CIE info day
Division 1 “Vision & Colour”

Kees Teunissen & Dragan Sekulovski
Philips Lighting, Research
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innovation + you

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Content

CIE Division 1: Vision & Colour

- General information : Kees Teunissen
- Vision Section : Dragan Sekulovski
- Colour Section : Kees Teunissen

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General Information

CIE Division 1: Vision & Colour

General

- Terms of Reference
  - To study visual responses to light and to establish standards of response functions, models and procedures of specification relevant to:
    - photometry,
    - colorimetry,
    - colour rendering,
    - visual performance and
    - visual assessment of light and lighting.

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cie
CIE 2017
CIE 2017 Midterm Meeting
October 20-28, 2017 / Ramada Plaza Jeju, Korea
"Smarter Lighting for Better Life"
"Smarter Lighting for Better Life"
CIE 2017
Midterm Meeting
October 20-28, 2017 Jeju, Korea
"Smarter Lighting for Better Life"
CIE 2017
Midterm Meeting
October 20-28, 2017 Jeju, Korea

CIE Division 1 representatives

CIE Division 1: Vision & Colour

Technical Committees

1. 1-63 Validity of the Range of CIE DE2000
2. 1-76 Unique Hue Data
3. 1-81 Validity of Formulae for Predicting Small Colour Differences
4. **1-83 Visual Aspects of Time-Modulated Lighting Systems**
5. **1-84 Definition of Visual Field for Conspicuity**
6. 1-85 Update CIE Publication 15:2004 Colorimetry
7. 1-86 Models of Colour Emotion and Harmony
8. **1-88 Scene Brightness Estimation**
9. **1-89 Enhancement of Images for Colour Defective Observers**
10. **1-91 Methods for Evaluating the Colour Quality of White-Light Sources**
11. 1-92 Skin Colour Database
12. **1-93 Calculation of self-luminous neutral scale**
13. 1-95 The Validity of the CIE Whiteness and Tint Equations
14. 1-96 A Comprehensive Model of Colour Vision
15. **1-97 Age- and Field-Size-Parameterised Calculation of Cone-Fundamental-Based Spectral Tristimulus Values**
16. **JTC 01 (D1/D2/D4/D5) Implementation of CIE 191:2010 Mesopic Photometry in Outdoor Lighting**
17. **JTC 07 Discomfort Caused by Glare from Luminaires with a Non-Uniform Source Illuminance**

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Reporterships

	Title	Reporter
DR 1-68	**A Gamut Area Measure and Colour-shift Graphic, based on CIE 13.3-1995**	**Kees Teunissen**
DR 1-66	The Effect of Dynamic and Stereo Visual Images on Human Health	Hiroyasu Ujike
DR 1-65	Categorical colour identification	Taiichiro Ishida
DR 1-63	Tristimulus integration	Li Changjun
DR 1-64	Real colour gamut	Li Changjun
DR 1-62	Typical LED spectra	Sophie Jost
DR 1-61	Source whiteness metric	Aurelien David
DR 1-60	Future colour-difference evaluation	Guihua Cui
DR 1-58	Liaison with ISO TC130 Graphic Technology	Phil Green
DR 1-53	Gloss Perception and Measurement	Frédéric Leloup
DR 1-67	Revisiting Correlated Colour Temperature	Youngshin Kwak

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Research Fora

- Each Division Director may, with the approval of the Division, create a Research Forum (RF) the function of which is to facilitate ongoing knowledge exchange and research.
- The function of the RF will be achieved by offering the opportunity for researchers to discuss ideas and exchange data on a given scientific or technical topic that is not considered within a current TC or Reportership.

- **Research Forum** - A practicable approach for the evaluation and specification of colour rendition properties of white-light sources. Convenor: Kees Teunissen NL → "**Matters relating to specifying colour rendition of white-light sources**"

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CIE Division 1: Vision & Colour

Publications

1. CIE TN 007:2017: Interim Recommendation for Practical Application of the CIE System for Mesopic Photometry in Outdoor Lighting
   - *This Technical Note defines the method for **calculating the adaptation coefficient** to be used in conjunction with the equations of the mesopic photometry system defined in CIE 191:2010 (CIE, 2010), which describes the recommended system for mesopic photometry and is based on visual performance. It provides the recommended **method for calculating the spectral luminous efficiency function** for mesopic vision and the associated mesopic quantities and is intended to be applicable to outdoor lighting for drivers, motorcyclists, cyclists and pedestrians.*
   - http://files.cie.co.at/934_CIE_TN_007-2017.pdf
2. CIE 224:2017: CIE 2017 Colour Fidelity Index for accurate scientific use

➢ The new fidelity index for accurate scientific use is **not** a replacement for the general colour rendering index (R_a)!

Vision Section

CIE Division 1: Vision

(J)TCs/Reporterships in Vision Section

- **TC1-83** Visual Aspects of Time-modulated Lighting Systems
- **TC1-84** Definition of Visual Field for Conspicuity
- **TC1-88** Scene Brightness Estimation
- **TC1-89** Enhancement of Images for Colour Defective Observers
- **TC1-93** Calculation of Self-luminous Neutral Scale
- **TC1-97** Age- and Field-Size-Parameterised Calculation of Cone-Fundamental-Based Spectral Tristimulus Values
- **JTC 1 (D1/D2/D4/D5):** Implementation of CIE 191:2010 Mesopic Photometry in Outdoor Lighting
- **JTC 7 (D3/D1):** Discomfort caused by glare from luminaires with a non-uniform source luminance
- **JTC 8-cont (D1/D2/D3/D4/D5/D6/D8):**Terminology in light and lighting
- **R1-66** The effect of dynamic and stereo visual images on human health

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TC1-84 Definition of Visual Field for Conspicuity **Nana Itoh JP**

- A TC meeting was held in Jeju
- Revised WD will be delivered within a month to TC members. Hope to move on TC Ballot by the end of this year.

[Request for Division 1 – extension of TC activity]

- – The TC was approved by Division 1 to extend its activity to 2019, with the following ballot results:
- – Against: 0 Abstention: 0 In favour: 19

It is a very important topic with an unfortunate title. If anyone is interested in visibility of signage or similar problems, please contact Nana, she has more time now but she still needs more (active) people!

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TC1-88 Scene Brightness Estimation: **Yoshiki Nakamura JP**

- A TC meeting in Jeju was canceled. Following items are ongoingly considered by members.
  - Experiments on scene brightness carried out by members were explained and the results of them.
  - Outline of TC report was discussed and generally agreed.
- Some members were roughly assigned to write some part of the report

Not much is happening in this TC at the moment, but the usage of luminance/spectral image for brightness estimation and possibly glare is probably the future.
This opinion was also shared by Prof. Akashi during the very successful workshop on glare during the CIE conference.

