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ISO TC42 process for the selection of representative skin tones

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Abstract

Members of several working groups within the ISO Technical Committee 42 (photography) have begun addressing the important topic of providing guidance for which skin tones to use for image quality testing in various photographic applications. For example, when color patches for skin tones are used in TC42 standards, they should be inclusive and represent a broad range of skin types. Skin tones are present in more than 60% of all captured photographs [1, 2] and therefore need to accurately be corrected in digital cameras, properly displayed and printed on various softcopy and hardcopy devices, and the permanence of the printed colors needs to be determined. During the 2023 plenary meeting of TC 42 in Japan, an ad hoc working group (AHG) was initiated to develop such guidance and report back during the upcoming 2025 plenary meeting in Berlin.

The group has investigated existing skin tone studies, including Fitzpatrick, Von Luschan, L'Oreal, PERLA, Monk, Pantone ST, Massey NIS, Verkruysse, Holm and Wueller. It is currently drafting an ISO Technical Report that will document the work and result in recommendations regarding the selection of skin tone color patches and spectra to use for ISO related applications.

Introduction

Around two thirds of the photographic images captured include people [1,2]. This means that in photography, the correct representation and reproduction of skin tones is of utmost importance. The reproduction starts with the image capture using a camera. For a capture device it is not sufficient to take an image of a test chart that contains color patches with a colorimetric representation of the various skin types, because most cameras do not fulfil the Luther/Maxwell/Ives condition. This means that the spectral sensitivities are not linear combinations of color matching functions. In other words, cameras do not see colors the same way the human visual system sees colors. To measure the image quality of captured skin tones correctly, it is important to use the real spectral reflectances of an inclusive set of skin tones. Once the skin tones are captured and encoded, we can usually work with colorimetric values calculated from the spectra, because the usual intention is to show the colors to a human observer either on a display or as a print. But it is important that the skin tones are rendered for the light source used to illuminate the print or for the calibrated white of the display to which the human observer is adapted.

The AHG reviewed all ISO standards developed by TC42 and identified eight relevant documents which include skin tone representations.

The relevant image capture-related standards and technical reports are:

1. ISO 19093:2018 Photography — Digital cameras — Measuring low-light performance
2. ISO 17321-1:2012 Graphic technology and photography — Colour characterisation of digital still cameras (DSCs) — Part 1: Stimuli, metrology and test procedures
3. ISO/TR 17321-2:2012 Graphic technology and photography — Colour characterisation of digital still cameras (DSCs) — Part 2: Considerations for determining scene analysis transforms
4. ISO 19264-1:2021 Photography — Archiving systems — Imaging systems quality analysis — Part 1: Reflective originals

These four documents typically use only two skin tone patches, a "dark skin" patch and a "light skin" patch, from a color rendition chart first defined in 1976. [3]

The following image permanence and printing standards or technical specifications include test patches intended to represent skin tones.

1. ISO/PAS 18940-1:2023 *Imaging materials — Image permanence specification of reflection photographic prints for indoor applications — Part 1: Test methods*
2. ISO/TS 21139-22:2023 *Permanence and durability of commercial prints - Part 22: Backlit display in indoor or shaded outdoor conditions - Light stability*
3. ISO 18946:2023 *Imaging materials — Reflection colour photographic prints — Method for testing humidity fastness*
4. ISO/TS 20791-2:2021 *Photography — Photographic reflection prints - Part 2: Evaluation of colour variation in printing*

One of these documents uses only two skin tone patches, a "dark skin" patch and a "light skin" patch, from the ColorChecker colour rendition chart defined in 1976. [3] Two other documents use the same two patches along with a third, darker brown patch. The fourth document uses a total of 6 different light brown patches, but no dark brown patches.

