工業技術研究院
Industrial Technology Research Institute

CIE Taiwan 台灣照明委員會

2015 CIE第28屆大會-照明研討會

Flicker from Lighting on High Speed Road & Lighting Quality

溫照華博士

量測技術發展中心/工業技術研究院

Flicker from Lighting on High Speed Road

Reporter Ship R4-49

Reporter： Chao-Hua Wen

Affiliation： ITRI, Taiwan

Date： July 4th, 2015

Content

- Purpose
- Related studies in Taiwan
- Method
- Simulation
- Flicker metrics
- Summary

工業技術研究院
Industrial Technology
Research Institute

Taiwan Government Policy

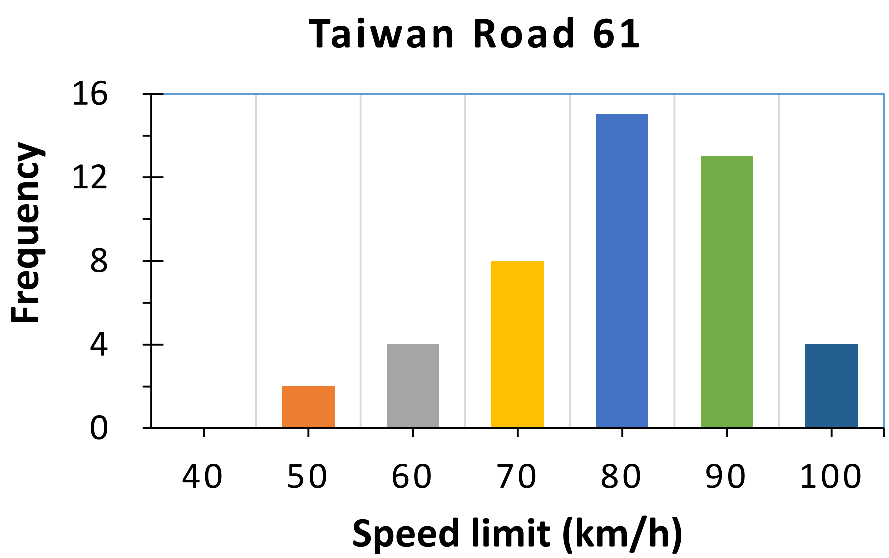
- Sunset Program of Mercury Street Lights (Nov. 2014)
  - By the end of 2016, to invest US$ 1.83 billion of total 692,000 LED lighting installation instead of the mercury street lights, so Taiwan will be the world's first country of fully eliminate mercury street lights.
- Ascent Plan of Green Energy Industry (Aug. 2014)
  - Major strategy is to establish "product specifications and standards and specifications", in order to achieve the goals of to be a main global supplier of LED components and modules, and to construct a global infrastructure of lighting products.
- White Paper on Energy and Industrial Technology (Ministry of Economic Affairs, 2012)
  - Continue to promote the demonstration of LED street lamp application before 2015. In 2020, it is expected that LED lights replace all conventional street and road lights.

Purpose

- The experiments aim at finding the range of repetition frequencies of luminances in the field of vision which have to be avoided in the lighting of express-ways.
- The relevant frequencies in this problem are given by the number of light sources passed per second by a motorist on the express-ways, and therefore depend on the spacing of the light sources, luminous intensity distribution of LED road light sources and the driving speed.
- Schreuder (1998) reported that there was no nuisance as a result of flicker in the central zone of a tunnel which is illuminated by artificial lighting, when the frequency is lower than 2.5 Hz or higher than 15 Hz.
- New challenges
  - Power consumption, LED road light instead of HPS
  - Irregular waveform results from variant luminous intensity distribution of LED road light sources or complicated real scenes
  - Higher speed limit on expressways than in tunnels

