Goals of an *Ergonomic and Sustainable Image Technology (ESIT) for Colour Images* by an *Expert Group(EGIT)* for Applications in Regulations, in Standards, and in Hardware and Software.

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1 Introduction

The EGIT is an international group of colour scientists, and consists at present of only a few members. The expert knowledge is interdisciplinary in the colour areas of physiology, psycho-physics, image technology, ergonomics, colourimetry, design, architecture, and art. The EGIT proposes ergonomic and sustainable solutions for important user applications in colour image technology.

1.1 Basic goal of standard organisations (BGSO) for ergonomics and sustainability

Many Standard Organisations, for example the ISO, have now the goal to increase the net benefit of the users by their standard documents. Especially ergonomic and sustainable goals are supported, see for example https://www.iso.org/committee/53348.html and https://www.iso.org/standard/76913.html

These goals seems to fail in two example cases, which are presented shortly in the following. Therefore the EGIT has started activity with this document.

1.2 Basic goal of the EGIT

1. Make proposals for an ***Ergonomic and a Sustainable Image Technology (ESIT).***
2. A Regulation Authority (RA), for example of the EU, may consider the proposal and may start activity for solutions.

1.3 Members and activity of the EGIT and knowledge exchange

1. Members shall have a wide interdisciplinary colour knowledge or shall support this area.
2. For example the TUB-server http://color.li.tu-berlin.de/index.html includes interdisciplinary knowledge in image technology and colourimetry since 25 years.
3. The knowledge of the EGIT is presented and exchanged in video meetings about four times a year.
4. The registration for interested colour experts is free, see under *Intended workshops and presentations in 2022 on* http://color.li.tu-berlin.de/XY91FEN.html

2. Colour loop with light and surface colours in image technology (CLIT)

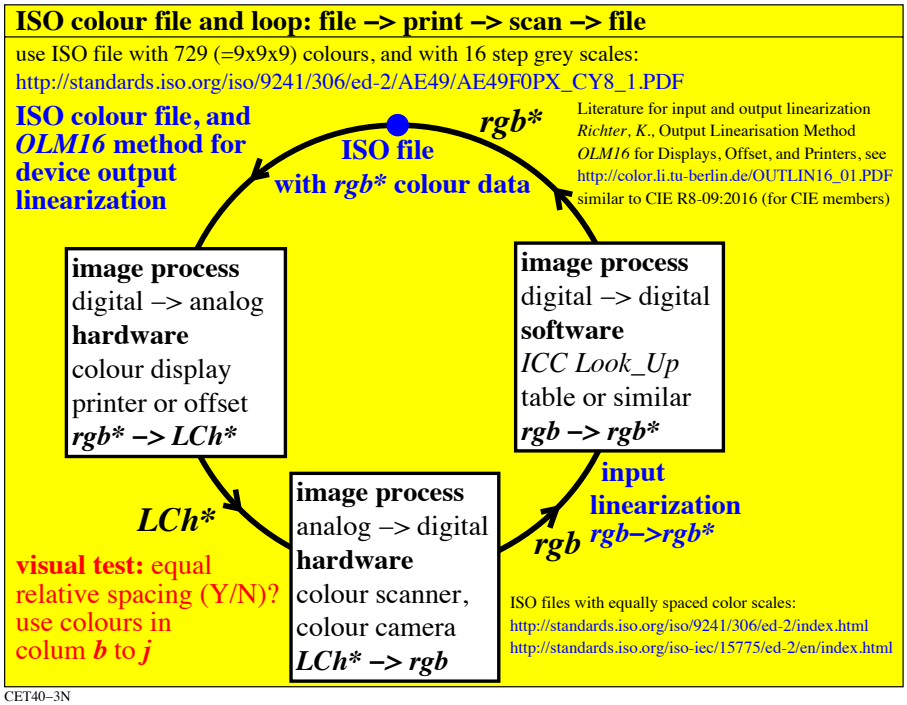

Figure 1: Colour loop: ISO file -> digital-analog transfer -> analog-digital transfer -> ISO file.
For the download of this figure, see http://color.li.tu-berlin.de/CET4/CET40-3N.PDF
In information technology, digital and analog ISO-test charts are used to realize the colour loop of Figure 1.

The *rgb** colour data in an ISO file shall be approximately equal for each software and hardware combination at the end of the loop compared to the beginning of the loop. There are technical solutions to reach this goal. However, in two examples cases for the print and display output the industrial interests seem to conflict with ergonomic and sustainable requirements.

