# Identification of aim values for a CMYK-OGV based process agnostic ECG Characterization Dataset: FOGRA55

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**Abstract**

For many design and print workflows, the final printing conditions are either unknown or known to be a variety of slightly different printing systems or processes. In order to achieve a consistent and predictable colour reproduction throughout the process even without knowledge of the exact final printing condition, one solution is to utilize a colour exchange space as the intermediate colour reference for the print data preparation phase as well as in proofing. In CMYK printing, there are dedicated exchange colour spaces such as eciCMYK_v2, based on the characterization data FOGRA59, that reflects the typical gamut shape of CMYK printing across different processes. With the Extended Colour Gamut (ECG) also being used for high quality pictorial printing, the need for an ECG replacement colour space was identified, leading to the development of FOGRA55. The aim of this report is to improve the process agnostic FOGRA55 based on the beta version published in 2018 and validate the usability of this characterization dataset as RPC (Reference Printing Condition). Different OGV inks were used to determine the solid aim values of OGV in the dataset in the first experiment, which led to the final FOGRA55 characterization dataset. Two further experiments were conducted to validate the feasibility and usability of FOGRA55. The results of the second experiment confirmed that the FOGRA55 dataset with revised solid aim values is more suitable as RPC for CMYKOGV-like-systems than the previous version (FOGRA55_v1). Furthermore, the result of the third experiment demonstrate the potential improvement for colour communication in terms of better colour predictability and accuracy in some ECG workflows.

Fogra

## Introduction

Fogra characterization datasets, known as Fogra Standards, are typically reflecting a concrete printing process. With FOGRA53 Fogra developed and published the first colour exchange space (2) coming along with the ICC profile eci CMYK (5).

In a Fogra research project (4), the need of an exchange colour space for ECG workflow has been identified. This colour space is designed to be process agnostic and it should reflect the shape and size of a typical ECG printing gamut. In light

of the widespread usage of CMYKOGV printing, the CMYKOGV-based FOGRA55_v1 was developed and published in 2018.

The first part of this work is the determination of the refined solid aims of OGV-colorants for FOGRA55 based on a statistical analysis of the colorimetrical characterization of practical OGV-inks used in ECG printing that are collected in print experiments as described in experiment 1 as well as user feedback gathered so far.

The most suitable OGV candidate resulting from experiment 1 is to be implemented in the characterization dataset FOGRA55_v2, which will become the final FOGRA55 standard. The second part of this work focuses on the validation of the FOGRA55_v2 regarding its usability as the colour reference for media relative colour reproductions. This is achieved by implementing FOGRA55_v2 as reference printing condition (RPC) for an ICC-based media relative workflow in combination with 13 industrial common ECG press profiles. These profiles are derived from 13 7C printing conditions (7C), of which 9 are offset systems and 4 are digital print systems. The evaluation in experiment 2 utilizes the PSD colour accuracy evaluation to determine the suitability of FOGRA55_v2 as an exchange colour space for ECG. PSD stands for Process Standard Digital, which was developed by Fogra in 2011 (10). The free-of-charge PSD handbook can be considered as guidance, which provides aim values and tolerances for industrial typical digital printing. The colour accuracy evaluation is covering both the established colour accuracy (side-by-side) and the media relative evaluation. For both types of visual appraisal (side-by-side and colour memory or sequential viewing) the PSD standard covers three tolerance bands termed A, B, and C as stipulated in ISO/TS 15311-2 (8). To determine the improvement of FOGRA55_v2, the results are compared to the reproduction results based on FOGRA55_v1.

The last part of this work focuses on the demonstration of the potential gain of utilizing the colour exchange space workflow for ECG printing systems. It should be noted that the available constraints for developing FOGRA55_v1 remain valid. The most important ones are the utilization of ISO 12647-2:2014 for the CMYK part (hence FOGRA51) and the proofability.

**Experiment 1: experimental setup and proposal of OGV-Aims for FOGRA55**

For a typical colour transformation chain in a colourmanaged print production, the usage of a reference colour space is involved. This serves both as a reference for the designer e.g., via a proof and as a feasible reference for the downstream print production. The more similar the exchange colour space is to the potential output colour space, the better the reference colour space to be reproduced regarding colour accuracy. One of the key parameters that influences the

feasibility of the exchange colour space is its shape of the gamut, which is determined notably by the solid aims of process inks.