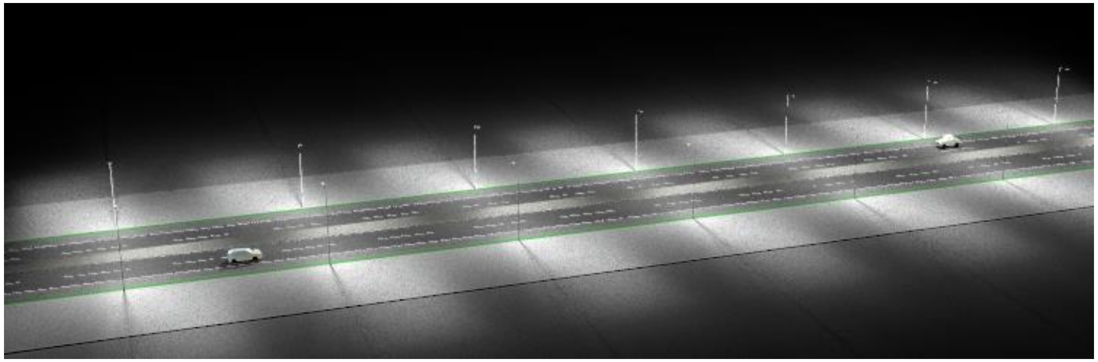
Method

- Road light simulation by DIALux evo 4.0 & DIALux 4.12
- Optimization of pole distance subjected to a consumer luminaire and the mounted height in ME3a condition
- Both main factors in the experiment
  - Pole distance (5 levels) and Speed limit (6 levels)
- Waveform calculation of the vertical illuminance at the driver position for each lane
- Comparisons among the existed flicker metrics

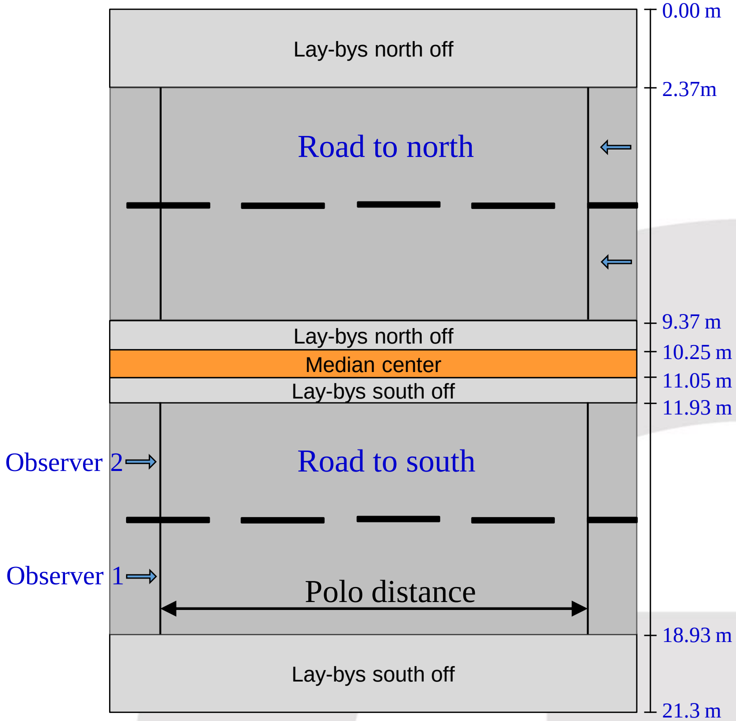


Road Scheme

- Road profile
  - median center Width: 0.800 m
  - lay-bys south off leftside Width: 0.880 m
  - Road to South Width: 7.000 m
  - Number of Lanes: 2
  - Surface (dry): CIE R3
  - q0 (dry): 0.070
  - Surface (wet): Wet surface W3
  - q0 (wet): 0.200
  - lay-bys south off right Width: 2.365 m
  - Maintenance factor: 0.57