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TC1-89 Enhancement of Images for Colour Defective Observers:
Po-Chieh Hung US

- A TC (Web) was held on: Nov. 21 in 2016, Mar.1 in 2017.
- A TC meeting was held in Jeju,
- Sent several comments to JTC-8 to change ILV DIS
- Clearance of copyright, many figures are used from prior publications
- Finalize the above items and start to vote on the draft within 2017.

Po-Chieh has been pulling this one like a locomotive! Very active with many meetings, should produce a TR soon. If you are interested in color deficient observers, look out for a NC vote soon.

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TC1-93 Calculation of Self-luminous Neutral Scale: **Robert Carter US**

- A TC meeting was held in Jeju
- The Committee Draft report has been edited by Division 1 editor and by CIE Central Bureau editor.
- Whittle's 1992 formula is recommended for grey scale (matching, thresholds, equal perceptible differences, similarity) on self-luminous devices.
- Substitutions successful in CIELAB, CIEDE2000, OSA-UCS - Related publications by Oleari, Melgosa and others

The TC is coming to an end soon, still to see how to apply the output of the TC, specially for lighting.

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TC1-97 Age- and Field-Size-Parameterised Calculation of Cone-Fundamental-Based Spectral Tristimulus Values: **Jan Henrik Wold NO**

- TC meeting was held in Jeju
- The output of the TC will be a TR together with a number of software components that can produce Age and Field Size parameterized tristimulus values (CIE 2006 photometry)
  - Standalone program in Python
  - Web interface
  - Matlab library

The TC has had some trouble with finding active members beside the chair. The python program is done and in beta distribution. The TR should be in WD in 2019. Move to new basic colorimetry is needed but will result in quite a stir.

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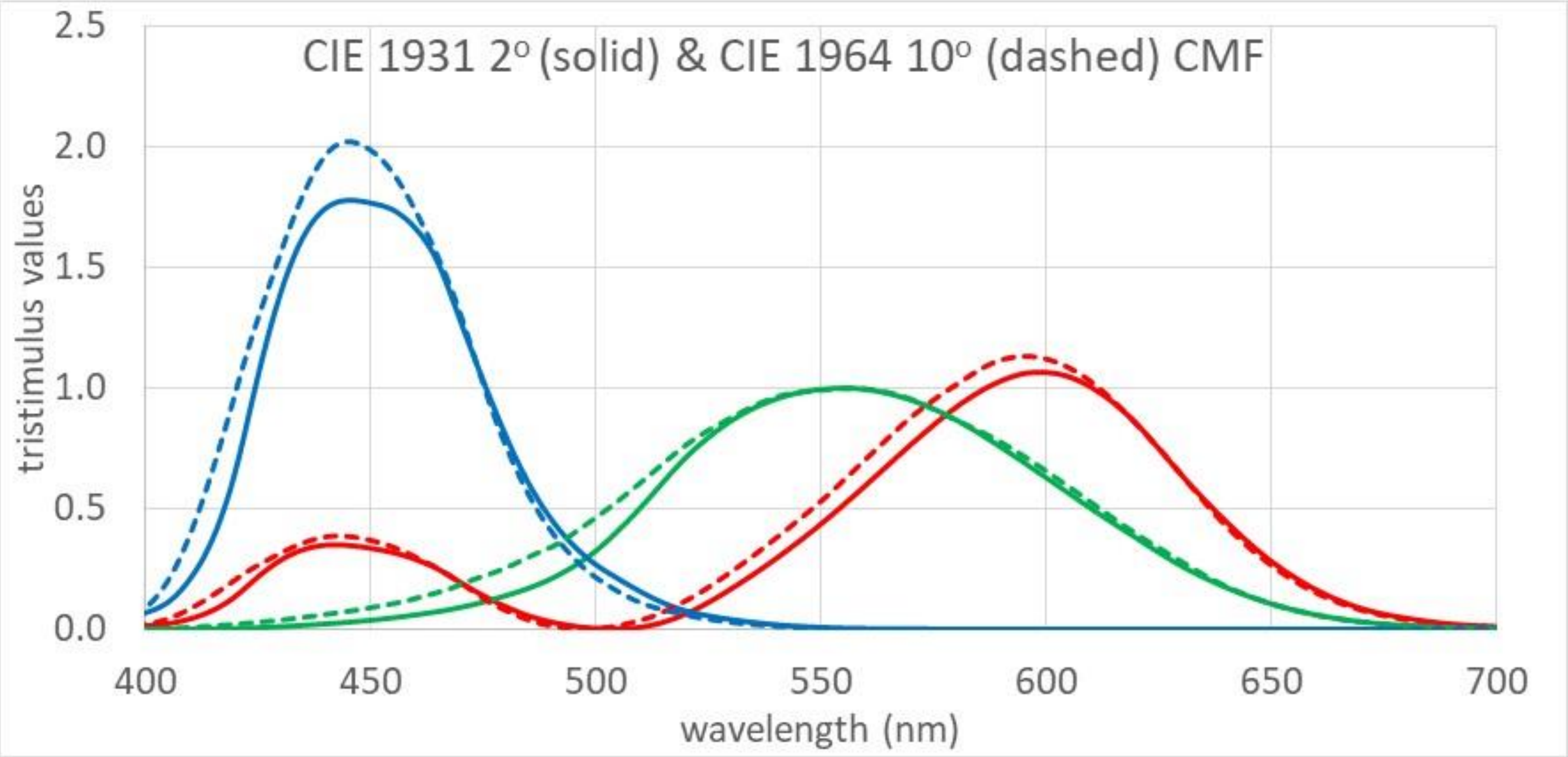
TC1-97 CIE-170: cone-fundamental-based tristimulus functions