During the development of FOGRA55_v1 in 2018, the decision towards the solid aims for the additional process inks (other than CMYK) OGV were made based on the statistical preferences shown at that time in ECG printing (9), namely PANTONE+ Orange 021 C, PANTONE+ Green C and PANTONE+ Violet C. The colorimetrical values from the digital PANTONE+ library as used in Adobe Photoshop were implemented in FOGRA55_v1. Mixing those M2-based colour definitions with the M1-based CMYK part was an additional reason for the revision of FOGRA55_v1.

To verify the practical feasibility of the solid coloration aims for OGV proposed in FOGRA55_v1 (4), several solid colorations of OGV-inks dedicated for ECG printing were collected and analyzed. Since the submitted inks or data for ink on paper tests are from four different sources, they are referred to as ink series 1 to 4 in this report. Series 1and 2 each covers one orange, one green and one violet offset ink printed on one premium coated offset paper in 15 different ink film thicknesses, while series 3 includes one orange, one green and one violet offset ink printed on a coated offset paper in four different ink layer thicknesses. Series
4 covers one orange one green and one violet ink for flexo printing, each with three different pigment concentrations. The colorimetrical measurement of all printing samples was conducted with measurement mode M1 on white backing according to ISO 13655:2009 (6). The colorimetrical values of ink series 3 are provided by the ink supplier, while values of ink series 4 are collected from field testing in flexo printing and submitted by a member from the project committees of Fogra research project 13.003 (4). All collected colour values are provided in M1 mode and are referred as candidates for FOGRA55_v2.

For better visualization, the four datasets with over 100 measurements are split into three categories. The first category concludes the average based on all measurement series, the second category covers the average values calculated based on measurements of offset inks, while the third uses the average based on measurements of flexo inks.

These categories are listed in Table 1. In Figure 1 the individual measurements are plotted together with the existing solid coloration published in FOGRA55_v1, as well as the values stipulated in ISO/DTS 21328 (7).

| Colorant | | | L* | a* | b* | C* | h |
|---|---|---|---|---|---|---|---|
| O | FOGRA55_v1 | | 61 | 66 | 85 | 108 | 52 |
| | Potential FOGRA55_v2 | Mean 1-4 | 67 | 55 | 82 | 98 | 56 |
| | | Mean 1-3 (offset) | 65 | 58 | 88 | 105 | 57 |
| | | Mean 4 (flexo) | 71 | 49 | 69 | 85 | 55 |
| | ISO/DTS 21328 proposal | | 70 | 56 | 80 | 98 | 55 |
| G | FOGRA55_v1 | | 58 | -77 | 0 | 77 | 180 |
| | Potential FOGRA55_v2 | Mean 1-4 (overall) | 62 | -73 | 0 | 73 | 180 |
| | | Mean 1-3 (offset) | 60 | -75 | 0 | 75 | 180 |
| | | Mean 4 (flexo) | 65 | -68 | 1 | 68 | 179 |
| | ISO/DTS 21328 proposal | | 66 | -73 | 1 | 73 | 179 |
| V | FOGRA55_v1 | | 19 | 59 | -75 | 95 | 308 |
| | Potential FOGRA55_v2 | Mean 1-4 (overall) | 24 | 46 | -56 | 72 | 310 |
| | | Mean 1-3 (offset) | 22 | 47 | -56 | 73 | 310 |
| | | Mean 4 (flexo) | 29 | 46 | -56 | 72 | 309 |
| | ISO/DTS 21328 proposal | | 24 | 46 | -55 | 72 | 310 |

***Table 1:*** *A list of proposed OGV aim values for CMYKOGV printing, including the values published in FOGRA55_v1, the values derived from the experiment 1, as well as the values stipulated in ISO/DTS 21328 (7). The aim values are listed as CIELAB and CIECh values.*

