Evaluating the Image Permanence of Full Tonal Scale Human Skintone Colors in Photographs Using the CIELAB Colorimetry Based WIR i-Star “Retained Image Appearance” Metric

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Abstract

People are the principal subjects in the great majority of consumer photographs and the rich and vibrant reproduction of skintones in prints is an essential requirement for professional portrait and wedding photographers. Current ISO and WIR methods for the evaluation of image permanence in color prints only take into account fading in cyan, magenta, and yellow patches, as well as fading and color imbalance changes in neutral scale patches (at a single density of 1.0 with ISO 18909 and at two density points, 0.6 and 1.0 with WIR). The ISO and WIR methods do not directly address fading and color balance changes in human skintones. This shortcoming is particularly significant for prints made with complex inkjet inksets that, in addition to cyan, magenta, and yellow inks, may contain dilute cyan and magenta inks, as well as red, green, blue, orange, or other ink colors and multi-level black/gray inks. WIR i-Star, a CIELAB colorimetry-based, full tonal scale “retained image appearance” metric, provides a method to evaluate the permanence of human skintone colors, neutrals and near-neutrals, as well as a full range of the printable colors in sRGB or other color spaces over the full tonal scale found in photographs. The WIR i-Star metric can be used to evaluate changes in colors as well as changes in both localized and overall image contrast.

Introduction

It has been estimated that approximately 80-percent of amateur photographs include people in the scene and people are the central subjects in nearly 100-percent of professional portrait and wedding photographs. Despite the obvious importance of human skintone colors in photography, current image permanence test methods such as ISO 18909:2006 [1] with only a single starting density level of 1.0 and the WIR Visually-Weighted Endpoint Criteria Set v3.0 [2] with two starting density levels of 0.6 and 1.0 developed by Wilhelm Imaging Research, do not yet include full tonal scale human skintone colors in the analysis of fading, changes in color balance, or stain formation.

Figure 1. *The WIR i-Star sRGBcolorspace Target (v1.0) is a generic 800 patch test target for I* analysis. The target maps 12 hues with varying lightness and chroma, plus neutrals, near-neutrals, and skintone colors over the full tonal gradient and color gamut of the sRGB color space. Test targets can be made for other color spaces such as Adobe RGB and ProPhoto RGB (a large gamut colorspace also known as ROMM RGB).*

Figure 2. *The human skintone colors section of the generic WIR i-Star target consists of 100 patches generated by adjusting the L* values of the measured LAB values for the “Light Skin” and “Dark Skin” color patches in the Macbeth ColorChecker chart. Photographs of people may range from very high L* values in specular highlight areas to very low L* values in deep shadow areas of the face. The number of skintone color patches and neutral/near-neutral patches relative to the total number of patches in the test chart provides a means of weighting these colors in the i-Star analysis. The skintone colors section of the target can also be analyzed separately as an i-Star “Region of Interest.”*

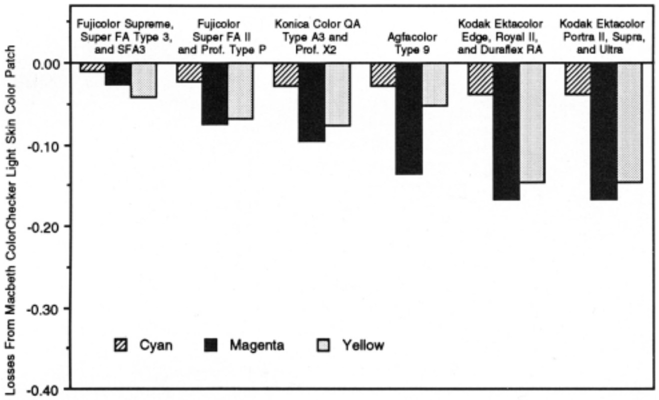


Figure 3. *Process RA-4 compatible color negative papers compared by density losses from the Macbeth ColorChecker Light Skin Color patch. (From the 1993 book: "The Permanence and Care of Color Photographs," by Henry Wilhelm with contributing author Carol Brower Wilhelm. [3]) With the Kodak Ektacolor papers, the comparatively large losses of both the magenta and yellow dyes seriously degrade skintone colors, resulting in a unpleasant, washed-out greenish appearance.*