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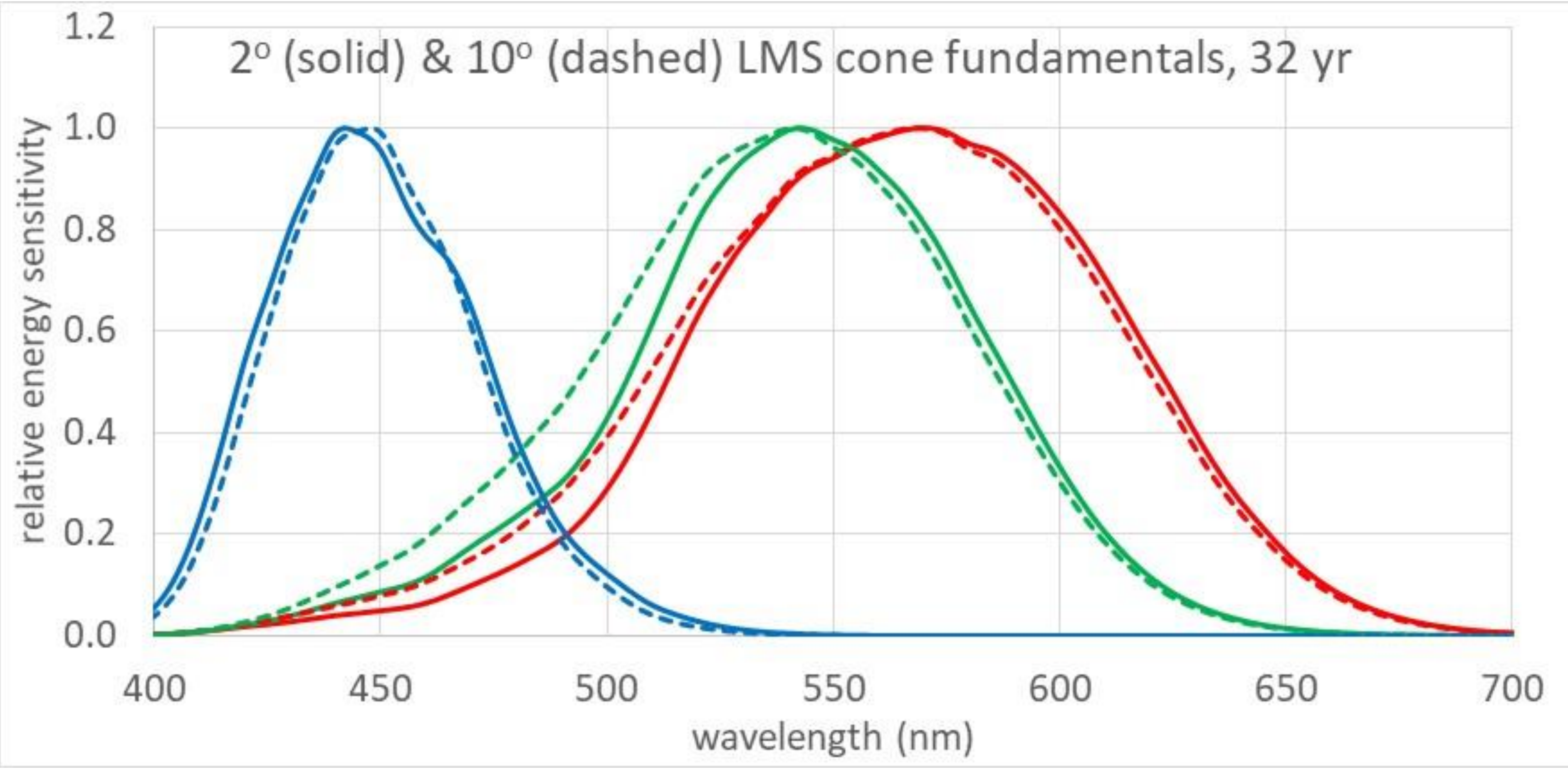
TC1-97 CIE-170: cone-fundamental-based tristimulus functions



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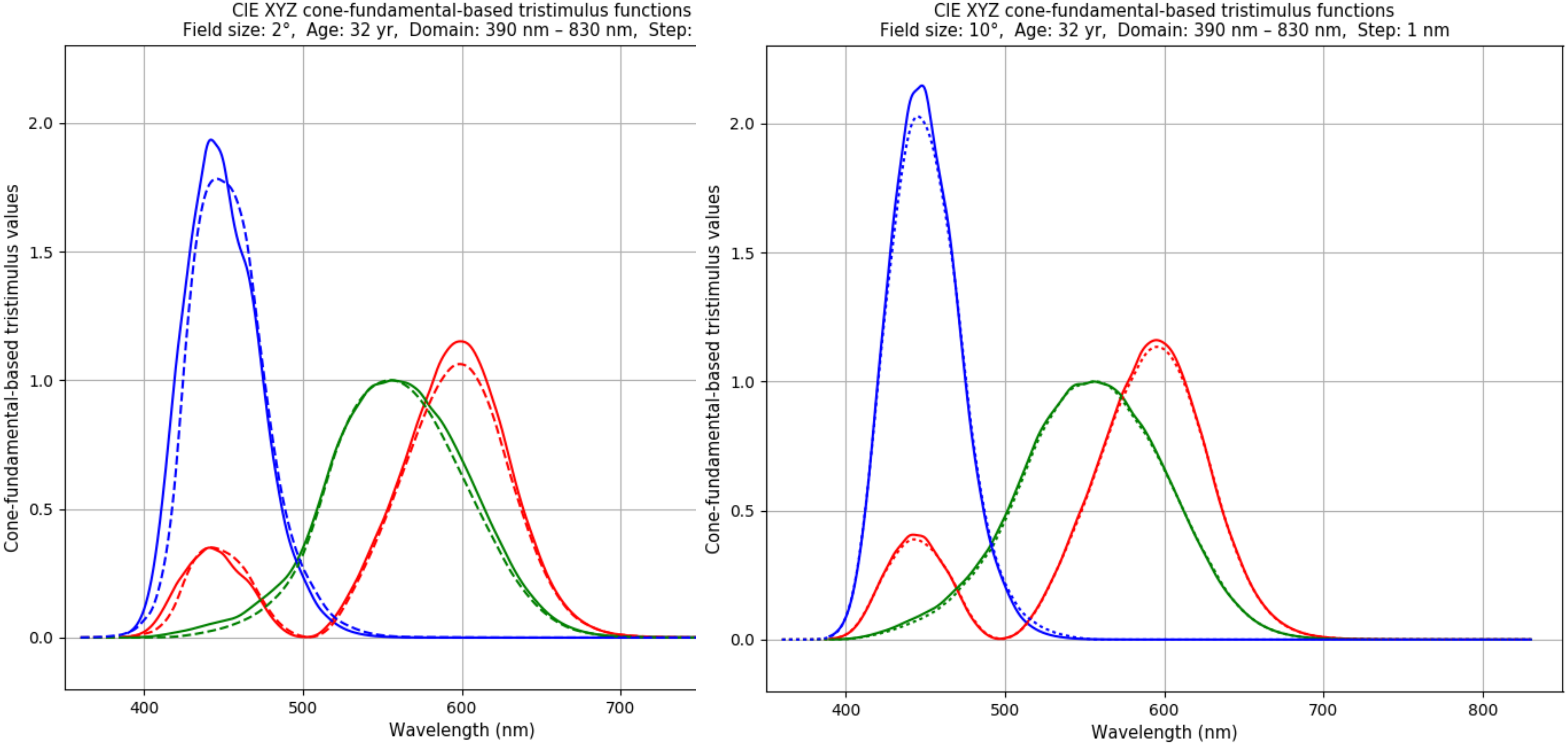
2006 cone-fundamental-based tristimulus functions versus CIE 1931 2-deg functions (left), and CIE 1964 10-deg functions (right)



