Quantification of Color Variation Introduced During Premedia Production

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Abstract

The successful implementation of color management in any digital print environment is dependent on the ability to characterize and control the critical stages of production workflow. Despite the continuous improvements in both color profiling tools and in the devices they characterize, current color management strategies often fail to address the potential for color variance based on operator-defined actions during the course of normal production operations. This variation may result in an unacceptable deviation from the expected or target outcome in print production scenarios where any level of operator intervention is considered general practice.

To quantify the potential variation resulting from specific operator-defined actions, a study was conducted in which several production workflows characteristic of digital print environments were replicated. Assuming different levels of color management understanding, a series of user-defined profile decisions were applied to a standardized target and a selected set of representative test images within the context of software applications customarily used in premedia production. The resulting test files were printed and color variance was determined via ΔE and paired comparison for a set of workflow combinations representative of those common in many premedia production environments.

Introduction

The premedia phases of the digital print production workflow extend from the initial creation of digital files through to the raster image processing of files at the print device. While print quality has continuously improved through the application of quality control measures for physical print reproduction, quality control measures are more difficult to implement due to the behavioral aspects inherent to the premedia production process.

Quality control in premedia production can be improved through the application of standard operation procedures (SOPs) during the creation of print-ready digital files. The creation of such SOPs for color management practices and PDF creation are commonplace in many professional environments, although they may not insure quality improvements based on both the variance in SOPs between different environments and the thoroughness to which operators implement already established SOPs. Further, even with established SOPs, the SOPs themselves may introduce variation (*e.g.* Failure to embed a color profile may lead to unwanted variation downstream in production).

Through a series of interviews and direct observation of both technical and creative professionals involved in premedia production, several reoccurring differences in established SOPs were identified. The most significant variable relating to premedia color reproduction was the differences in the definitions of clear and consistent use color preferences and/or color settings within software applications. When paired with the variations in subsequent procedures for the handling of color profiles assigned, embedded or missing from an image file, the potential for color variation was determined to be very high.

Independent of this, inconsistencies in the reproduction of spot colors (*e.g.* Pantone, etc.) were identified as a reoccurring problem, especially for those files destined for digital print production environments.

Testing Method

Overview

For each of the common areas identified, a series of tests was conducted in an effort to replicate the varying procedures observed and quantify the color variance that resulted from them. For consistency, an RGB-based workflow was assumed for all tests and, as it was observed to be the most commonly used default RGB setting, AdobeRGB was used as the source profile for all test images.

The pictorial references used included two color-intensive RGB test files, “interior” and “fruit bowl,” and the ISO “three musicians” file, which was converted from SWOP CMYK to AdobeRGB colormetrically to preserve appearance. The Granger Rainbow RGB file was also included in the study for visual assessment of gamut shifts resulting from the workflows followed.

For measured assessment, the digital version of the MacBeth ColorChecker created by Bruce Lindbloom (www.brucelindbloom.com) in L*a*b* was converted colormetrically into the AdobeRGB space. AdobeRGB was selected here for both the reasons stated above and because its gamut could encompass all patches on the digital ColorChecker without any clipping of color.

Finally, for spot color testing, a Photoshop document with six Pantones swatches was created in LAB as a reference. The six patches selected were chosen because each was outside most CMYK gamuts and all six are commonly used in testing at RIT. The patches, each from the Pantone Solid Coated Library, included 165C, 1675C, Reflex Blue, Pantone Process Blue, Rhodamine Red and Rubine Red.

To articulate the color variation for each representative workflow scenario, all test images produced were assessed by paired comparison against a reference original and the digital values of

the MacBeth ColorChecker and LAB spot color swatches were used for calculation of ΔE when compared against the reference.

The software used for the study was Adobe PhotoshopCS, Adobe IllustratorCS, Adobe InDeignCS, QuarkXPress 6.5, Microsoft Word 2004 and Acrobat Professional 6.02. All tests were conducted on a Macintosh running OS10.3.9.