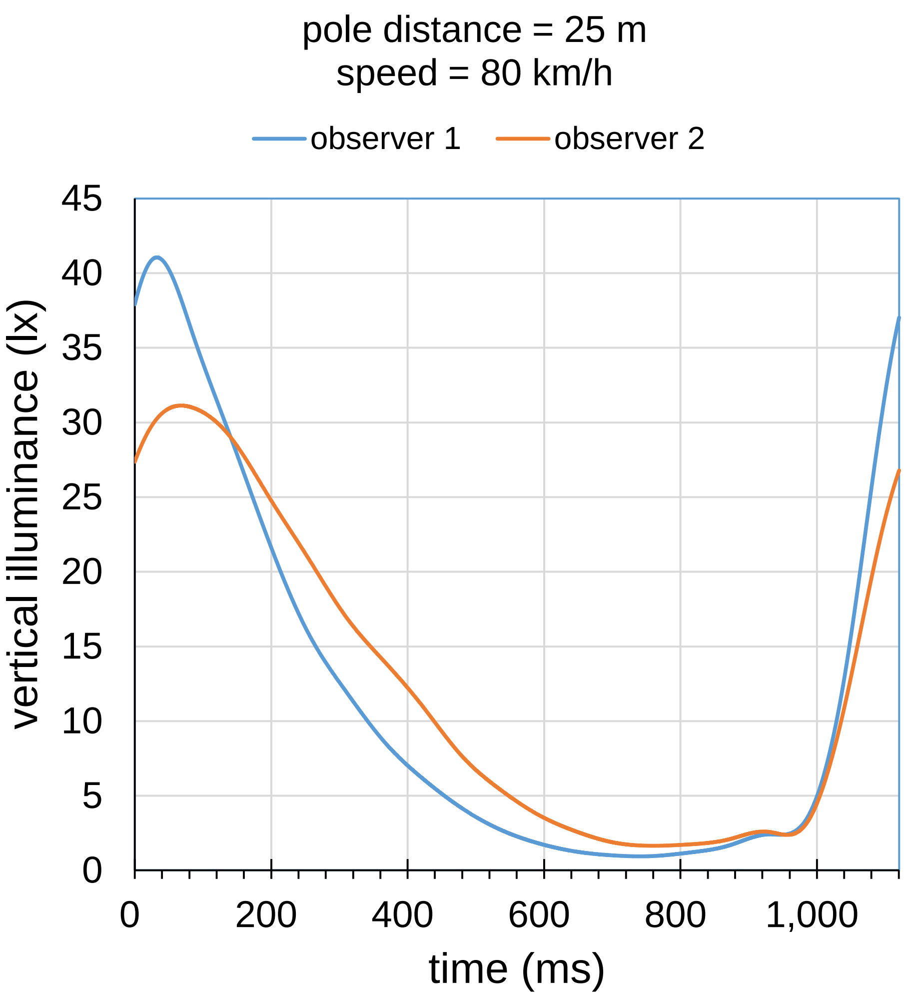


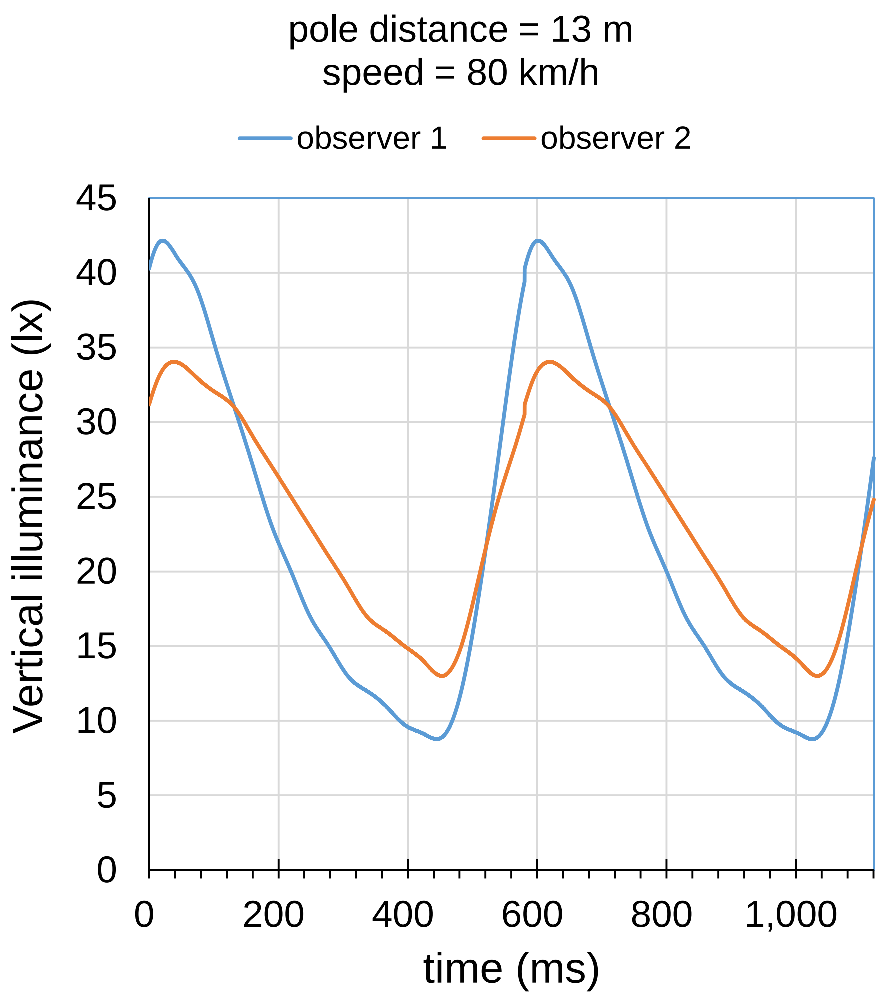
- Luminaire arrangements
  - Luminaire: Philips RVM-270W160LED4K-R-LE2-HS RoadView
  - Luminous flux (luminaire): 17845.27 lm
  - Luminous flux (lamp): 17845.27 lm
  - Luminaire Wattage: 258.9 W
  - Arrangement: both sides opposite
  - Pole Distance: 10/13/15/25/50 m
  - Boom inclination (3): 5.0 °
  - Boom length (4): 1.597 m
  - Light centre height (1): 10 m
  - Light overhang (2): -0.700 m