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JTC-1 Implementation of CIE 191: Mesopic Photometry in Outdoor Lighting: **Stuart Mucklejohn GB**

- TC (WEB) was held on Jan.1, June7, Sep.27, Oct.27 in2017
- TC meeting was held in Jeju
- JTC was split in two WG
  - **WG 1** (**Tatsukiyo Uchida JP**): To investigate adaptation and viewing conditions and define visual adaptation fields in outdoor lighting.
  - **WG 2** (**Stuart Mucklejohn GB**): To define lighting applications where mesopic photometry could be used; To provide guidelines for implementing mesopic photometry in outdoor lighting.

*This JTC had a lot of changes in organization. WG2 has decided to give interim results as a TN (**CIE TN007:2017**).*

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JTC-7 Discomfort Caused by Glare from Luminaires with a Non-Uniform Source Illuminance: **Co-chairs: Naoya Hara JP, Yukio Akashi JP**

- TC (WEB) was held on: Dec.2016, Feb.2017, Sep. 2017
- TC meeting was held in Jeju
- 4th WD was balloted in the JTC. Revised WD will delivered to CIE Central Bureau in Apr.2018
- The proposal for fixing UGR is not to fix it, but apply it only on surfaces with a luminance larger than 500 cd/m²

Probably the most exciting of the vision related TC/JTCs. (Un)fortunately the members of the JTC quite easily came to a joined proposal for a fix on UGR in the Jeju meeting.

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TC1-83 Visual Aspects of Time-modulated Lighting Systems:

Dragan Sekulovski NL

- A TC meeting was held in Jeju
- **TN 006:2016** "Visual Aspects of Time-Modulated Lighting Systems – Definitions and Measurement Models"
  - The Technical Note got quite some interest! The definitions get more and more often used, as do the recommended measures (NEMA 77, Energy Star)
- Direct and indirect view ghosting experiments in China, links to spatial vision
- Ghosting and color breakup experiments in Korea
- Proposal for a ghosting model from the UK
- Study on the probability of detection of the stroboscopic effect other than the 50% visibility threshold
- Workshops on TLM and TLA were held in Jeju.
- Further validation of the time domain model for flicker will be considered in the Netherlands.

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Temporal Light Artifacts and temporal light modulation in general

- Besides **TC1-83**, there is rising interest in temporal light modulation issues.
- In February 2017 in Canada! there was a workshop on standardization of issues related to TLMs and produces a TN: **CIE TN 008:2017**
- New (Cross Division) Research Forum on Temporal Light Modulation beyond visual effects (convener: **Jennifer Veitch CA**)

Definitions

temporal light artefact

TLA

change in visual perception, induced by a light stimulus the luminance or spectral distribution of which fluctuates with time, for a human observer in a specified environment

Note 1 to entry: The change of visual perception is a result of comparing the visual perception of the environment lit by the modulated light to the visual perception of the same person in the same environment, when the environment is lit by non-modulated light.

flicker

perception of visual unsteadiness induced by a light stimulus the luminance or spectral distribution of which fluctuates with time, for a static observer in a static environment

Note 1 to entry: The fluctuations of the light stimulus with time include periodic and non-periodic fluctuations and may be induced by the light source itself, the power source or other influencing factors.

Note 2 to entry: Flicker is a type of temporal light artefact.

Note 3 to entry: The definition given here is different from the current definition of "flicker" in the ILV (CIE, 2011, term 17-443). It is suggested to replace the definition in the ILV in its next revision by the one given here.

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Definitions

stroboscopic effect

change in motion perception induced by a light stimulus the luminance or spectral distribution of which fluctuates with time, for a static observer in a non-static environment

Note 1 to entry: The stroboscopic effect is a type of temporal light artefact.

EXAMPLE 1 For a square periodic luminance fluctuation, moving objects are perceived to move discretely rather than continuously.

EXAMPLE 2 If the frequency of a periodic luminance fluctuation coincides with the frequency of a rotating object, the rotating object is perceived as static.

phantom array effect

ghosting

change in perceived shape or spatial positions of objects, induced by a light stimulus the luminance or spectral distribution of which fluctuates with time, for a non-static observer in a static environment

Note 1 to entry: The phantom array effect is a type of temporal light artefact.

EXAMPLE When making a saccade over a small light source having a square periodic luminance fluctuation, the light source is perceived as a series of spatially extended light spots.

Definitions

static observer

observer who does not move her/his eye(s)

Note 1 to entry: Only large eye movements (saccades) fall under this definition. An observer that only does involuntary micro-saccades is considered static.

static environment

environment that does not contain perceivable motion under non-modulated lighting conditions

Other definitions

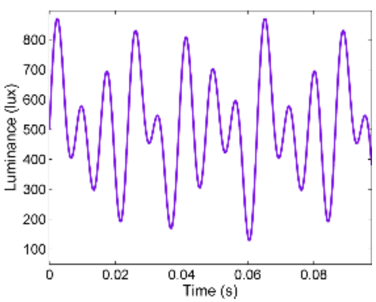
The TN also includes other definitions on the physically measurable properties of the light intensity waveform and basic definitions of visibility.

Measures

The TN describes two general frameworks, one in the time domain and one in the frequency domain, that can be used to develop measures for visibility of TLAs. It gives example implementations of the frameworks and recommends using PstLM and SVM to characterize the corresponding TLAs until the revision in the upcoming CIE TC 1-83 TR

Preferred measure – stroboscopic effect

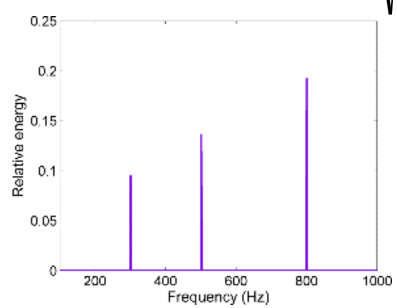
Stroboscopic Visibility Measure (*SVM*) *



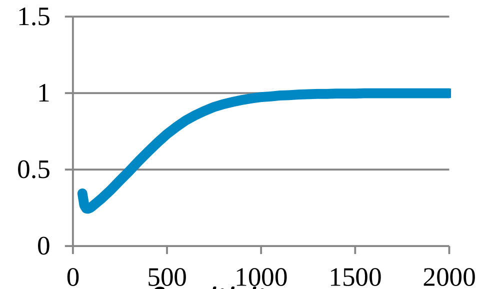
Spectral analysis in frequency domain:

- Frequency range: 80 – 2000 Hz
- Filter/Normalization: Sensitivity curve*
- Summation of weighted Fourier components

$$SVM = \sqrt[3.7]{\sum_{m=1}^{\infty} \left(\frac{C_m}{S_m} \right)^{3.7}}$$



Fourier components



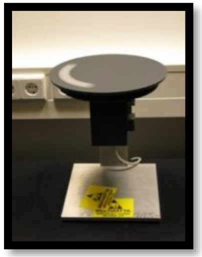
Sensitivity curve

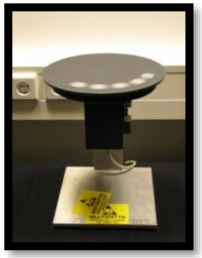
SVM

Limit depends on visibility, duration and risk of application

Limit range: SVM tbd

** SVM and sensitivity curve result from perception study carried out by Philips Research*





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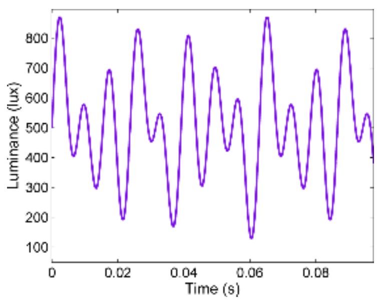
Preferred measure - flicker

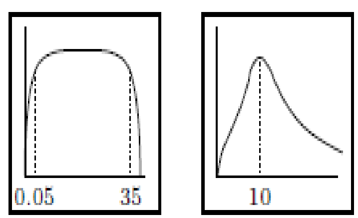
IEC Short term flicker (P_{st}) *

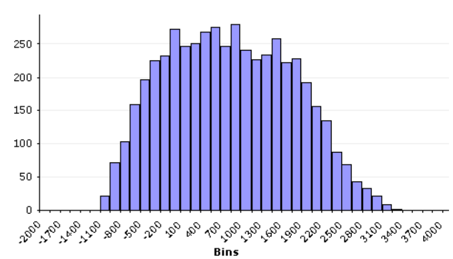


Spectral analysis in time domain

- Frequency range: 0.05 – 80 Hz
- Filter: Demodulation and eye-brain filters
- Statistical summation of percentiles

$$P_{st} = \sqrt{0{,}031\,4\ P_{0,1} + 0{,}052\,5\ P_{1s} + 0{,}065\,7\ P_{3s} + 0{,}28\ P_{10s} + 0{,}08\ P_{50s}}$$





Demodulation + eye-brain response filter

Histogram signal

$\boldsymbol{P_{st}}$

50 % visibility limit:
$P_{st} = 1$

** References: IEC TR 61547-1, IEC 61000-3-3 and IEC 61000-4-15*

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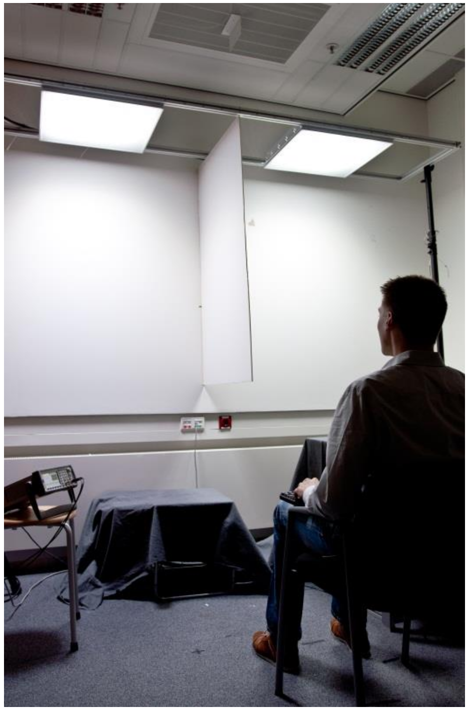
Do we really need this complex stuff?

Experiment : validation of measures for flicker

Goal: test measures predicting flicker visibility, i.e. FVM, FI, MD and P_{st}

Method

- Two luminaires mounted in a frame
- Distance from the wall: 1.5 meter
- CCT: 6200K
- Light level measured at the wall below luminaires: 209 cd/m^2
- 20 participants
- Forced choice paired comparison: "Which of the two stimuli flickers more?"
- Stimuli: 11 waveforms chosen from real world measurements



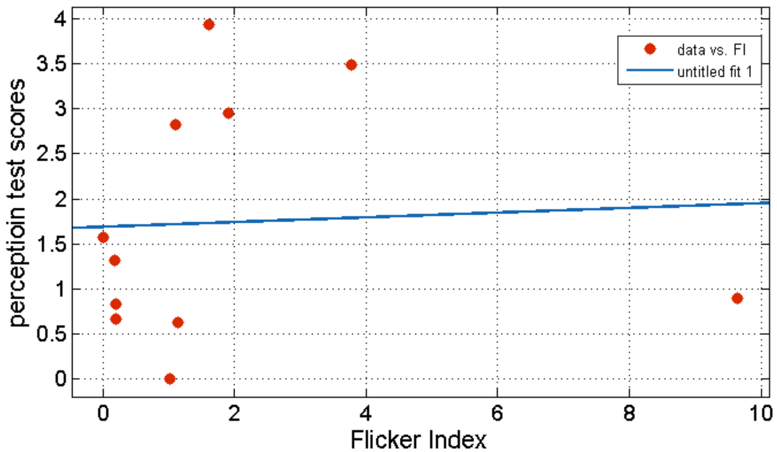
Analysis

- The percentages of responses are translated into z-scores

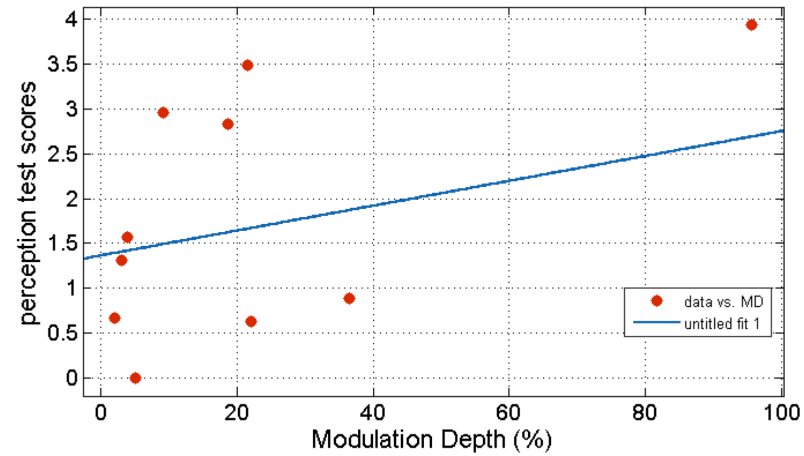
Do we really need this complex stuff?