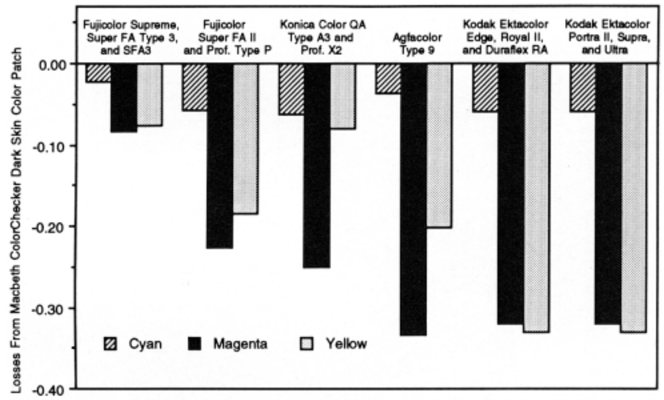


Figure 4. *Process RA-4 compatible color negative papers compared by density losses from the Macbeth ColorChecker Dark Skin Color patch. Most portraits, whether of light-skinned or dark-skinned people, have important areas of low-density highlights, and pictorial quality is adversely affected if these highlight areas fade or suffer significant color balance changes. Magenta and yellow are the two most important colors in human skintone reproduction with chromogenic systems.*

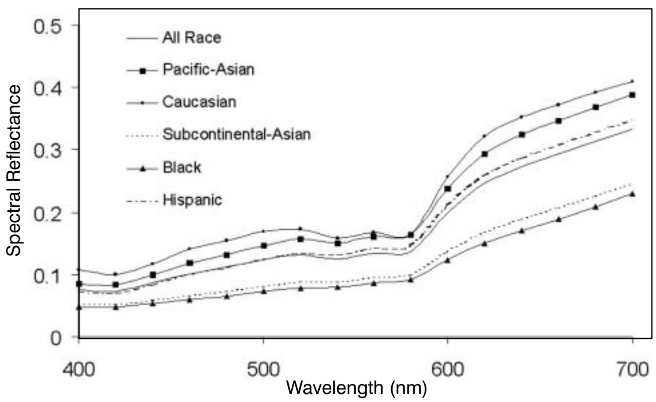


Figure 5. *Spectral reflectance of face skintone colors of different ethnic groups from a study by Qun Sun and Mark D. Fairchild.[4]*

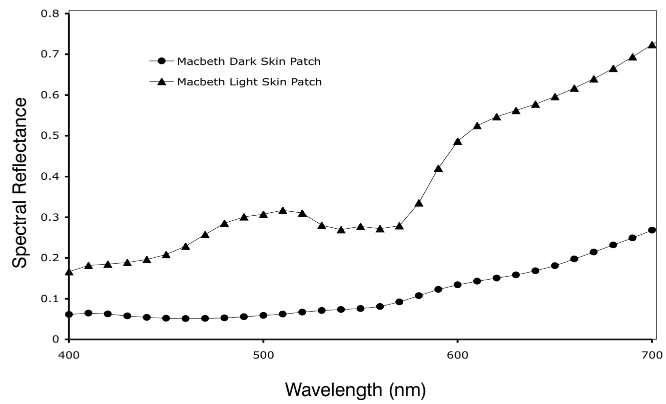


Figure 6. *Measured spectral reflectance of the "Light Skin" and "Dark Skin" paint patches in the Macbeth ColorChecker.[5]*

Historically, there have been a number of reasons for this shortcoming. In years past, test targets had to be printed with enlargers or other analog systems that did not lend themselves to precise control of color and density in individual test target color patches. In addition, densitometry – which has long been used in image permanence testing – has not been well suited for the analysis of changes in colors other than the simple "pure color" cyan, magenta, yellow, and neutrals consisting of equal densities of these three colors that make up the images of chromogenic (silver-halide) color prints. Unlike most inkjet prints, chromogenic color prints have no "black" or "gray" colorants.