In addition, ISO 18944:2018 *Imaging materials — Reflection colour photographic prints — Test print construction and measurement* is relevant, since it specifies requirements and recommendations for the digital test file content used to generate target prints for image stability testing of reflection color photographic prints. The digital test file is required to include target prints with a) neutral patches, b) cyan, magenta, and yellow-coloured patches, c) red, green, and blue-coloured patches, and d) a D_{min} patch area. An example of a layout of a subset target which includes these features, from Figure A.1 of *ISO* 18944:2018 is shown in Figure 1 below. However, ISO 18944:2018 does not include any requirements or recommendations related to skin tone patches.

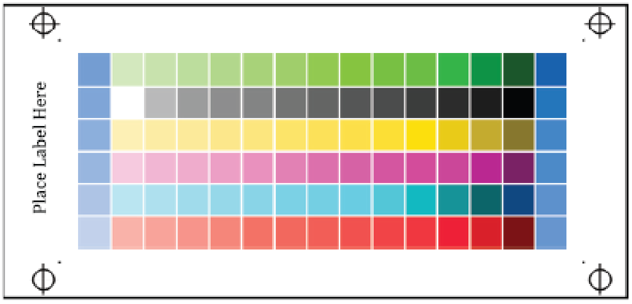


Figure 1 - Example of a layout of a subset target from ISO 18944:2018

During the future systematic reviews of the standards listed above, and during the development of any relevant new standards, the recommendations regarding the selection of skin tones from the ISO AHG which is currently preparing the ISO technical report will be considered.

Skin tone research and representations

Most photographs depict at least one person, so properly capturing and reproducing a diverse range of skin tones is very important. [1,2] Examples of the relative radiance spectra of real skin tones are shown in Figure 2 below. [4]

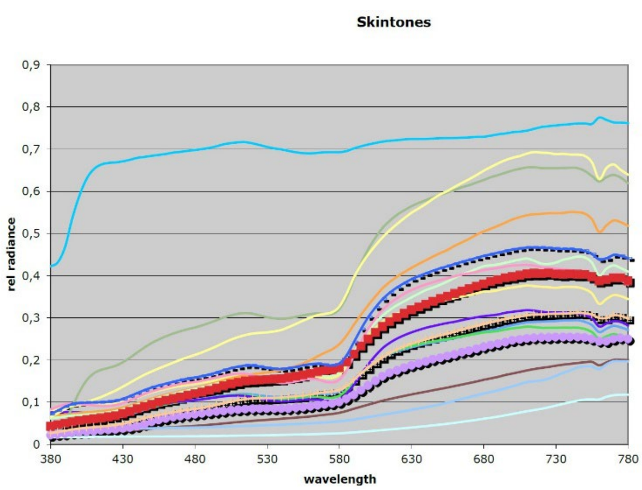


Figure 2 – Examples of the relative radiance spectra of real skin tones

A Set of 100 spectral measurements of human skin reflectance is available from the US National Institute of Standards and Technology (NIST). [5, 10].

The spectra are shown in figure 3. Note that the original spectral reflectance values range between 250 and 2500 nm, in 3 nm intervals. The wide wavelength range was based on a range of potential uses, including medical applications, that are beyond our area of focus.

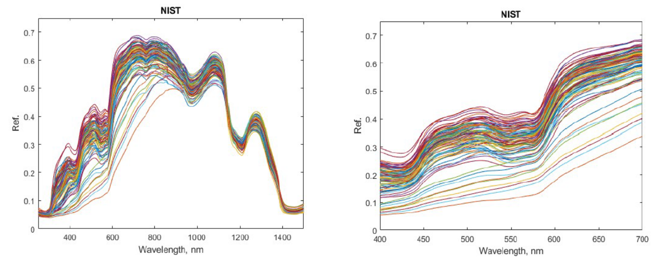


Figure 3 – NIST 100 reflectance spectra (250-1400 nm), and for visible wavelengths (400-700 nm).

Ideally, tests of photographic systems should use a large and diverse group of skin tones, including those depicted in Figure 2. However, in many cases it is challenging to do so. For example, it is very difficult, if not impossible, to obtain stable color patches having the necessary spectral reflectances to adequately match the spectral reflectances of the diversity of skin tones. It can also be difficult and expensive to create test charts having a large number and variety of skin tone patches, for example due to test chart size limitations.