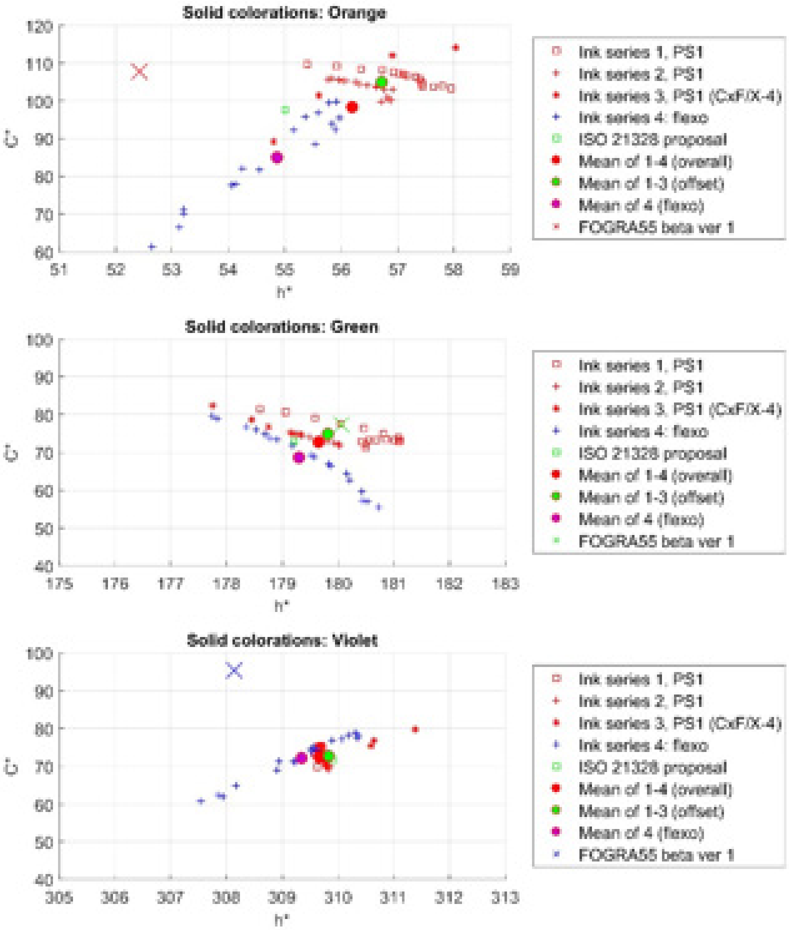


***Figure 1:*** *The CIEh-C* diagrams of the solid colorations for orange, green and violet inks in comparison to the current FOGRA55_v1 aims (cross) as well as the 3 variations of mean values proposed as candidates as aim values. PS1 stands for printing substrate.*

Figure 1 shows that the significant deviation between the aim values and actual measurements seen among orange colorations is in hue. The hue of the orange aim value of FOGRA55_v1 is 52°, while the hue values of practical prints with different densities range from CIEh=55° to CIEh=58°. The hue accessibility of the green colorations of FOGRA55_v1 is acceptable with its aim values lying in

an achievable hue range for practical prints. For violet colorations, the hue of the aim value of FOGRA55_v1 varies up to ΔCIEh=3° to that of the actual samples of ink series 1 and 2. Since the violet pigment of ink series 3 varies from the PANTONE+ Violet C so the difference is explainable. Furthermore, a significant difference between reference values and the actual prints can be spotted in chroma. The chroma of the reference value is out of reach for most tested ink series.

As expected, the dispersion of solids highly depends on the used substrate and process. In light of the anticipated use of FOGRA55 for high-quality pictorial ECG printing, which is typical for offset and digital printing rather than in flexography, the averaged values based on offset prints using typical substrates and ink film thicknesses were used as the new candidates (Means 1-3). The final manipulating of the solid colorations including the linear SCTV gradation for Orange, Green, and Violet were facilitated with the printing model of GMG Open Color V. 2.4.2.

