same printer and inks. Thus, the notion that a properly profiled printer can deposit the right quantities and portions of ink to yield identical copies across multiple media types is seemingly logical but patently false. High quality ICC profiles cannot defy the physics and chemistry of image formation yet they help to achieve a well behaved starting point for translating colors and tones from one visual medium to another. They also enable soft proof simulations in professional image editing software that are predictive of the final image reproduction. Softproofing is important because current ICC profile conversions always assume an image file contains full color and tonal range when in fact many images have reduced gamut that can benefit from less color and tone compression into the output device colorspace. The skilled printmaker thus uses the softproof environment as a basis for further image edits which then lead to improved image reproduction. One doesn't necessarily need a custom profile to make a good print. It simply takes more time and materials to produce comparable results by other trial and error methods of digital printmaking.

New case studies will be undertaken soon at Aardenburg Imaging & Archives to show the I* metric results for more subtle image reproduction issues such as the determination of optimum driver settings and ICC profile rendering intents as well as differences between generic ICC profiles and custom ICC profiles.

References:

1) Mark McCormick-Goodhart, Henry Wilhelm, and Dmitriy Shklyarov,"A 'Retained Image Appearance' Metric For Full Tonal Scale, Colorimetric Evaluation of Photographic Image Stability," IS&T's NIP20: International Conference on Digital Printing Technologies, Final Program and Proceedings, IS&T, Springfield, VA, October 3–November 5, 2004, pp. 680–688. (Available in PDF format at Aardenburg-Imaging.com).

2) Mark McCormick-Goodhart, "An Introduction to the I* Metric", ©Aardenburg Imaging & Archives, February 7, 2007 (available in PDF format at Aardenburg-Imaging.com).

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