Color Settings & Color Profile Handling Tests

The selection of the specific color preferences or color settings within a software application defines the default LUTs used to process color data. This selection also defines what LUTs and workflow options may be available when opening or copy/pasting image files.

While most professionals surveyed agreed that the specific color settings utilized were important for color consistency during image editing and page design, direct observation showed that there were a conflicting variety of actual color preference settings in use both within software applications and between them.

Independent of the color settings selected, one of the most common causes of potential color variance observed was the lack of consistent handling of embedded or missing color profiles. While SOPs for some professionals made it a policy to always convert to the current RGB or CMYK working space, others specified that preserving embedded profiles was the best policy. Only a very small number of professionals specified that they generally "do not color manage." In practice, however, when faced with the profile handling dialogue box when opening image files in Photoshop, the action most commonly observed was for operators to simply to click "OK," an action that sometimes resulted in a deviation from the established SOP. Further, when asked whether color management was "on" or should be "on" in page layout programs like QuarkXPress or InDesign, many responded they didn't know or simply "no."

To assess the color variation incurred at the image editing phase of production, two versions of each test image, one with and one without a profile embedded, were opened multiple times in Adobe Photoshop under both Photoshop's default "North American General Purpose Defaults" and the "US Prepress Defaults" and processed through each of the selectable choices for profile handling available in the dialogue box faced when opening any image file. Each file was then saved for comparison with the reference original.

To test the impact of varying color settings downstream, the reference image files were placed in Illustrator, InDesign and QuarkXPress under each software application's default settings and under the US Prepress Defaults. An additional test was conducted to verify profile handling in Microsoft Word, which has no color settings menu to adjust.

Spot Color Creation/Processing Tests

A common assumption among many of the professionals contacted was that the same Pantone color specified in different software applications should produce the same color in the reproduction. In commercial print environments, where the actual spot color specified will be reproduced on a conventional press, the selection of a spot color implies the use of an extra plate and the corresponding spot color ink during production. In digital print environments, where most print devices are forced to to simulate specific spot colors through the use of LUTs optimized for their specific CMYK or hi-fi combinations, the specific digital values being sent to the print device are a critical variant.

Based on the assumption that spot colors specified in the same color space and using the same color profile would result in files with the same digital values, the AdobeRGB was specified profile in Photoshop, Illustrator, QuarkXPress and InDesign and documents were produced containing six spot colors patches. For consistency, all documents were saved as EPS files and then brought into Photoshop for comparison against the reference.

To verify the impact of color settings, the test was replicated using the default color settings in each application, which resulted in the use of sRGB for Photoshop, "Emulate Illustrator 6.0" for Illustrator and color management "off" (RGB not specified) in both QuarkXPress and InDesign. The resulting files were then compared against the LAB reference file.

Results

Color Settings & Color Profile Handling Tests

This proved to be a very limited test, as it was quickly determined that a broader range of image files that included a wider range of input profiles and the inclusion of more than one rendering intent would need to be factored in to provide more meaningful insight into the amount of variance that could be encountered. However, a preliminary view into the magnitude of variance was apparent in just the limited test conducted.

As expected, preserved embedded profiles created no color variance, converting to the working space RGB created only minimal variance, while ignoring or discarding embedded profiles in favor of the working space RGB created the most variation in color. For converted files, it is important to note that the trade practice of converting all files to a common working space gained further credence as the tone and color of the pictorial files converted from larger AdobeRGB gamut down to the smaller sRGB gamut remained nearly identical in appearance to the AdobeRGB-based reference.

In contrast, the color shift observed by discarding embedded profiles at the image editing stage was significant.