**Experiment 2: experimental setup and result for the validation of FOGRA55_v2**

To validate the usability of the FOGRA55_v2 for printing presses in comparison to FOGRA55_v1, the following investigation is conducted using 13 press profiles derived from 13 7C-ECG printing conditions, the details of which are documented in Table 2. During the test, FOGRA55_v1 and v2 are used separately as reference colour aims for the media relative reproduction. The colour difference between the converted colour values and the references are evaluated according to (10) and the colour accuracy result is applied as the main criteria for the test. The test target used for this test is the Fogra Media Wedge Multicolor 7C V1, as shown in Figure 2, which contains the patches required for colour accuracy evaluation in (10).

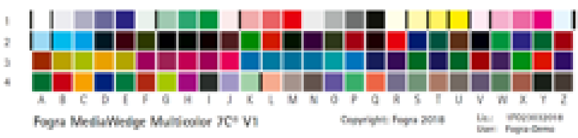

***Figure 2:*** *The selected testform for colour accuracy evaluation: the Fogra MediaWedge Multicolor 7C V1, short as MW7C (1).*

| ID | Print process | Colorants | Used substrate |
|---|---|---|---|
| 1 | offset | CMYKOGV | Coated stock |
| 2 | offset | CMYKOGV | Film |
| 3 | offset | CMYKOGV | Film |
| 4 | offset | CMYKOGV | Coated stock |
| 5 | offset | CMYKOGV | Coated stock |
| 6 | offset | CMYKOGB | Coated stock |
| 7 | offset | CMYKOGV | Coated stock |
| 8 | offset | CMYKOGB | Coated stock |
| 9 | offset | CMYKOGV | Coated stock |
| 10 | inkjet | CMYKOGV | Film |
| 11 | inkjet | CMYKOGV | Coated stock |
| 12 | inkjet | CMYKOGV | Film |
| 13 | electro-ink | CMYKOGV | Coated stock |

***Table 2:*** *Information of the printing conditions tested in this work.*

In the first step, the digital test target, consisting of 104 tone value combinations, is converted to the two references FOGRA55_v1 and v2 using the AtoB3 transformation (absolute colorimetrical) of the ICC profile built with CoPrA V.7 from ColorLogic. The resulting CIELAB (LABFOGRA55_v1 and LABFOGRA55_v2) are used as input values for further colour conversions involving the press profiles. The schematic description of the following colour conversion that took place is depicted in Figure 3. In this conversion, the aim is to reproduce the given reference colour values LABFOGRA55_v1 and LABFOGRA55_v2 separately with the given press profiles as colour correct as possible to the RPC, recognizing typical rules for production printing such as avoiding paper simulation. This conversion includes:

1. ICC transformation from CIELAB to 7C device coordinates with colorimetric rendering intent media relative (using the BtoA1 table)
2. ICC transformation from device values (from step 1) with colorimetric rendering intent absolute to CIELAB (using the AtoB3 table)

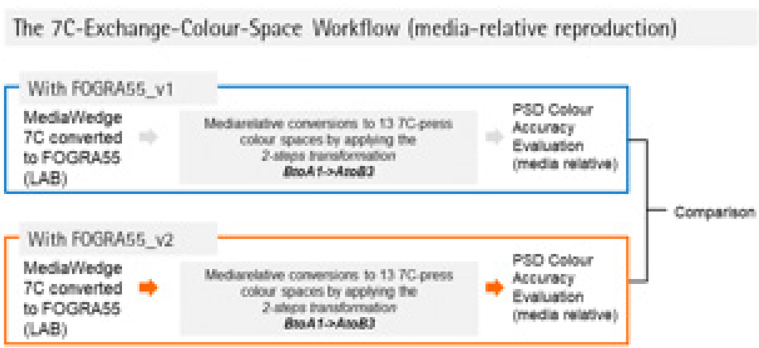


***Figure 3:*** *The schematic representation of the evaluation process. FOGRA55_v1 and FOGRA55_v2 were used as colour aims for the simulation separately, with the 13 press profiles as output profiles. The press profiles were created mostly by using CoPrA V.7 from ColorLogic.*

In the next step, the colour differences between the output colour values and the references LABFOGRA55_v1 and LABFOGRA55_v2 are calculated. In the end, the results of each reproduction are shown as the reached qualitative tolerance bands according to (10). Since in the simulated reproduction, the media relative rendering intend is applied, the corresponding colour accuracy evaluation method is used to determine the colour quality. Technically, a paper correction could be done by converting all press characterizations to predict the appearance of the print on a common agreed-upon substrate using SCCA (Substrate Corrected Colour Aims) - to then use the established side-by-side evaluation. Firstly, this algorithm is not accurate for large differences in paper tints. Secondly, such SCCA-data is not often found in the field of proof print creation, in which the proof print should be compared to the pertinent production print.