The Need for Human Skintone Colors in Permanence Tests

In the course of conducting psychophysical tests with sets of progressively faded chromogenic professional color portraits in the mid-1980's, Wilhelm recognized the importance of skintone colors and this was discussed in the book, *The Permanence and Care of Color Photographs* [3] which was published in 1993. Figures 3 and 4 are taken from the book. In particular, it was clear that people have very little toleration for skin colors

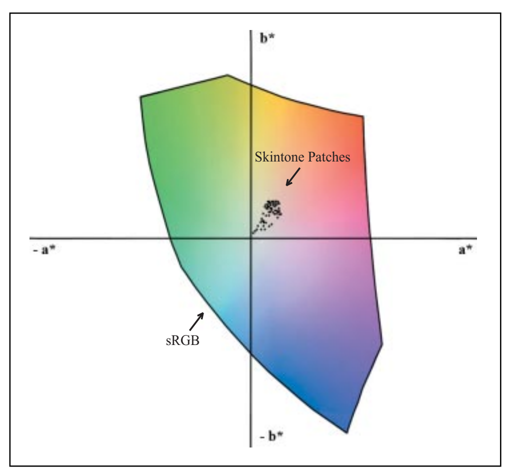


Figure 7. *Human skin colors have low chroma values and fall near the center of the sRGB color space. The skin colors represented here are from the Macbeth ColorChecker and the ANSI IT8.7/2-1993 color reflection target for input scanner calibration.[6]*

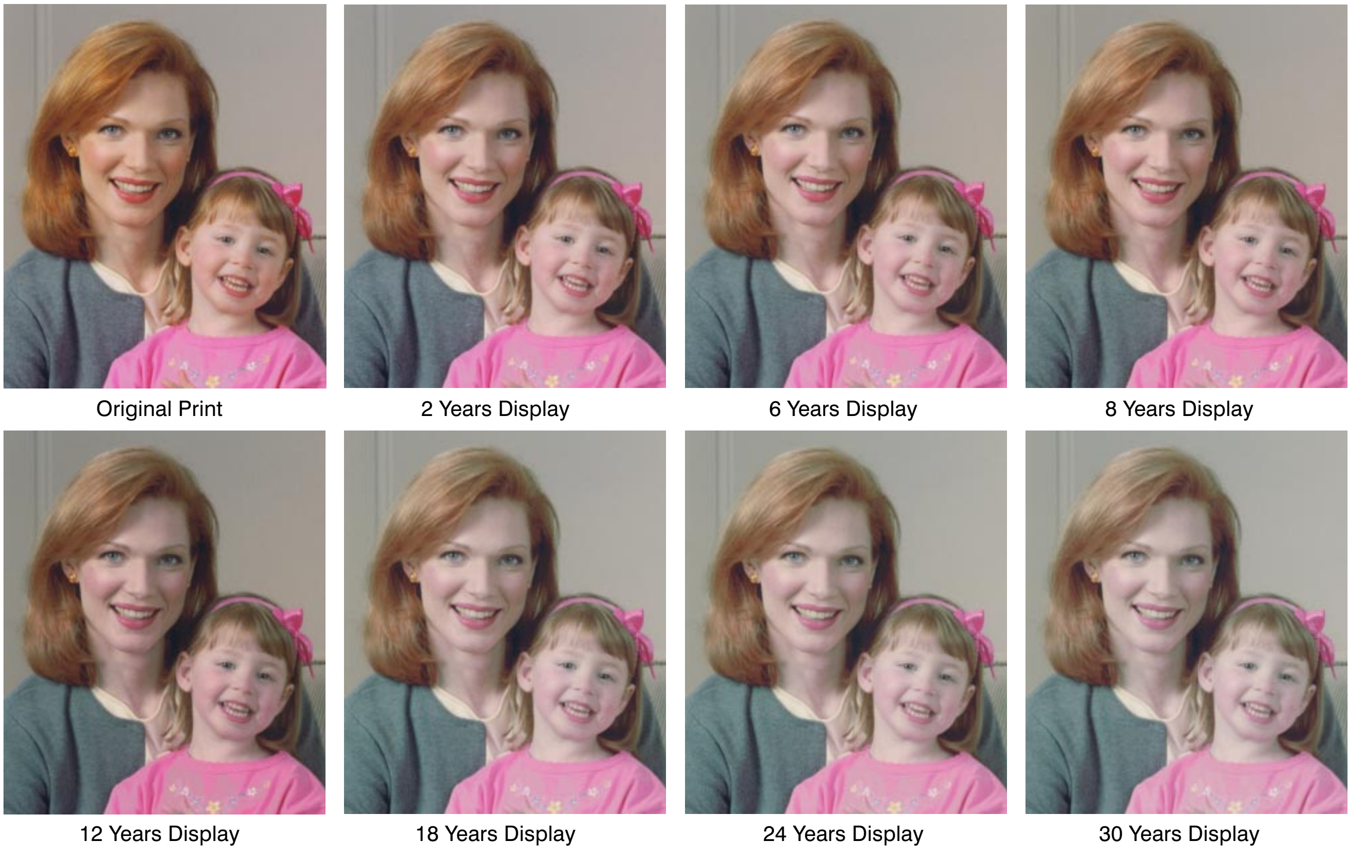
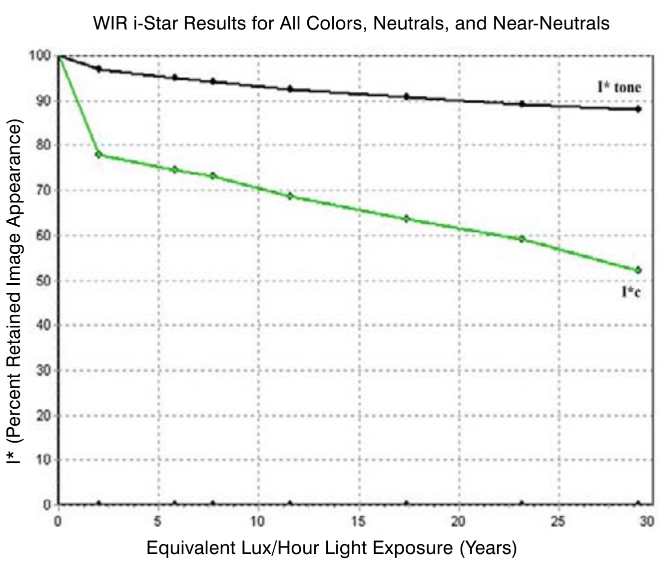