Well you don't have to use it, if you like random data

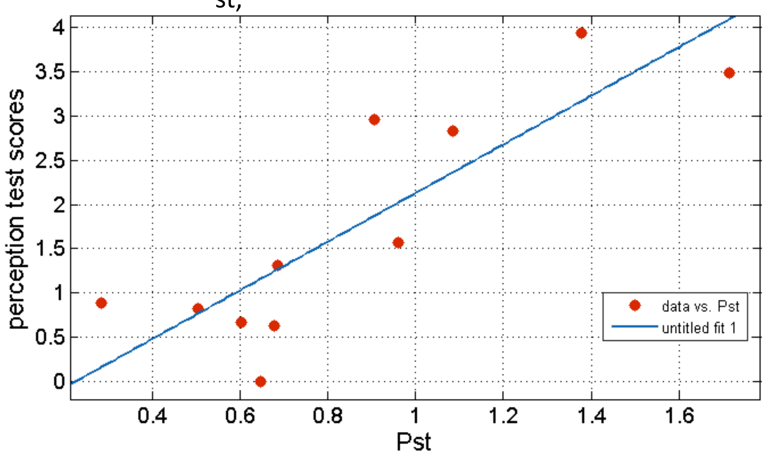
Flicker Index, Correlation: 0.0550



Modulation Depth, Correlation: 0.3306



$P_{st,}$ Correlation: 0.8491



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Demo TLA

Colour Section

CIE Division 1: Colour

Measuring and specifying colour rendition of light sources

- CIE 13.3-1995: "Method of Measuring and Specifying Colour Rendering Properties of Light Sources" ➔ CRI-R_a
- CIE 177:2007 "Colour Rendering of White LED Light Sources"
- CIE 224:2017: CIE 2017 Colour Fidelity Index for accurate scientific use
  - The new fidelity index for accurate scientific use is **not** a replacement for the CIE general colour rendering index (CRI-R_a)!
- CIE TC1-91 "Methods for Evaluating the Colour Quality of White-Light Sources" will not provide a recommendation which method to use.

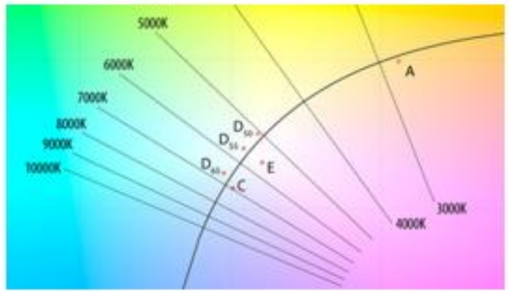
➢ **Reportership DR1-68 "A Gamut Area Measure and Colour-shift Graphic, based on CIE 13.3-1995" ➔ Next slides**

➢ **Research Forum "Matters relating to specifying colour rendition of white-light sources"**
  - Approved in Jeju, to be started.
  - Define the next set of measures to better describe differences in appearance of object colours in a lit environment

Color Rendering: CRI

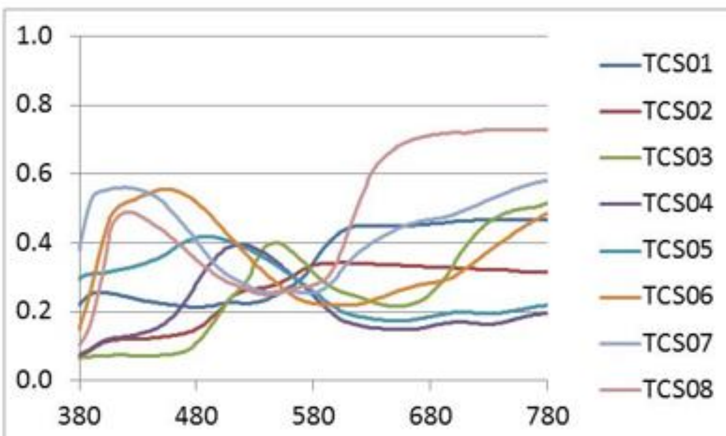
CIE general **C**olour **R**endering **I**ndex (R_a) ; CIE publication 13.3-1995

CCT



CCT ≥ 5000K Phase of Daylight

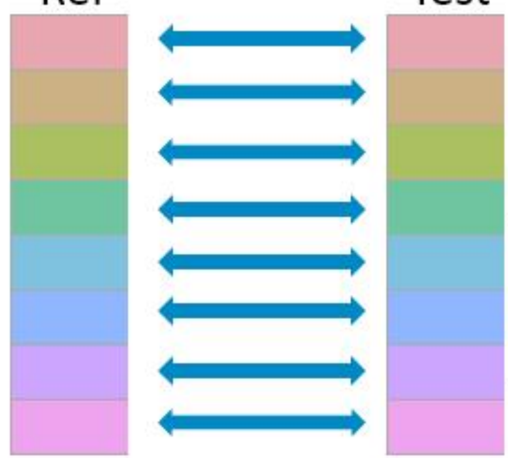
CCT < 5000K Black Body Radiator



CIE Test Colour Samples

Ref

Test



ΔE_1
ΔE_2
ΔE_3
ΔE_4
ΔE_5
ΔE_6
ΔE_7
ΔE_8

Difference

➔ Colour Rendering = Colour Fidelity = CRI = $R_a = 100 - \mathbf{4.6} \times \Delta E_{av}$

(**Similarity index** ; R_a = 100 when test source is "*equal*" to reference illuminant)