- Speed limit: 50/60/70/80/90/100 km/h

Waveforms of vertical illuminance (example)





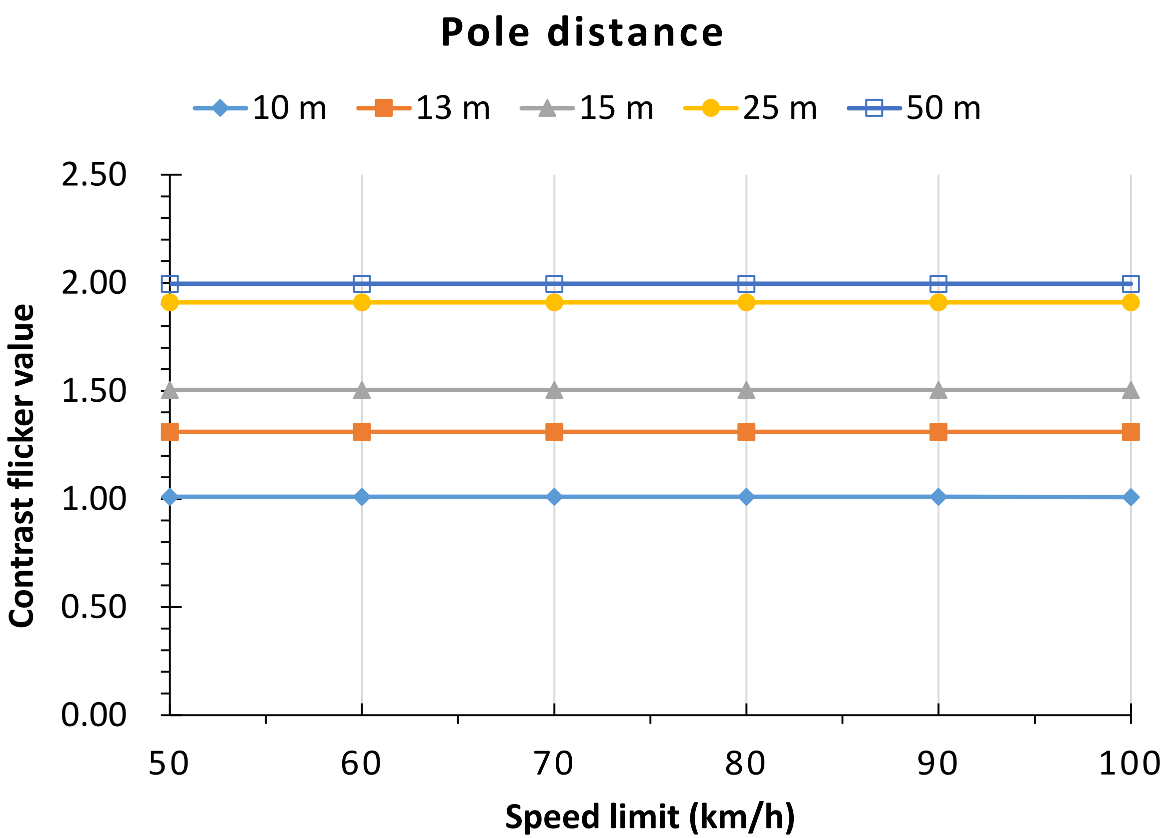
In this case, the modulation of the waveform for observer 1 is higher then observer 2.