Figure 8. *In these prints, made with a now-discontinued Canon i9900 Photo Printer and subjected to an accelerated glass-filtered cool white fluorescent light fading test, skintones and reddish hair exhibited a significant loss of chroma over time while maintaining fairly good overall color balance and contrast. The now-obsolete Canon ChromaPLUS BCI-6 dye-based inkset includes red and green inks together with cyan, light cyan, magenta, light magenta, yellow and black. The red ink (which is actually closer to an orange in color) proved significantly less stable in light fading than the other inks and this was not detected in tests with either the WIR or "ISO Illustrative" endpoint criteria sets, both of which measure changes only in pure color cyan, magenta, yellow and neutral patches. As shown in the figures below, WIR i-Star tracked the loss of chroma and the resultant loss in "retained image appearance" in the skintones. The printer firmware appears to include a significant amount of the "red" ink in skintone colors. The "years of display" figures were calculated with a light exposure assumption of 450 lux for 12 hours per day. The paper used for these tests was Canon Photo Paper Pro PR-101. The standard "WIR Display Permanence Rating" for this ink and paper combination with the Canon i9900 obtained using the WIR Visually-Weighted Endpoint Criteria Set v3.0 with prints framed under glass is 22 years. The Canon i9900, a 13x19-inch printer, was introduced in 2004 and replaced in 2006 by the Canon PIXMA Pro9000 with improved Canon ChromaLife 100 CLI-8 dye-based inks. As shown in the i-Star figures below, the skintones were much more affected than were the neutrals/all colors in the image while the overall color balance and changes in contrast were similar for both "neutrals/all colors" and "skintones."*