Difference from Assigning sRGB Profile

	ΔL*	Δa*	Δb*	ΔC	ΔE*oo
Orange #7	-3.0	-9.0	-9.0	-12.17	4.76
Blue #13	1.0	-1.0	0.0	-0.32	1.01
Green #14	1.0	12.0	-1.0	-9.22	5.09
Red #15	-5.0	-9.0	-38.0	-29.64	16.78
Cyan #18	2.0	12.0	4.0	10.63	6.13
Neutral #20	0.0	0.0	0.0	0.0	0.0
Neutral #22	0.0	0.0	0.0	0.0	0.0

As each file was effectively remapped to the new RGB gamut, a significant reduction in overall color saturation was apparent in the files that were assigned the sRGB profile. The overall color shift was significant enough to require color correction by most customers prior to acceptance.

Files placed into Illustrator under the US Prepress Defaults settings showed no difference in the resulting file. However, files placed under Illustrator's Default incurred significant shifts, particularly in warmer colors.

Difference from Illustrator Default Settings

	ΔL*	Δa*	Δb*	ΔC	ΔE*oo
Orange #7	4.0	10.0	10.0	13.72	4.99
Blue #13	-2.0	1.0	-4.0	4.11	2.01
Green #14	-2.0	-21.0	1.0	17.88	7.16
Red #15	6.0	10.0	-21.0	-5.01	13.46
Cyan #18	-1.0	-10.0	-3.0	9.37	4.02
Neutral #20	0.0	1.0	0.0	0.0	0.68
Neutral #22	0.0	1.0	0.0	0.0	0.99

The results from the QuarkXPress with both color management on and off created measured results that were identical, though both varied from the reference slightly.

Results from the InDesign tests both produced identical files that matched the reference, in part, due to a limit of the test condition. While the match with color management enabled was expected, the default setting with color management off would have produced significant variance if the test files used had been optimized for an RGB profile that did not match the profile used for the test files.

Finally, the Microsoft Word test confirmed that profiles are ignored as all images brought into the application were effectively reassigned to the default space. The results of this test are particularly important to consider in the context of the large number of users that use Microsoft Word to create files for digital print production environments.

Spot Color Creation/Processing Tests

The results for the spot color tests showed that, with the exception of Process Blue, the Pantone swatches made in Photoshop displayed the least overall variance from the reference file. The Photoshop results produced exact matches in several instances but also displayed noticeable shifts in other colors that illustrated the influence of specifying Pantone colors while in an RGB mode.

The assumption that files produced in different applications but using the same (AdobeRGB) profile proved incorrect. Under the same color settings, each application produced different LAB values for the same Pantone swatches and, excepting the fact that the AdobeRGB files created were generally closer to the reference than the files made under the default condition, there was little correlation in the results between applications.

Pantone 165C (Orange) Measurements

	L*	a*	b*	ΔC	ΔE*oo
Reference	63.0	61.0	75.0	–	–
AdobeRGB Photoshop	63.0	61.0	75.0	0.00	0.00
Default Photoshop	62.0	60.0	72.0	-2.95	1.18
AdobeRGB Illustrator	69.0	67.0	82.0	9.22	5.15
Default Illustrator	68.0	37.0	54.0	-31.21	8.68
AdobeRGB InDesign	67.0	40.0	66.0	-19.50	8.32
Default InDesign	67.0	33.0	68.0	-21.09	12.20
QuarkXPress	66.0	77.0	81.0	15.08	5.37

Pantone 1675C (Burnt Umber) Measurements

	L*	a*	b*	ΔC	ΔE*oo
Reference	41.0	44.0	48.0	–	–
AdobeRGB Photoshop	41.0	44.0	48.0	0.00	0.00
Default Photoshop	41.0	44.0	48.0	0.00	0.00
AdobeRGB Illustrator	49.0	60.0	64.0	22.61	9.14
Default Illustrator	53.0	32.0	38.0	5.68	27.13
AdobeRGB InDesign	50.0	34.0	54.0	0.34	10.28
Default InDesign	49.0	34.0	55.0	-0.45	10.67
QuarkXPress	44.0	58.0	56.0	15.51	5.21