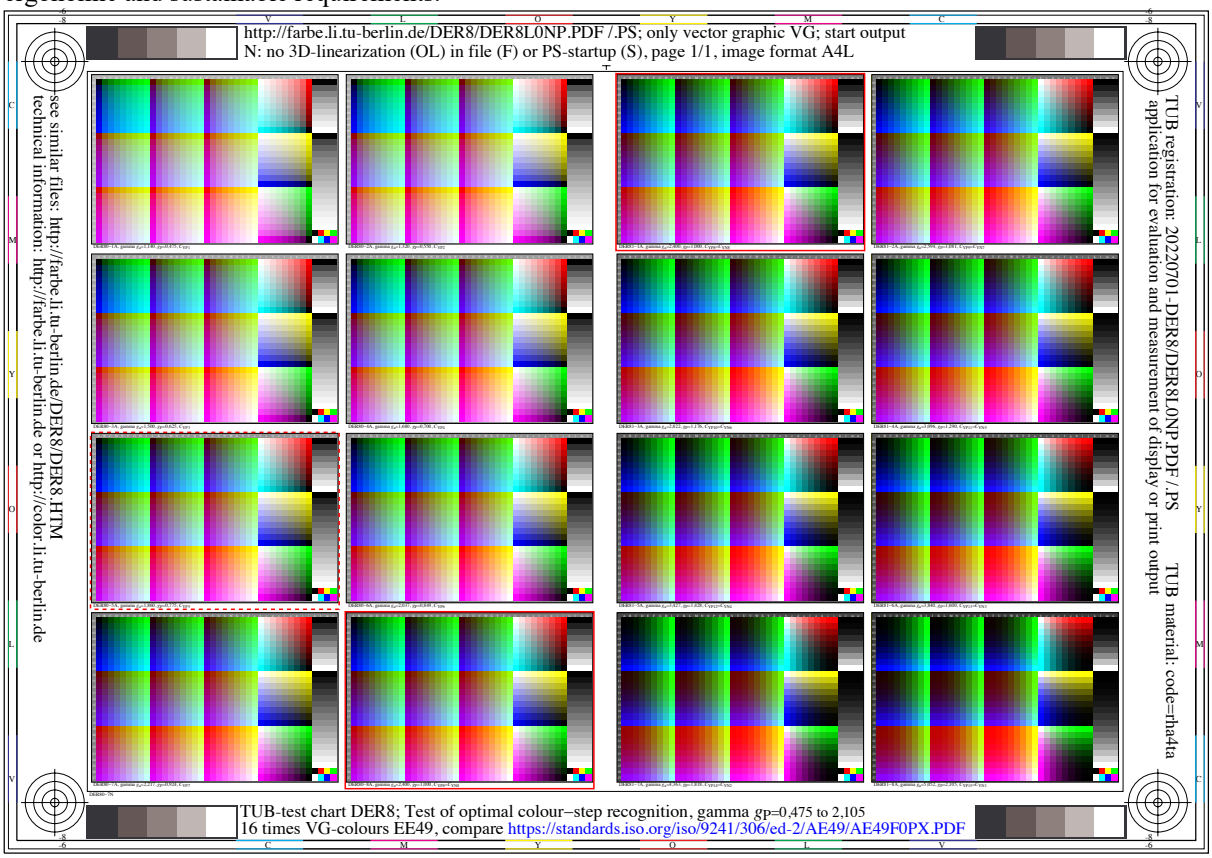

Figure 2: Equally spaced colour series in *rgb and their visual reproduction with 16 gamma values according to ISO 9241-306:2018.**
For the download of this figure, see http://color.li.tu-berlin.de/DER8/DER8L0NP.PDF
Figure 2 shows 1080 colour samples according to ISO CEN DIN 9241-306:2019. The 16 images differ by the absolute gamma values approximately in the range $1{,}2 <= g <= 4{,}8$ or the relative gamma values $0{,}5 <= g_P <= 2$ The *rgb* data in the files change by the equation $rgb' = rgb^g$. In a wide range of use cases only one special gamma value *g* produces an ergonomic output.

Visually in the left first image the difference of the dark grey steps is large and in the right last image many dark steps cannot be distinguished. For the display or the print output only one of the 16 images show approximately the ergonomic equally spaced output.

Example case 1: Print output of ISO CEN DIN 9241-306/ed-2:2019 according to ISO/IEC 15775 (in print)
Visually four of the 16 grey steps cannot be distinguished in the DIN print of ed-2:2019. However, all 15 differences of the ISO print of 2008 are approximately equal as intended. The colourimetry calculates the regularity index *g** according to ISO/IEC 15775, Annex G. For the print of 2019 it is valid $g^*=0$ and for the print of 2008 it is valid $g^*=90$. The value 90 indicates approximately that one difference is by 10% smaller compared to the other similar step differences ΔL^* in CIELAB.