Apart from the numeric results of colour differences, the PSD quality level is also determined and listed in Table 3 and 4. Here the Quality Level A represents high print image quality and a high visual agreement between proof and production printing. Typical examples are large-format professional studio photos (fine art) or cardboard POP displays. Quality Level B describes a good print image quality combined with a good visual agreement between proof and production printing. Typical examples are banners and roll-ups. Quality Level C is identified with an acceptable print image quality and an acceptable visual agreement between proof and production prints (10). The better the reached quality level, the better the realisability of the colour aims.

Tables 3 to 5 contain the results of all IDs with both references, FOGRA55_v1 and v2. The overall results in Table 3 show an improvement feasibility with FOGRA55_v2. For the 5 IDs among the 13 printing conditions that already reached Quality A with FOGRA55_v1 as reference, the quality level is

maintained with FOGRA55_v2 as reference. Apart from these 5 IDs, all other IDs have reached a better quality level with FOGRA55_v2.

| | Quality level according to (10) | | Overall quality level with v2 is … |
|---|---|---|---|
| ID | FOGRA55_v1 | FOGRA55_v2 | |
| 1 | A | A | maintained |
| 2 | Failed | C | improved |
| 3 | B | A | improved |
| 4 | A | A | maintained |
| 5 | A | A | maintained |
| 6 | C | B | improved |
| 7 | A | A | maintained |
| 8 | B | A | improved |
| 9 | C | B | improved |
| 10 | C | B | improved |
| 11 | C | A | improved |
| 12 | Failed | C | improved |
| 13 | A | A | maintained |

***Table 3:*** *Resulting Media Relative quality levels when using FOGRA55_v1 or FOGRA55_v2 as a reference printing condition while aiming for a colour consistent output in 13 typical ECG printing conditions.*

The detailed results of the evaluations are documented in the following tables 4 and 5 for the relevant PSD criteria (10):

- Mean value of the colour differences in $\Delta E_{2000}$
- 95 quantile of the colour differences in $\Delta E_{2000}$

| | $\Delta E_{00}$ (95 Quantile) | | | | | |
|---|---|---|---|---|---|---|
| | Numeric result | | | PSD Quality Level | | |
| ID | F55_v1 | F55_v2 | Improvement with v2? | F55_v1 | F55_v2 | Quality level with v2 is… |
| 1 | 1,3 | 1,3 | No | A | A | improved |
| 2 | 3,3 | 2,7 | Yes | B | B | maintained |
| 3 | 1,9 | 1,3 | Yes | A | A | maintained |
| 4 | 1,4 | 1 | Yes | A | A | maintained |
| 5 | 1,3 | 1,1 | Yes | A | A | maintained |
| 6 | 2,2 | 1,7 | Yes | A | A | maintained |
| 7 | 1,4 | 1,2 | Yes | A | A | maintained |
| 8 | 1,8 | 1,4 | Yes | A | A | maintained |
| 9 | 2,4 | 1,6 | Yes | B | A | improved |
| 10 | 2 | 1,4 | Yes | B | A | improved |
| 11 | 1,9 | 1,4 | Yes | A | A | maintained |
| 12 | 3,4 | 2,9 | Yes | B | B | maintained |
| 13 | 1,4 | 1,2 | Yes | A | A | maintained |