CRI calculations in CIE 1964 (U*V*W*)-system

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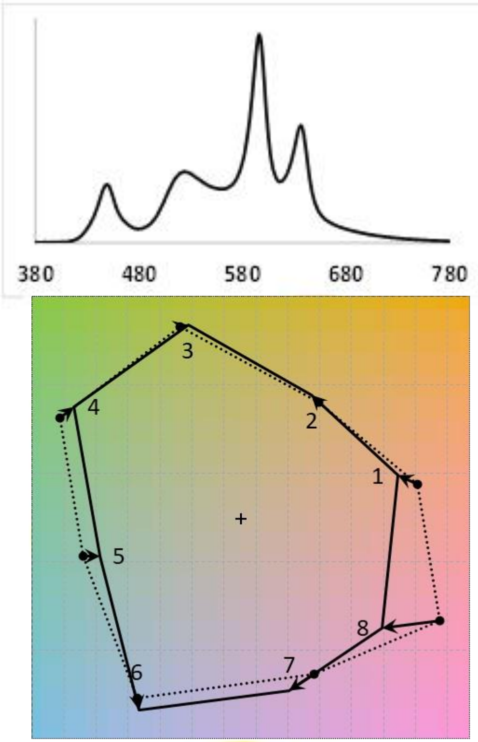
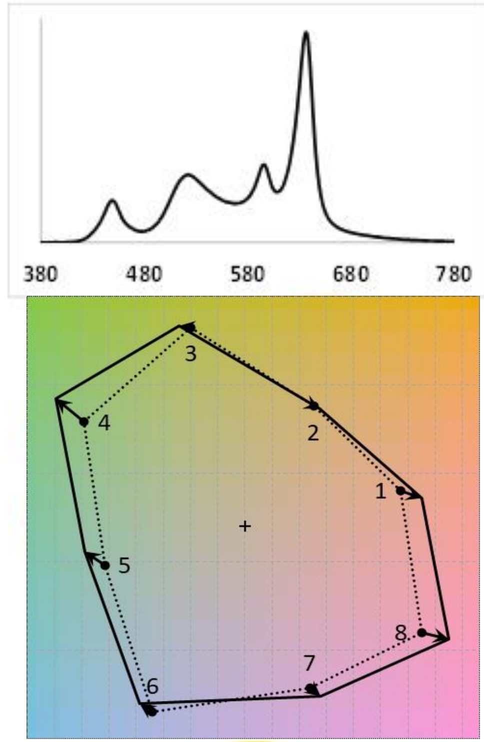
Color Rendering: Limitations of CRI

R_a provides information on **color fidelity**, but does not capture other important aspects contributing to light quality, such as **changes in color saturation**.





Same CCT

Same fidelity (R_a)

Different spectrum

Difference in color saturation

(not yet specified)

Difference in user preference

(cannot be predicted with CRI)

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Combined-index system

Add information next to CRI

- Fidelity ➔ Similarity wrt Reference illuminant
  - Close to 100 = high similarity
  - Already available : CIE CRI R_a

- **Colour Gamut** ➔ Increase or decrease in colour gamut area wrt Reference illuminant
  - Indicates average direction of colour shifts
  - Can be computed from available CIE 13.3:1995 data

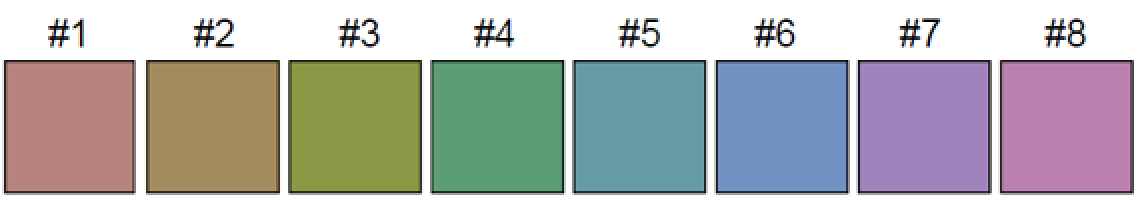
- **Colour Vector Graphic** ➔ Visualization of colour shifts
  - Representation of (CIE 13.3:1995) colours shifts in CIE 1964 U*V* diagram

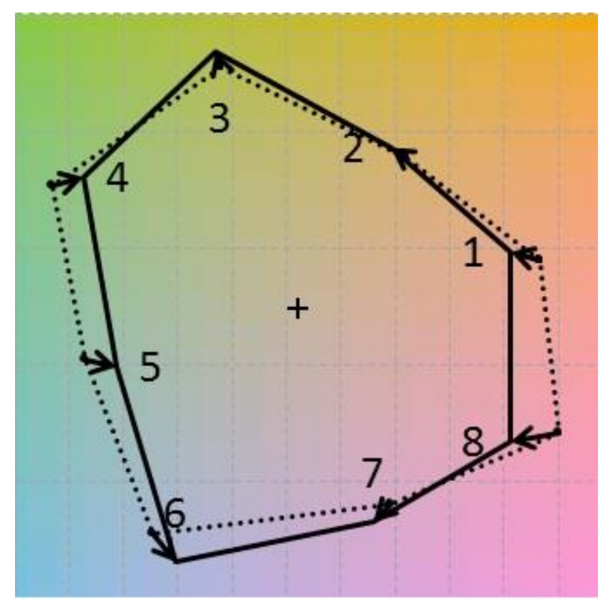
Combined-index system

- Add a **Colour Gamut Index**, **<u>next to</u>** **CRI**
- Same calculation method as for R_a [CIE13.3-1995]
- Calculate gamut area with the 8 CRI test colour samples in CIE 1964 U*V*(W*) colour space for:
  - reference illuminant (G_{ref})
  - lamp to be tested (G_{test})