Conclusion: The print of 2019 is NOT ergonomic and in addition NOT sustainable because the very dark output of 2019 needs more toner material compared to the ergonomic output. ISO/IEC 15775 has an ISO sustainable label, see https://www.iso.org/standard/76913.html.

Regulation authorities may look for a sustainable output. The hardware and software shall fulfill the requirements for the output according to ISO/IEC 15775.

Remark: ISO/IEC 15775 includes in addition the print requirement 100% UCR technology. This technology uses for the print of grey colours only the achromatic toner black. For sustainability it is for example not allowed to overprint the three toners CMY for the print of black N. This produces for users a threefold material consumption. For example by spectral measurements of the reflection of mean grey the increase of the material consumption can be determined.

Example case 2: Display output according to ISO 9241-306:2018 on HDR and sRGB displays
ISO 9241-306 includes many ISO-files for the display output with output questions, see https://standards.iso.org/iso/9241/306/ed-2/AE49/AE49.HTM
The ISO files include the 1080 colours with 15 different gamma values on 16 pages. Fig. 1 includes the 16 gamma values on one page.

The gamma value of any High Dynamic Range (HDR) display is larger compared to the gamma value of the standard display sRGB according to IEC 61966-2-1. Therefore an HDR image or a HDR video produces visually many dark steps on the standard sRGB display, in a worse case similar to the last image in Fig. 2. This HDR image output is therefore NOT an ergonomic output on the sRGB display.

Solution: The two editions of ISO 9241-306:2008 and ed-2:2018 describe as example a gamma slider of the *macOS* operating system, see Fig. 2 of http://color.li.tu-berlin.de/index.html. With this slider it seems possible to produce for any HDR image or any HDR-video production an ergonomic output. However, since *macOS 12.3.1:2022* the gamma slider is deleted.

Effects of the slider deletion, possible development goal, and proposal for applications according to ISO 9241-306
1. If there is no alternate solution by the *macOS* operating system, then for the intended ergonomic output according to ISO 9241-306 the user has to buy new hardware.
2. After 20 years the slider-software is deleted on macOS. A reason may be an assumption of the manufacturer to sell more HDR products for the new special HDR productions..
3. The delete of the slider-software solution produces many difficulties for many applications on the display work places according to ISO 9241-306. The well-being and the health of the display users is not any more supported. This shall be considered by the manufacturer.
4. In addition, there seems to be no advantage to use the HDR display technology for the wide use cases in offices and at home according to the ergonomic standard ISO 9241-306, see later for the technical reasons.
5. A reinstallation of the slider-software may allow to use HDR displays. For this the luminance shall be reduced according to the requirements of ISO 9241-306. A reduce of the luminance will reduce the energy consumption and increase sustainability.

Technical background and unsolved questions about the value of the HDR technology for the use case according to ISO 9241-306

1. Luminance and lightness of HDR and sRGB displays
The visual system is mainly optimized by the varying spectral reflections $R(\lambda)$ of surface colours in nature. For the visual contrast threshold the value is ΔR=0,05, see http://cie.co.at/eilvterm/17-31-019. This is equivalent to $R / \Delta R = L / \Delta L = 20$. For surface and sRGB colours the visual window is between about R_N=0,025 for black N (=noir) and R_W=0,900 for white according to ISO 9241-306. This leads to $R / \Delta R = L / \Delta L = 36$.
It is important that this value is *independent* of the display luminance L according to the *Weber-Fechner* law and therefore also valid for HDR displays. Therefore the discrimination on HDR displays is NOT increasing.

According to ISO 9241-306 and for sRGB displays it is valid for the luminance of the white screen L_W=142 cd/m^2 and for the black screen L_N=4 cd/m^2. For HDR displays the peak luminance may be by a factor 5 larger compared to sRGB displays. However, this large luminance produces is NOT recommended in ISO 8995-1 and produces fatigue. There is a risk to reduce the well-being and health of the users.

The HDR luminance of the display white shall therefore be reduced to L_W=142 cd/m^2. This decreases the energy consumption and increases sustainability. At the work place in offices the lightness range is by colorimetry not larger for HDR compared to sRGB displays.