Pantone Reflex Blue Measurements

	L*	a*	b*	ΔC	ΔE*oo
Reference	19.0	32.0	-74.0	–	–
AdobeRGB Photoshop	20.0	35.0	-72.0	-0.57	2.60
Default Photoshop	21.0	35.0	-71.0	-1.46	3.22
AdobeRGB Illustrator	20.0	25.0	-63.0	-12.84	2.48
Default Illustrator	39.0	2.0	-42.0	-38.57	17.81
AdobeRGB InDesign	35.0	2.0	-51.0	-29.58	16.58
Default InDesign	31.0	13.0	-48.0	-30.89	10.55
QuarkXPress	17.0	34.0	-69.0	-3.70	3.48

Pantone Process Blue Measurements

	L*	a*	b*	ΔC	ΔE*oo
Reference	47.0	-33.0	-57.0	–	–
AdobeRGB Photoshop	49.0	-20.0	-54.0	-8.28	5.73
Default Photoshop	52.0	-7.0	-50.0	-15.38	13.49
AdobeRGB Illustrator	48.0	-34.0	-36.0	-16.35	7.05
Default Illustrator	57.0	-29.0	-38.0	-18.06	11.39
AdobeRGB InDesign	54.0	-32.0	-46.0	-9.83	7.68
Default InDesign	55.0	-24.0	-44.0	-15.74	9.16
QuarkXPress	44.0	-10.0	-58.0	-7.01	10.86

Pantone Rhodamine Red Measurements

	L*	a*	b*	ΔC	ΔE*oo
Reference	52.0	79.0	-19.0	–	–
AdobeRGB Photoshop	52.0	79.0	-19.0	0.00	0.00
Default Photoshop	52.0	79.0	-19.0	0.00	0.00
AdobeRGB Illustrator	60.0	87.0	3.0	5.80	11.16
Default Illustrator	56.0	66.0	-6.0	-14.98	6.62
AdobeRGB InDesign	55.0	69.0	-9.0	-11.67	4.98
Default InDesign	53.0	71.0	-4.0	-10.14	5.77
QuarkXPress	59.0	86.0	2.0	4.77	10.28

Pantone Rubine Red Measurements

	L*	a*	b*	ΔC	ΔE*oo
Reference	44.0	78.0	8.0	–	–
AdobeRGB Photoshop	45.0	72.0	11.0	-5.57	2.24
Default Photoshop	46.0	72.0	11.0	-5.57	2.78
AdobeRGB Illustrator	58.0	87.0	23.0	11.58	15.15
Default Illustrator	53.0	68.0	2.0	-10.38	9.52
AdobeRGB InDesign	50.0	77.0	2.0	-1.38	4.98
Default InDesign	48.0	75.0	6.0	-3.17	3.98
QuarkXPress	55.0	82.0	34.0	10.36	15.27

Overall, specifying the Default color settings in each software application produced files with the furthest deviation from the reference file. Illustrator's default (using the Emulate Illustrator 6.0 settings) consistently produced values that were the furthest out and values that varied the greatest between its two most commonly used settings. QuarkXPress proved to be the most consistent regardless of color settings and produced identical files both under its default settings and with color management active.

Conclusions

The diverse nature of premedia production workflows makes it difficult to precisely quantify color variation and, while many of the results of this investigation are limited only to the very specific workflows replicated, the results also yield important insight into the magnitude of color variation that can result from procedural decisions common in the graphic arts.

The magnitude of the variance identified and the critical points within the workflow where they occur are significant when a system view of production is considered. Variance introduced at the early stages of production may prove to very difficult and costly to adjust for at later stages of production. Standardizing tasks at the specific nodal points in the premedia production process most likely to influence this variation will minimize correction cycles downstream in production. The importance of this is underscored by the steady increase in demand for print-ready PDFs, an industry trend that continues to push critical production decisions further upstream in the document workflow.

From the standpoint of the specific software used, further refinement of the color management user-interface and improved uniformity in the interpretation of spot color definitions will aid in the quest for most consistency during file creation and editing. With an average cycle of 18 months between software updates, vendor-led changes are likely, although the onus will remain on the user to stay continually up to date with evolving trade practices.

References

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Author Biography

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