The CIE has a project underway titled CIE TC 1-92: Skin Colour Database, chaired by Kaida Xiao. The purpose is 1) to investigate the uncertainty in skin color measurement and to recommend protocols for good measurement practice, and 2) to tabulate skin color measurements that are in accordance with these protocols covering different ethnicities, genders, ages and body locations. Once their technical report is published, it could be considered as a potential normative reference for various imaging applications.

Research and development that led to color palettes including skin tones

Over the last fifty years, various color test charts and color palettes have been developed which include patches intended to represent skin tones. These palettes serve different purposes. Some are designed for medical use, some for cosmetics, and others to represent skin tones in print, display and image capture. These charts and palettes are described below.

ColorChecker Test Chart

The original design of the most widely used color test chart was described in a 1976 publication [3]. The original name for this color rendition chart was the “Macbeth ColorChecker”, which was also referred to as the “Macbeth chart”. A more current version of the chart is shown in Figure 4. The 24 color patches are surrounded by a black border and include 6 patches in a grey lightness scale and saturated red, green, blue, cyan, magenta and yellow patches in the two bottom rows of the chart. The original spectral reflectance of the color patches in the top two rows were chosen to approximate natural objects such as blue sky and green foliage.

The two color patches in the upper left are intended to represent dark skin and light skin. The designers of the MacBeth ColorChecker contended that the lightest human skin being photographed is practically white, due to the use of talcum powder, while the darkest human skin is practically black, and that both have nearly uniform spectral reflectance. [3] They also contended that the characteristic spectrum of human skin is primarily due to absorption by melanin and hemoglobin, such that the spectra for all types of human skin form a continuous homologous series. The medium light skin and medium dark skin patches were selected to test the ability of systems to reproduce the color associated with this typical spectrum at two different exposure levels. [3]

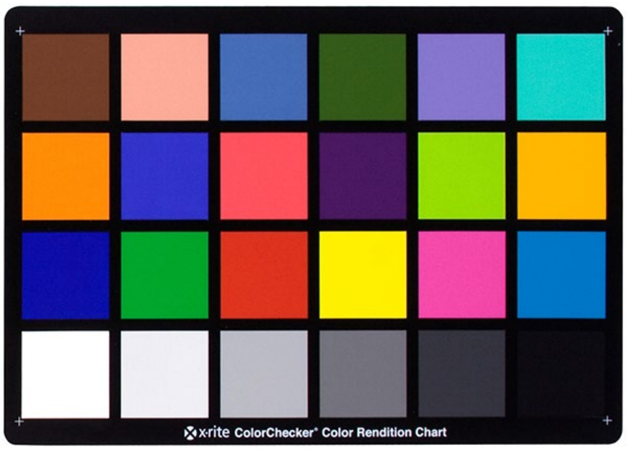


Figure 4 – X-Rite ColorChecker® Color Rendition Chart

In 1997, the Gretag Color Control System Division merged with the MacBeth division of Kollmorgen Instruments to form Gretag-Macbeth, which sold the similar Gretag-MacBeth ColorChecker chart. In 2006, X-Rite acquired the holding company which owned Gretag-Macbeth and began selling the X-rite ColorChecker. In 2021, X-Rite photo and video products were transferred to another company named Calibrite, which currently sells the Calibrate ColorChecker Classic color rendition chart.

The ISO TC42 standards described earlier that include dark skin and light skin patches are based on the spectral reflectance of the original Macbeth ColorChecker described in [3]. A comparison of this original ColorChecker chart with an X-Rite ColorChecker chart was made using a SpectraScan PR-740 Spectroradiometer. It shows that the spectral data in the TC42 standards provides a reasonably accurate representation of the original ColorChecker, as shown for example in Figure 5 below.