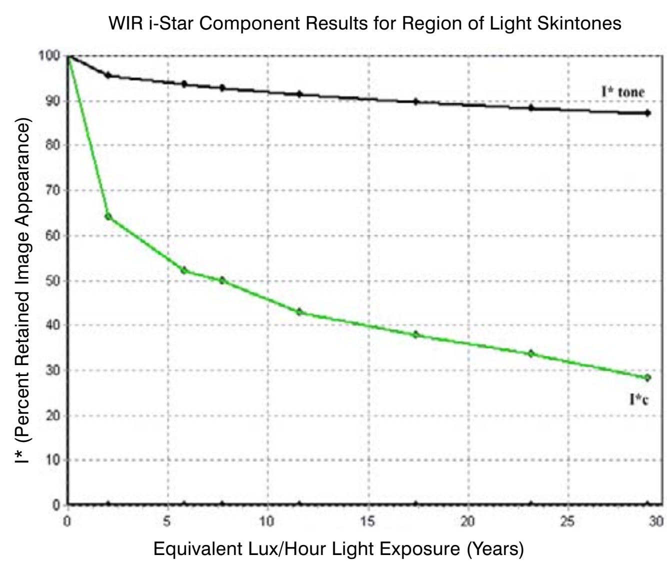


Figure 9. *WIR i-Star analysis can be applied to specific images by downsampling and printing to create a measurement test target with pixel blocks that are large enough to be measured with a spectrophotometer. Such image-specific targets are useful for obtaining psychophysical correlations with perceived fading, staining, and changes in color balance in defined classes of images such as professional portraiture, wedding photography, landscape photography, etc.*

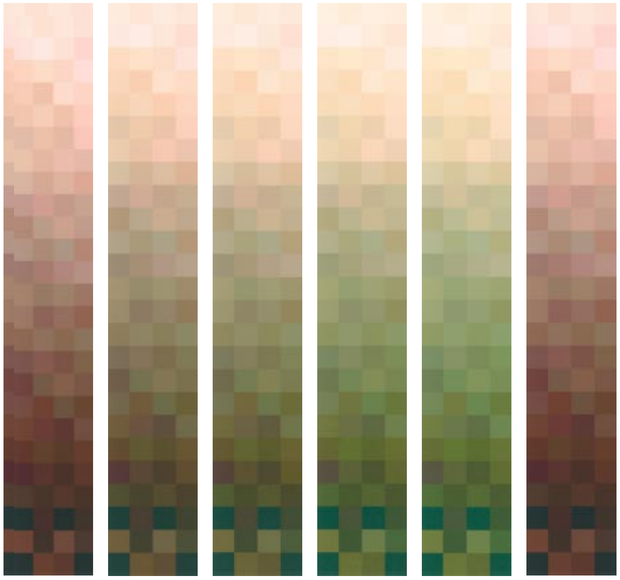
that shift toward green as a result of loss of magenta. However, the great difficulty of preparing properly calibrated test targets and the time-consuming limitation of having to make each measurement with a manually-operated densitometer during the course of image stability tests prevented general adoption of skintone analysis in the author's light stability and Arrhenius dark storage tests. The inability to include skintone colors and full tonal scale analysis in the author's endpoint criteria sets was a source of great frustration over a period of many years and was the primary motivation for the development of i-Star by WIR (with Mark McCormick-Goodhart, consultant). [7]

The need for full tonal scale skintone and near-neutral analysis in image permanence testing is even more important today with modern, complex inkjet ink systems that may contain up to twelve individual ink colors (e.g., multi-level black/gray inks, red, green, and blue inks, orange inks, violet inks, and other specialized colors). It is necessary to use a spectrophotometer and a large number of color patches to properly measure and comprehensively evaluate changes in images as they deteriorate. It is only fairly recently that automated spectrophotometers and the associated computerized systems for handling large amounts of data have become available at reasonable cost, making this possible.

The necessity for analysis of both neutrals and "near-neutrals" has become clearly evident with the advent of the multi-level black/gray pigmented inksets introduced by Epson in 2005 (Epson UltraChrome K3 pigment inks), and in 2006 by Canon (Canon Lucia pigment inks) and Hewlett-Packard (HP Vivera pigment inks). In print permanence testing, measuring changes in color balance has always been an essential part of the methodology (see ISO 18909:2006 for example). With chromogenic prints, for example, changes in color balance of a neutral patch – composed of equal densities of cyan, magenta, and yellow – could be assumed to indicate associated changes that would take place in other colors, including critical human skin colors.