2. Chroma of HDR and sRGB displays
The ICC colour profiles according to ISO 15076-1 use the CIELAB system according to ISO/CIE 11664-4:2019 for colour management. This seems not appropriate for yellowish monochromatic colours on the spectral locus. This may happen for HDR displays. For most yellowish monochromatic colours between the monochromatic green and the red for CIELAB undefined chroma values appear or extreme chroma differences. The visual chroma values and differences are therefore much smaller than calculated according to ISO/CIE 11664-4, see some examples in Fig. 23 and Fig. 24 on the page http://color.li.tu-berlin.de/DEA_S.HTM
For a WCG display the Fig. 23 shows the chromatic values (A_2, B_2) of the *TUB relativity model of colour vision.* Fig. 24 shows the CIELAB chroma values *(a*, b*).* The chroma values for a high contrast >36:1 and a low contrast 2:1 are shown. An increase of the chroma b^* is visible near the yellowish spectral locus compared to B_2.

Therefore any company message of a much larger CIELAB chroma of HDR displays compared to sRGB displays may be an error. There is an error according to ISO/CIE 11664-4 for all monochromatic yellowish colours near the spectrum locus. The surface colour are usually located more within the chromaticity diagram and the error is then reduced.
Technical remark: The colours of all colour pairs *R-C, Y-B*, and *G-M* have approximately the same antagonistic chromatic values C_{A2B2}. The antagonistic data A_2 and B_2 mix to the white of D65 with A_2=0 and B_2=0 as intended. This is not the case for the CIELAB data a^* and b^*.

3. Summary: Value of the HDR technology for the ergonomic output according to ISO 9241-306 and for sustainability
The recommended luminances of both the display and the paper are equal at the display-work places according to ISO 9242-306. The visual system adapts to the recommended office illuminance I=500 lux. The reflectance R_Z=0,18 of grey Z, R_W=0,9 of white W and R_N=0,025 of black N are recommended in offices. The luminance L is calculated by the formula $L=I\,R/3{,}14$. This formula calculates the luminance L_Z=28 cd/m^2, L_W=142 cd/m^2, and L_N=4 cd/m^2.

If the recommended office illuminance according to ISO 8995-1 is increased by a factor 5 (not recommended), then the three luminance of grey, white and black increase by the same factor. The visual appearance of the colours grey, white and black remains equal by the colour constancy rule. This is similar for chroma and lightness which are calculated in the CIELAB space. This is also similar, if the analog ISO-test charts are used in nature. In nature the illuminance may increase between a cloudy day and a sunshine day with blue sky a factor 5.

Therefore for a wide range of applications in offices and in nature there seem to be no advantage of HDR displays compared to sRGB displays. In addition the sustainability decreases for HDR displays because the energy consumption may increase proportional to the display luminance.

Most of the sRGB displays on the market seem to fulfill the requirement of L_W=142 cd/m^2 for the white display. This luminance corresponds to the recommended illuminance I=500 lux in offices according to ISO 8995-1. There seem to by no advantage to use HDR displays. At present several HDR displays may produce luminance which is by a factor 5 larger compared to sRGB displays.

Conclusion for the print output
For the use case of print work place in offices, at home or in the “on demand” printing area the print output often fails to agree with the ergonomic and sustainable requirements according to ISO/IEC 15775. The print of ISO CEN DIN 9241-306:2019 is one example.

Conclusion for the display output
For the use case of display work place in offices or at home there is visually approximately no increase of chroma and lightness of the present HDR displays compared to sRGB displays. The higher energy consumption and the expected fatigue of users which may work under the NOT recommended high luminance of HDR displays fails to agree with the ergonomic and sustainable requirements according to ISO 9241-306, ISO/IEC 15775, and ISO 8995-1.

General conclusions, solutions and possible activities
1. For example under macOS a revision of the slider deletion or an alternate solution is required for the many applications according to the ergonomic standard ISO 9241-306.

2. Any Standard Organization, for example the ISO, may compare HDR and sRGB projects. The projects shall be compatible with the ISO goal to increase the net benefit of the users. By ergonomic and sustainable reasons any standard organization may support software solutions which transfer HDR-production material by software for the standard sRGB output.

3. Any Regulation Authority, for example of the EU, seems to agree to the above ISO goal and may start activity in the area of Fig. 1 and 2.

4. Any user may report, if the visual output in print or on displays agrees with the standard requirements.

5. Any user may buy printer or display systems with hardware and software according to the ergonomic and sustainable standards ISO 9241-306 and ISO/IEC 15775.

The above conclusions are limited for the wide range of use cases at work places and in nature as described in this paper and the above standards.