***Table 4:*** *The comparison conducted according to (10) with evaluation method for media relative reproduction based on the mean colour differences.*

| | $\Delta E_{00}$ (95 Quantile) | | | | | |
|---|---|---|---|---|---|---|
| | Numeric result | | | PSD Quality Level | | |
| ID | F55_v1 | F55_v2 | Improvement with v2? | F55_v1 | F55_v2 | Quality level with v2 is… |
| 1 | 3,4 | 3,4 | No | A | A | maintained |
| 2 | 9,1 | 6,6 | Yes | Failed | C | improved |
| 3 | 5,4 | 3,3 | Yes | B | A | improved |
| 4 | 3,9 | 2,5 | Yes | A | A | maintained |
| 5 | 3,8 | 3,2 | Yes | A | A | maintained |
| 6 | 7,4 | 4,3 | Yes | C | B | improved |
| 7 | 3,3 | 2,9 | Yes | A | A | maintained |
| 8 | 5,2 | 3,1 | Yes | B | A | improved |
| 9 | 7,1 | 5 | Yes | C | B | improved |
| 10 | 7,7 | 5,1 | Yes | C | B | improved |
| 11 | 7,7 | 4 | Yes | C | A | improved |
| 12 | 12,8 | 8,3 | Yes | Failed | C | improved |
| 13 | 3,4 | 2,7 | Yes | A | A | maintained |

***Table 5:*** *The comparison conducted according to (10) with evaluation method for media relative reproduction based on 95 quantile values of colour differences.*

As indicated as well in Figure 4 and expected due to the slightly reduced chroma of the OGV aims, the reference FOGRA55_v2 can be achieved with smaller colour differences for almost all IDs with the simulated media relative reproduction. Hence, the improved FOGRA55_v2 is more suitable than the previous version FOGRA55_v1.

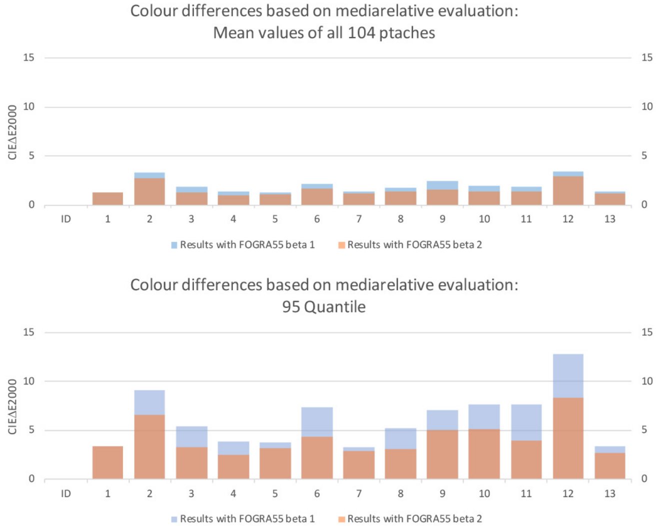


***Figure 4:*** *The improvement of results with FOGRA55_v2 based on comparison conducted according to (10) with evaluation method for media relative reproduction.*

## Experiment 3: consistency across different printing conditions with FOGRA55-Workflow

To further investigate the improvement with FOGRA55_v2 as exchange colour space regarding the consistency across the 13 ECG systems, the following comparison is made based on the MCDM (mean colour differences to mean) evaluation. The MCDM value is used as an indicator for the variations among the reproduction within the 13 IDs. The smaller the MCDM values, the better the consistency among all IDs.

The MCDM values are calculated respectively for the 3 ICC transformations to simulate the following workflows. The target used for this experiment is the MediaWedge RGB (3) with 126 tone value combinations as shown in Figure 5, assigned with an AdobeRGB profile as its source colour space, since AdobeRGB is one of the most commonly used RGB source colour space in high quality pictorial contents in the graphic industry. The simulated workflows are:

1. Direct output in which the RGB-images are reproduced with direct mapping to each of the device spaces with the perceptual rendering intent.
2. Media relative colour reproduction with FOGRA55_v1 as reference, in which the RGB-images are firstly transformed to the reference colour space, before the media relative process conversion toward the press profile takes place.
3. Media relative colour reproduction with FOGRA55_v2 as reference with steps analog to workflow 2.