But with the new multi-level black/grey inkjet inksets, this assumption is no longer valid. The neutral scale is largely composed of these extremely stable carbon-based inks and the fading and changes in color balance of these inks may have very little relationship to the fading and changes in color balance of skintones and other "near-neutral" colors. Exactly how much will depend upon the particular inkset and printer driver configuration used by the printer manufacturer. In effect, with traditional methods, we have lost the ability to analyze changes in color balance of these new inksets.

Today's inkjet and other color-managed digital printing systems make it a relatively simple matter to print test targets with full tonal scale skintone colors, neutrals, near-neutrals, and the full range of colors and tones that comprise color photographs (see Figures 1 and 2 for a representative sRGB test target



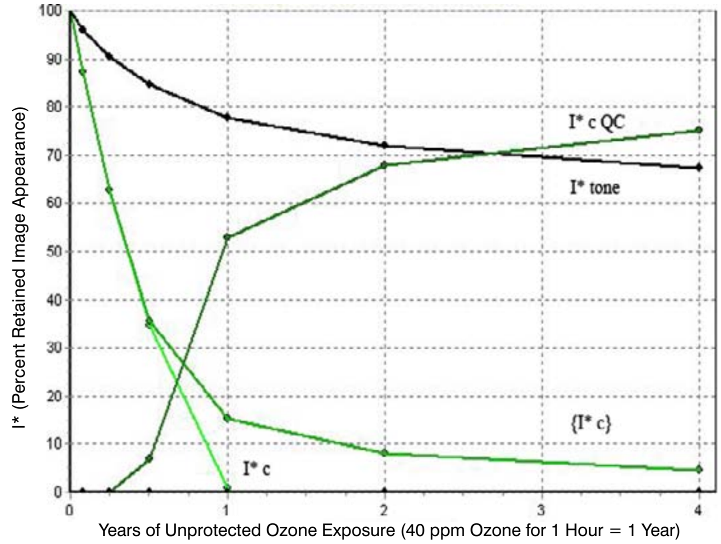
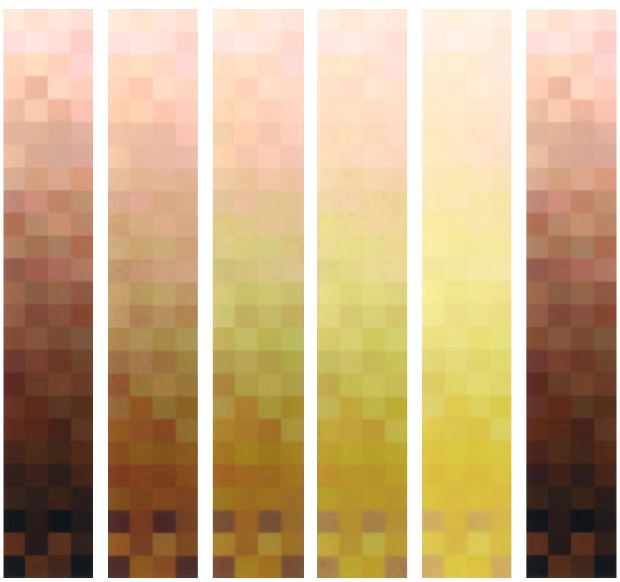


Figure 10. *Unprotected ozone exposure of prints made with 3rd-party Calidad inks (from Australia) printed with an Epson C87 printer.*



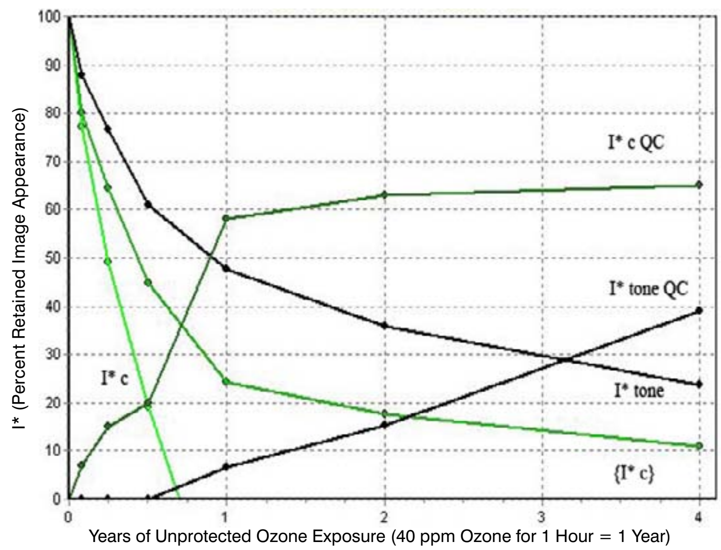


Figure 11. *Ozone exposure to prints made with obsolete Canon ChromaPLUS inks and PR-101 porous photo paper printed with a Canon i9900 printer.*