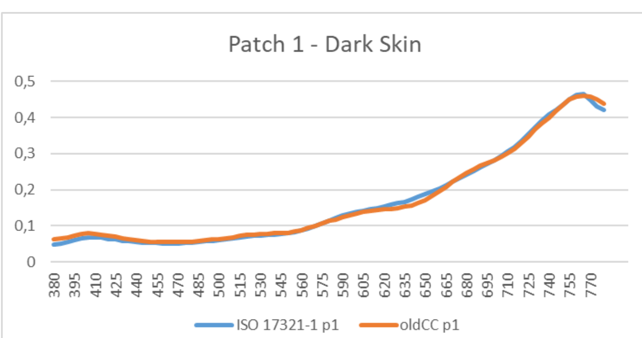


Figure 5 – Spectra of original ColorChecker Patch 1 and ISO/TR 17321-2 data

However, several color patches on the X-Rite ColorChecker are substantially different from the ISO data and the original ColorChecker. In particular, the Patches 1 (dark skin), 3 (blue sky), 4 (foliage), 5 (blue flower), 8 (purplish blue), and 13 (blue) of the X-Rite ColorChecker are significantly different from the original ColorChecker. While the original ColorChecker appears to mimic these items spectrally, the X-Rite ColorChecker seems to only mimic them colorimetrically. Patches 2 (light skin), 6 (bluish green), 7 (orange), 10 (purple), 14 (green), and 17 (magenta), are slightly different, while the remaining color patches are essentially the same. The new chart does not include the names for the patches found on the old chart.

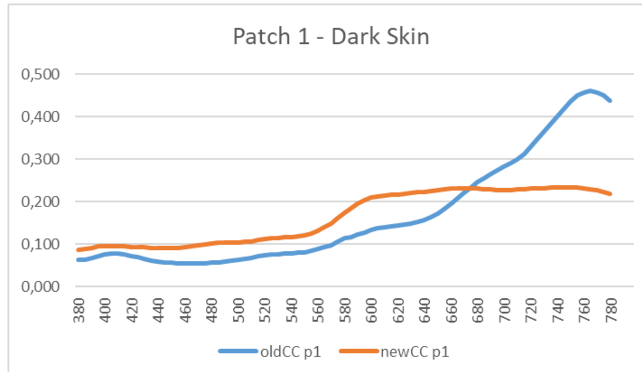


Figure 6 – Spectra of original ColorChecker Patch 1 compared to the newer version

Fitzpatrick skin tone scale

The Fitzpatrick scale, shown in Figure 7, classifies skin tones based on how the skin responds to sun exposure. It includes a wider range of skin tones than the X-Rite ColorChecker® Color Rendition Chart. This skin tone scale was developed by American dermatologist Thomas Fitzpatrick in 1975, to estimate the response of different skin types to ultraviolet (UV) light. It originally included only the first four skin tones and was expanded to include the two darker tones in 1988 [3].

Figure 7 – Fitzpatrick Scale Classification of 6 Skin Types

The Fitzpatrick scale is widely used for skin phototyping, which is based on a person's tendency to sunburn and ability to tan. While it was not designed to classify the diverse variety of skin tones from around the world, it is often used for this purpose. For example, it has been used to classify skin tones when selecting images to be used in machine learning applications.

L'Oréal skin type chart

A more diverse skin tone representation, the 66-patch skin type chart shown in Figure 6, was developed by L'Oréal to enable matching skin tones to appropriate cosmetic products. [5]

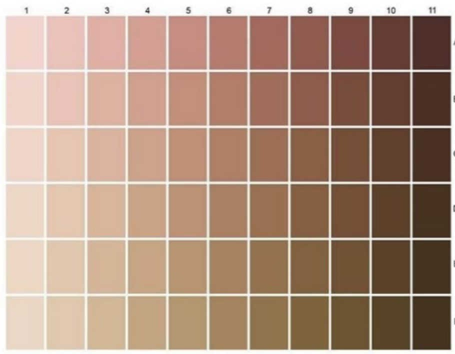


Figure 8 – L'Oréal 66-patch skin type chart

Unfortunately, this chart has too many patches to be practical for most applications in photography and print.