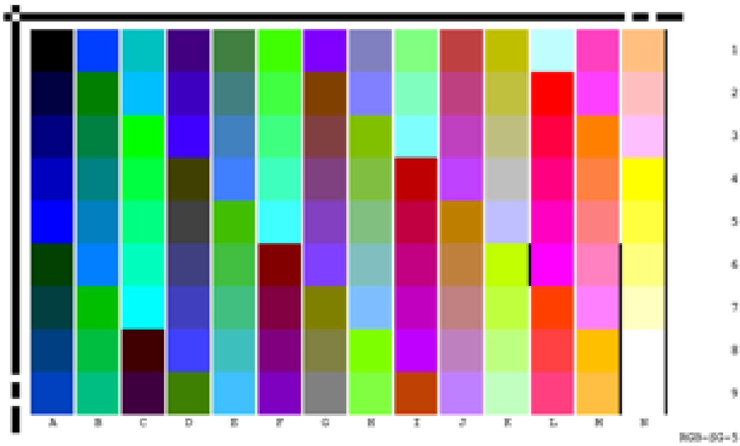

***Figure 5:*** *The selected testform for colour accuracy evaluation: the Fogra MediaWedge RGB V0, short as MWRGB (3).*

The actual ICC transformations applied for each of the 13 IDs were schematically depicted in Figure 6. The outcomes of this experiment are 13 colour reproduction results for each of the three workflows, which are stored as lists of CIELAB values (for 126 patches) and used for further evaluation.

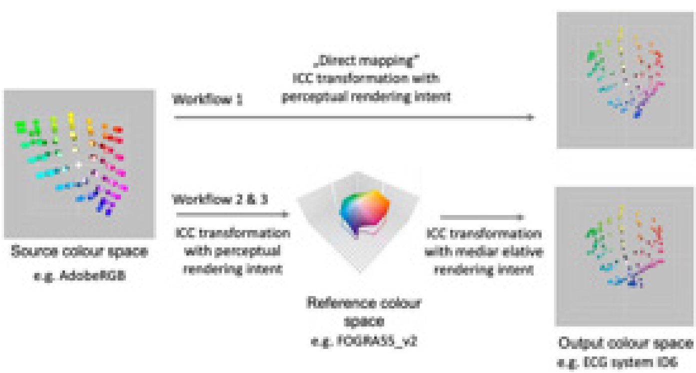


***Figure 6:*** *Schematic representation of the ICC transformations applied with each of the ECG systems (IDs). In most common print productions, the ICC transformation between reference to output space is often conducted with the rendering intent media relative and BPC (Black Point Compensation). In this experiment, the usage of the media relative transformation seems sufficient as presenting an exemplary difference between the mentioned different reproduction methods.*

Based on the reproductions in colorimetrical values (CIELAB values), for each patch of the MWRGB, one MCDM value is calculated respectively for each of the workflows. The mean values over all 126 patches are summarized in Table 6 and shown in Figure 7, while the detailed results of each IDs are shown in Figure 8, in which the relative probability of the colour differences is shown and the graph indicates the distributions of feasible colour differences with the respective workflows.

| | MCDM (in $\Delta E_{00}$) across 13 IDs | | |
|---|---|---|---|
| Workflow | Mean | 95 quantile | Max |
| 1 | 1.4 | 2.5 | 3.1 |
| 2 | 1.4 | 2.1 | 2.3 |
| 3 | 1.4 | 1.9 | 2.4 |

***Table 6:*** *Average MCDM of all IDs for defined workflows.*

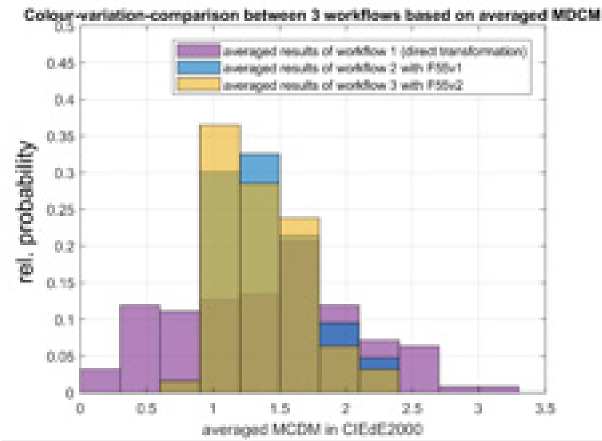


***Figure 7:*** *Colour variations comparison of the mean MCDM for defined workflows: direct reproduction with press profiles, media relative reproduction with FOGRA55_v1 and FOGRA55_v2 as reference.*