design). Adequate test targets necessarily require a large number of color patches in order to comprehensively evaluate – and fairly rank – the permanence of color images made across the full range of current and future printing technologies. These printing methods include a wide variety of aqueous, solvent-based, and UV-curable inkjet inksets, as well as with digitally-printed chromogenic (silver-halide) color prints, dye-sub prints, and prints made with various types of dry toner and liquid toner electrophotographic systems.

Application of the WIR i-Star Full Tonal Scale "Retained Image Appearance" Metric in the Permanence Evaluation of Skintone Colors

As can be seen in Figure 7, human skintone colors have low chroma and in this respect can be thought of as a class of "near-neutral" colors. Varying in lightness, skintone colors have similar spectral reflectance curves across worldwide ethnic groups (Figure 5) and the paints used with the "Light Skin" and "Dark Skin" patches of the Macbeth ColorChecker are a reasonably good match to these curves (Figure 6).

The WIR i-Star metric and associated software applications were developed by Wilhelm Imaging Research for both image permanence evaluations and for image quality assessments. [7] Both applications address the same need: that is, from a starting reference point, to accurately assess changes that may occur in color and tone (including both global and localized contrast) throughout the full tonal scale of color and B&W photographs.

The "I" in I* represents "information content" and the asterisk makes reference to the CIELAB color model and the L*, a*, and b* values that are used to make I* calculations. Unlike current color difference models, WIR i-Star metric evaluates both color and tone over the full tonal scale of photographic images.

The application of WIR i-Star in the evaluation of light fading is shown in Figure 8 with a now-obsolete Canon dye-based inkset which includes a relatively unstable orange ("red") ink that is utilized by the printer driver and firmware when printing skintone colors. The fading that occurs over time with this ink/paper combination is characterized by a progressive loss of chroma of the skin colors with relatively little change in color balance or loss of overall density. Examples of "unprotected ozone resistance" tests with two different ink/porous paper combinations are shown in Figures 10 and 11 (please see Reference 7 for additional information about WIR i-Star data reports).

Conclusions

Human skintone colors over the full density range of photographs are a critically important component of the majority of photographs and, along with neutral and near-neutral colors, need to be included in print permanence assessments. With suitable test targets, WIR i-Star provides a comprehensive method for evaluating fading, changes in color balance, and yellowish stain formation with skintone colors. It also provides a method for evaluating the permanence behavior of both specific photographic images and classes of photographic images.

Ongoing work includes a range of psychophysical tests to better establish "WIR i-Star Based Endpoints" for "noticeable" and "acceptable" deterioration of photographic images that will permit predictions of "years of display," "years of dark/album storage," and "years of unprotected ozone resistance." [8] WIR i-Star metrics and software are applicable for both image permanence and image quality evaluations. [9]

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Notes and References

[1] *ISO 18909:2006 – Photography – Processed photographic colour films and paper prints – Methods for measuring image stability,* International Organization for Standardization, Geneva, Switzerland, *www.iso.org*.

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[4] Qun Sun and Mark D. Fairchild, "Statistical Characterization of Face Spectral Reflectances and Its Application to Human Portraiture Spectral Estimation," *www.cis.rit.edu/fairchild/PDFs/PAP14.pdf* (Fig. 2, p. 27), Munsell Color Science Laboratory, Chester F. Carlson Center for Imaging Science, Rochester Institute of Technology, Rochester, New York. See also: Qun Sun and Mark D. Fairchild, "Statistical Characterization of Face Spectral Reflectances and Its Application to Human Portraiture Spectral Estimation," *Journal of Imaging Science and Technology,* Vol. 46, No. 6, November/December 2002, pp. 498–506.