IT8 chart

A color rendition test chart, commonly known as the "IT8 chart", was first standardized in 1993 as ANSI standard IT8.7/2 - 1993 Graphic technology - Color reflection target for input scanner calibration. Currently, this standard is known as ANSI CGATS/ISO 12641-1:2018 Graphic technology - Prepress digital data exchange - Color targets for input scanner calibration - Part 1: Color targets for input scanner calibration. The target includes 264 color patches in a grid of 22 columns x 12 rows, along with 24 grey patches, as shown in Figure 7. It enables a graphic arts color input scanner to be calibrated for the dye set used to create the target.

The IT8.7/2 standard does not specify any color patches that are intended to represent skin tones. However, the colors in columns 20 through 22 are not specified in the standard and can be any colors chosen by the chart manufacturer. Some manufacturers have decided to include color patches representing skin tones, as shown in column 22 of Figure 9.

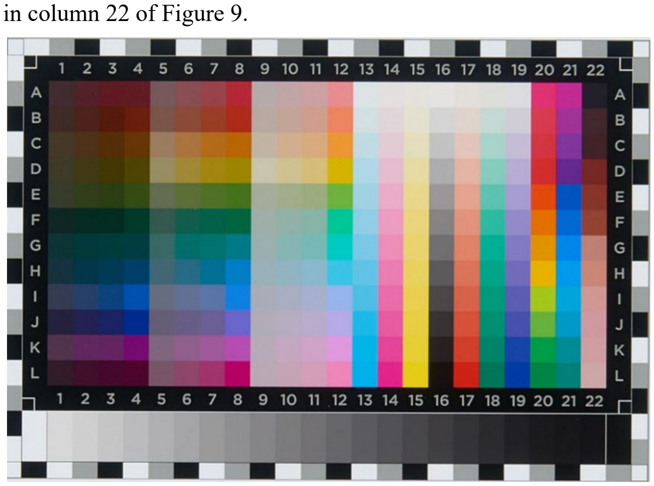


Figure 9 – IT8 Color reflection target for input scanner calibration

Pantone SkinTone Guide

The Pantone SkinTone Guide [8] is a collection of 138 separate skin tone patches arranged in a fan, as shown in Figure 10. Digital values for each patch are available. The color of each patch is identified by a unique Pantone Number which represents both the tone and the undertone. The guide is designed for representing skin tone in print, for D65 (Daylight 6500K) illumination. It is said to have been "created by scientifically measuring thousands of actual skin tones across the full spectrum of human skin types" and "specially formulated to be the closest physical representations of skin colors", that is to attempt a spectral match between printed ink and measured skin tone.

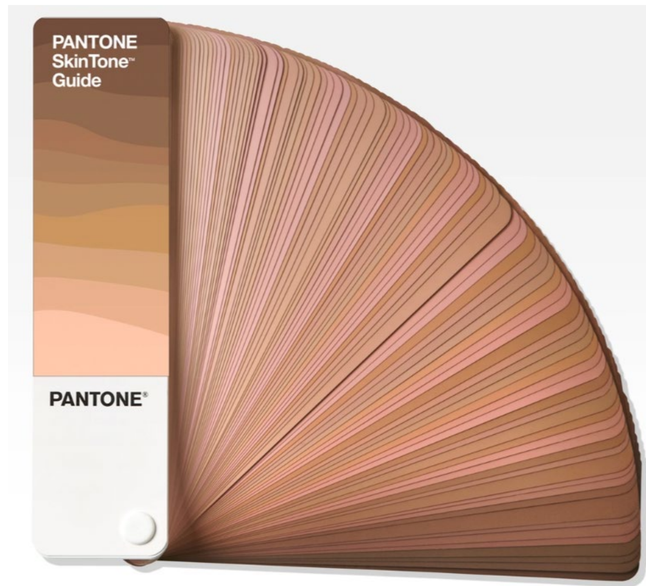


Figure 10 – PANTONE® SkinTone™ guide

PERLA color palette

The Project on Ethnicity and Race in Latin America (PERLA) was formed in 2008 to empirically examine race and ethnicity across Latin America. The 11 color patches in the PERLA color palette, shown in figure 11, came from internet photographs, and the palette was extensively tested to see if it covered the range of colors found in Latin American survey respondents.