As shown in Figure 7, the distribution of the results of workflow 2 and 3 is skewed to the right with the centre at 1.5 and 1 respectively, while the distribution of the results of workflow 1 is rather symmetric. The detailed results in Figure 8 show that compared to workflow 1, the spread of colour differences across the 13 IDs in workflow 2 and 3 is smaller, 0-9 and 0-8 respectively.

This experiment shows that with workflow 2 and 3, in which either versions of FOGRA55 is used as RPC, smaller colour variations can be achieved across different output processes than workflow 1. The result of workflow 3 is slightly better than workflow 2, which confirms the improvement due to the adjustment in FOGRA55_v2.

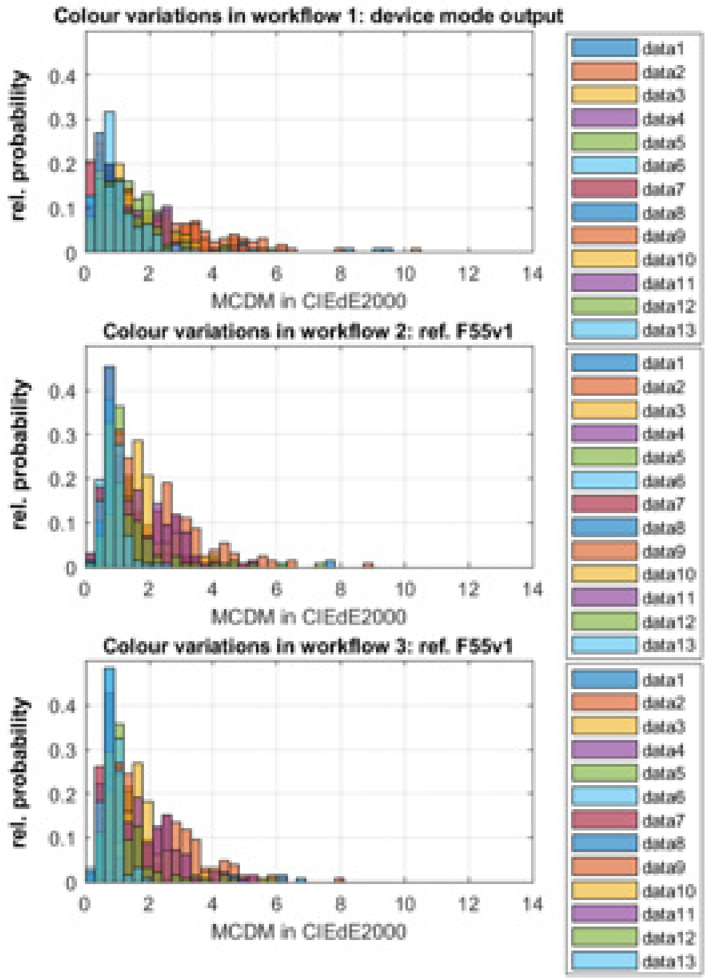


***Figure 8:*** *Colour variations results of all 13 IDs for each of the 3 workflows: direct output with press profiles, media relative reproduction with FOGRA55_v1 and FOGRA55_v2 as reference.*

## Conclusion

It has been shown that in spite of the slightly reduced gamut, the revised and final aim values for Orange, Green, and Violet better suit the anticipated use case. Although FOGRA55 is designed to be process agnostic, having more realisable aims helps to improve colour communication between print buyers and print service providers by closer meeting the design intent. In addition, using FOGRA55 as a RPC allows to better balance the tradeoff between colour predictability and accuracy versus using device capabilities (e.g. full gamut and tonal range). Now print service providers have a fair and realistic chance to match rich artwork (FOGRA55 7C, e.g. by using PDF/X-5n or 6n) on their ECG-like- presses - Printing the Expected.

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