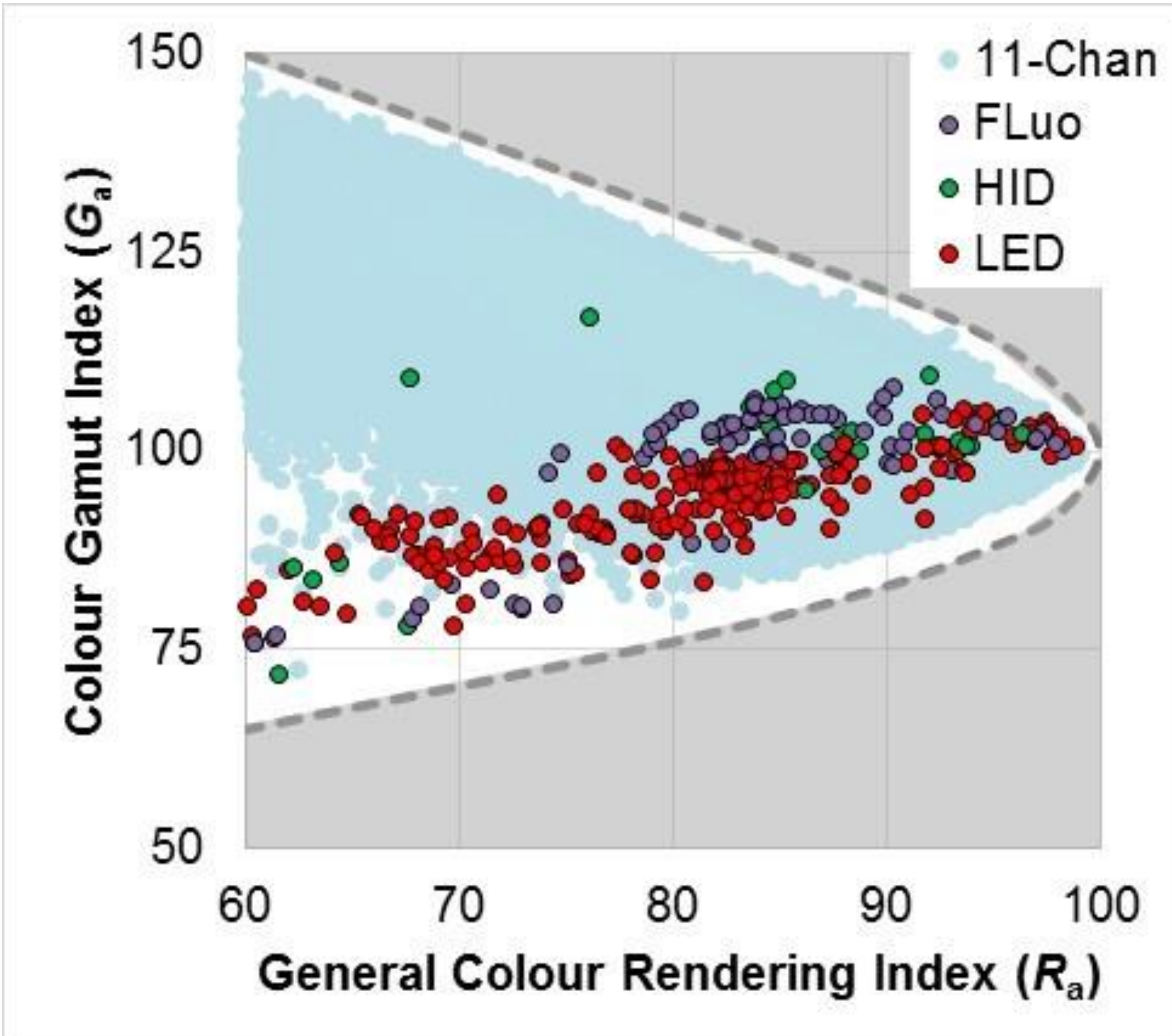
  (considering the adaptive shift)

Colour Gamut Index: $$G_a = 100 \times \frac{G_{test}}{G_{ref}}$$





Combined-index system



Combined-index system

Reportership DR1-68

- Title: A gamut area measure and colour-shift graphic, based on CIE 13.3-1995
- Established: April 2017
- Terms of Reference:
  - To produce a Technical Note, which includes a gamut area measure and colour-shift **information that can be used in conjunction with the general colour rendering index (R_a)**, for interim use till an improved set of CIE defined color quality measures is available and accepted by the lighting community. In addition, an **Excel tool** will be provided to compute the colour rendering index and gamut area index values as well as a colour-shift graphic. The Excel tool could replace the outdated DOS-based computer tool to compute the general colour rendering index, R_a, and the special colour rendering indices ($R_1 – R_{14}$).
- Members: Kees Teunissen (NL), Yoshi Ohno (US) and Kenji Mukai (JP)
- Others: Jan Denneman (GLA) and LightingEurope and Shuxiao Wang (CABR)
  - Established: April 2017
  - Circulated for D1/BA commenting: Jan 9, 2018
  - Expected publication of TN and calculation tool end Q1-2018

Example colour rendition information, based on CIE 13.3

Colour rendition report, according to CIE TN-xxx

Test Source:	Example LED spectrum
Notes:	SPD from Excel calculation tool for the "CIE 2017 Colour Fidelity Index for accurate scientific use"
Date / Time:	Tuesday, January 16, 2018 — 4:28:59 PM

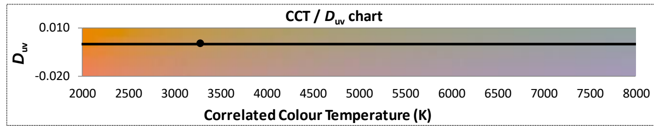
CCT , D_{uv} , R_a , G_a

Correlated Colour Temperature (K)	3288	CIE1931 x-coordinate	0.41744
Distance to Blackbody Locus (D_{uv})	-0.00031	CIE1931 y-coordinate	0.39570
General Colour Rendering Index (R_a)	**80**	CIE1976 u'-coordinate	0.24152
Colour Gamut Index (G_a)	**93**	CIE1976 v'-coordinate	0.51512

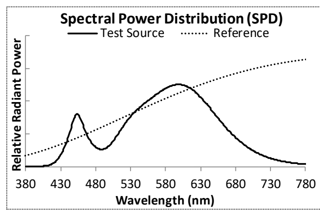
Chromaticity coordinates

CCT / D_{uv} combination, SPD versus wavelength, and the special CRI (R_i) values

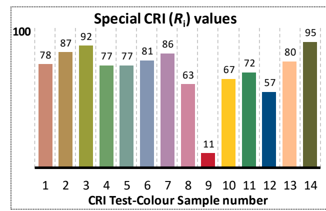
CCT, D_{uv} graphic



SDP + reference

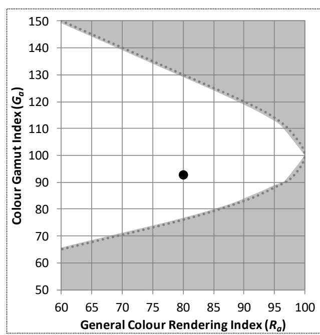


Special CRI (R_i)

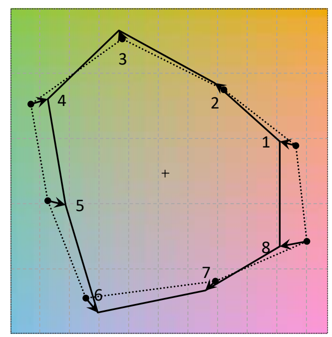


Combined colour-rendering (R_a) & colour-gamut (G_a) and the CIE 1964 (U*,V*) colour-shift graphic

R_a- G_a graphic

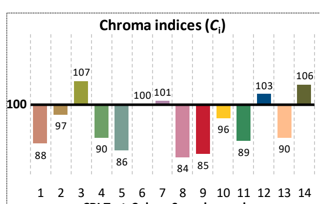


Colour Shift Graphic (CSG)

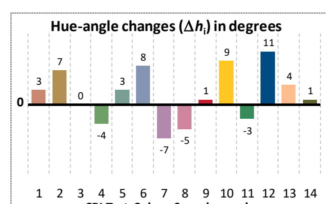


CIE 1976 (L*u*v*) based chroma indices (C_i) and hue-angle changes (Δh_i)

Chroma Indices (C_i)



Hue-angle changes (Δh_i)



Demo Colour Rendition