[5] C. S. McCamy, H. Marcus, and J. G. Davidson, "A Color-Rendition Chart," *Journal of Applied Photographic Engineering,* Vol. 2, No. 3, Summer 1976, pp. 95–99.

[6] *ANSI IT8.7/2-1993, "Graphic technology – Color reflection target for input scanner calibration,* American National Standards Institute, Inc., 1993 (Reaffirmed 1999). This standard is available from NPES, The Association for Suppliers of Printing, Publishing, and Converting Technologies, 1899 Preston White Drive, Reston, Virginia 20191-4367; tel: 703-264-7200; fax: 703-620-0994; *www.npes.org*. See also: Francisco Hideki Imai, Norimichi Tsumura, Hideaki Haneishi, and Yoichi Miyake, "Principal Component Analysis of Skin Color and Its Application to Colorimetric Color Reproduction on CRT Display and Hardcopy," *Journal of Imaging Science and Technology,* Vol. 40, No. 5, September/October 1996, pp. 422–430.

[7] Mark McCormick-Goodhart, Henry Wilhelm, and Dmitriy Shklyarov, "A 'Retained Image Appearance' Metric for Full Tonal Scale, Colorimetric Evaluation of Photographic Image Stability," *Final Program and Proceedings – IS&T's NIP20: International Conference on Digital Printing Technologies*, October 31 – November 5, 2004, pp. 680–688. Article PDF is available from *www.wilhelm-research.com*.

[8] Henry Wilhelm, Kabenla Armah, Dmitriy Shklyarov, Barbara Stahl, and Dimitar Tasev, "A Study of 'Unprotected Ozone Resistance' of Photographs Made with Inkjet and Other Digital Printing Technologies," *Proceedings of "Imaging Conference JAPAN 2007,"* The 99th Annual Conference of the Imaging Society of Japan, Tokyo, Japan, June 6–8, 2007, pp. 137–140. A PDF of this article is available from *www.wilhelm-research.com*.

[9] WIR i-Star ImagePermanence Pro software is available from Wilhelm Imaging Research, Inc., Grinnell, Iowa U.S.A. A version of WIR i-Star is also available for image quality evaluations. For additional information visit *www.wilhelm-research.com*.

Author Biography

Henry Wilhelm was one of the founding members of American National Standards Institute (ANSI) Committee IT-3, which was established in 1978 and developed the ANSI IT9.9-1990 image stability test methods standard published in 1990 (revised in 1996). For the past 20 years he has served as Secretary of the group, now known as ISO Working Group 5/Task Group 3 (a part of ISO Technical Committee 42).

Wilhelm currently serves as the Project Leader of the Indoor Light Stability Test Methods Technical Subcommittee of WG-5/TG-3.

Wilhelm received a one-year Guggenheim Fellowship in 1981 for what became a ten-year study of color print fading and staining under low-level tungsten illumination that simulates museum display conditions.

With contributing author Carol Brower Wilhelm, he wrote "The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures," published in 1993. The complete 758-page book is available in PDF form at no cost from www.wilhelm-research.com.

Wilhelm has been a consultant to many collecting institutions, including the Museum of Modern Art in New York, on various issues related to the display and preservation of both traditional photographic prints and digital print media.

Since 1995, he has been an advisor to Corbis on the long-term preservation of the Corbis Bettmann photography collections in a high-security underground storage facility to be maintained at minus 20 degrees C (minus 4 degrees F) and 35% RH. With more than 65 million images, it is one of the world's largest privately held photography collections. Wilhelm currently serves as a preservation consultant to Corbis France in the design and access work flow of the new Corbis-Sygma Cold Storage Preservation and Access Facility scheduled to open in Garnay, France in 2008. Corbis is a private corporation that is owned by Bill Gates.

Wilhelm is the recipient of the Photoimaging Manufacturers and Distributors Association (PMDA) "2007 Lifetime Achievement Award" for his work on evaluation of the permanence of traditional and digital color prints and for his advocacy of very low temperature cold storage (e.g., minus 20 degrees C [minus 4 degrees F] at 40% RH) for the permanent preservation of black-and-white and color prints, color negatives, transparencies, and motion picture films.

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