Figure 11 – PERLA color palette

Monk skin tone scale

The Monk skin tone scale, shown as swatches in Figure 12, is designed for machine learning applications. It was developed by Dr. Ellis Monk at Harvard University to address the biases in the Fitzpatrick scale, which is skewed towards lighter skin tones that are more UV sensitive. The 10 skin tones in the Monk skin tone scale represent a diverse range of tones, while using a manageable number of patches [9].

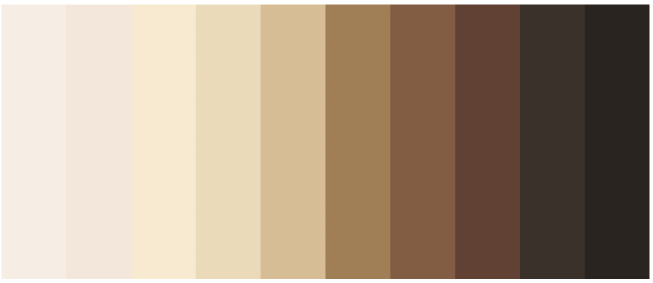


Figure 12 – Monk skin tone scale swatches

The Monk skin tone scale is often depicted using orbs, as shown in Figure 13. The orbs depict how each skin tone may appear in both the real world and in images. This is a helpful reminder that a person's skin does not appear to be a single, uniform color. Rather, it can exhibit a range of shades across the complex surfaces that comprise a person's face and body.

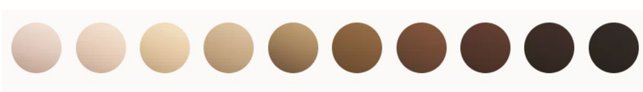


Figure 13 – Monk skin tone scale orbs

The Monk skin tone scale is intended for applications such as developing and testing face recognition algorithms. As a result, the Monk skin tone scale is represented using rendered sRGB values which are designed to be displayed on a monitor. The Monk skin tone scale values are also provided as LAB values, and both are listed in Table 1 below.

sRGB and Lab values for Monk skin tone scale

Patch	sRGB R	sRGB G	sRGB B	Lab L	Lab a	Lab b
Monk 01	246	237	228	94.211	1.503	5.422
Monk 02	243	231	219	92.275	2.061	7.28
Monk 03	247	234	208	93.091	0.216	14.205
Monk 04	234	218	186	87.573	0.459	17.748
Monk 05	215	189	150	77.902	3.471	23.136
Monk 06	160	126	86	55.142	7.783	26.74
Monk 07	130	92	67	42.47	12.325	20.53
Monk 08	96	65	52	30.678	11.667	13.335
Monk 09	58	49	42	21.069	2.69	5.964
Monk 10	41	36	32	14.61	1.482	3.525

It is believed that the LAB values were determined by converting the sRGB to D65 XYZ with the display black point scaled to zero and then using D65 as the white point for the CIELAB calculations (with no chromatic adaptation).

Considerations

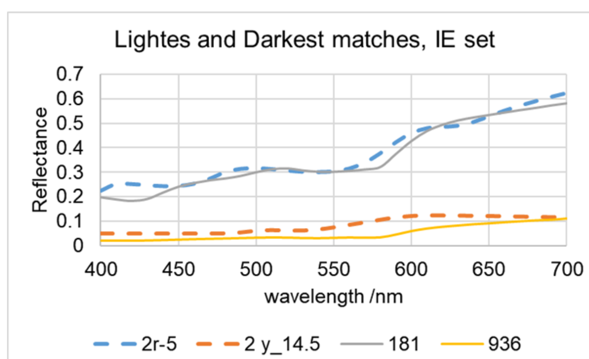
As mentioned in the introduction, ISO TC42 needs a set of spectral reflectances that represent the various skin types for image capture along with the corresponding colorimetric values that can be displayed or printed.

The number of recommended skin tones cannot be too large, because in many standards applications there is limited space for color patches. On the other hand, it needs to be large enough to represent an inclusive set of skin types.

There were cases where cameras were trained on only certain skin types, which led to problems with other skin types which were not included. It is especially important to include dark skin tones, because cameras naturally have problems with lower light levels.

After reviewing the various works and color palettes, the group initially considered the Monk skin tone scale. One reason was the appropriate number and diverse range of skin tones. But after closer investigation, the AHG found that the Monk scale will not work for the intended application. One reason is the fact that the 3 brightest patches are above an L* value of 90, which is beyond what a photographic print on paper can achieve. These Monk L* values are higher than the L* values of most papers, especially those without optical brighteners. Another reason is that the Monk skin tones are significantly more yellow than natural skin tones and do not show the red component from the hemoglobin in the blood flowing through the skin. The skin tones in this scale are rendered for a display with a reference white point of 6500 K. For such a cool reference white, it seems that the tones need to be turned into "warmer" tones in order to be perceived as natural. In addition to these two issues, we only found matches with the spectral data for the natural skin tones in the mid-section of the brightness values.

Since the Monk scale was not ideal for our purposes, we looked at the other candidate color palettes and decided to investigate the spectra of the color patches in the Pantone SkinTone Guide. Many of the Pantone skin color patches show an excellent spectral match with the insitu measured skin reflectance data, as shown in figure 14. Such a spectral match has the additional benefit of providing a colorimetric match under all types of light sources. Unfortunately, 138 tones are far too many to be included in a TC42 test chart.



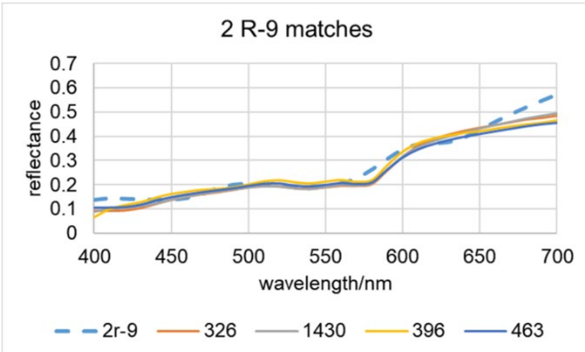


Figure 14 – spectral comparison between insitu measured skin tones and Pantone skin tones. (dashed lines are Pantone colors)

Next steps

The AHG is now working on a more detailed comparison to find the best matches between the skin tone measurements and the Pantone patches. Once this is completed, we intend to select an appropriate set of representative colors from these matches that cover a diverse range of skin tones. This will enable us to provide spectral data, colorimetric data, and high-quality printed representations that can be used for image quality testing throughout the whole photographic workflow.

Acknowledgement

We are pleased to acknowledge the many contributions of our colleagues in the ISO TC42 Skin Tone ad hoc working group (AHG).

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Author Biographies

Dietmar Wueller studied photographic technology at the Cologne University of applied sciences. He is the founder of Image Engineering, an independent camera test lab that has also developed into one of the world's leading suppliers of test equipment. Dietmar Wueller is the German chair of the DIN standardization committee for photographic equipment and also active in ISO TC42, the IEEE, EMVA (European Machine Vision Association) and other standardization activities.

Ken Parulski joined Kodak Research Labs in 1980 after graduating from MIT and retired as an Eastman Fellow and the Chief Scientist in Kodak's digital photography division in 2012. He now serves as a consultant to several major imaging companies and chairs the US Technical Advisory Group for ISO TC42. Ken has been an expert in ISO TC42 since 1992. He is a SMPTE Life Fellow and an inventor on more than 230 U.S. patents.

Dr. Rita Hofmann-Sievert, HonFRPS, has served as the Swiss expert for the ISO committee TC-42 since 1995 and has been a research lecturer at the University of Applied Sciences in Bern until 2022. She is an honorary member IS&T and has won the Progress Medal of the RPS in 2024.