Metrics for Flicker Measurement

- Contrast flicker value
- JEITA flicker amount (similar to VESA 305-5)
- SID/ICDM IDMS v1.03 flicker visibility
- Percentage flicker
- Flicker index
- Detection of stroboscopic effect & Acceptability of stroboscopic effect
- ANSI/HFES 100-2007
- Power voltage fluctuation
  - Central Research Institute of the Electric Power Industry of Japan suggested using ΔV10 as the standard for assessing voltage flicker
  - IEC 61000-4-15 gives a functional and design specification for flicker measuring apparatus intended to indicate the correct flicker perception level for all practical voltage fluctuation waveforms. (short term and long term flicker, Pst & Plt)

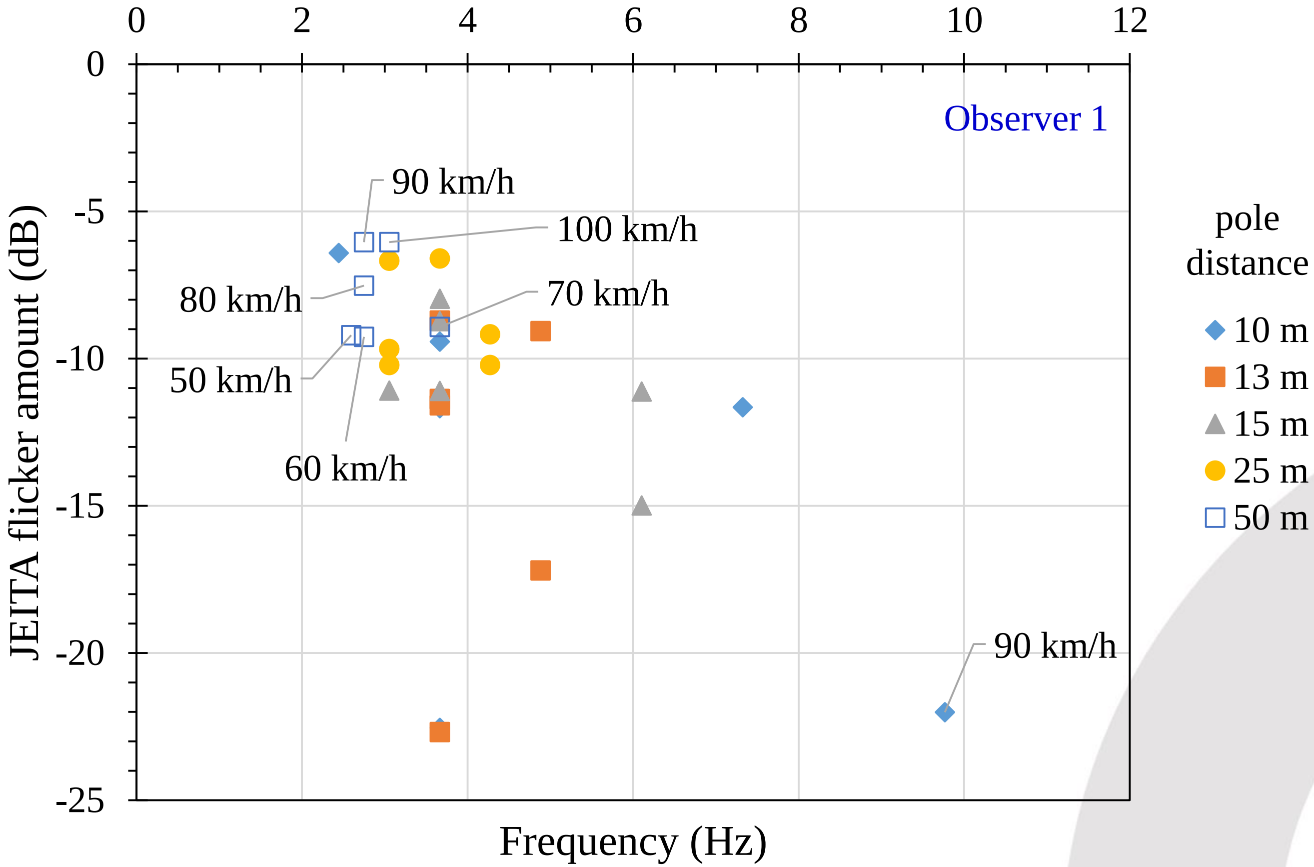
Contrast Flicker Value

- Longer pole distance, higher contrast flicker value.
- Speed does not change the contrast flicker value.



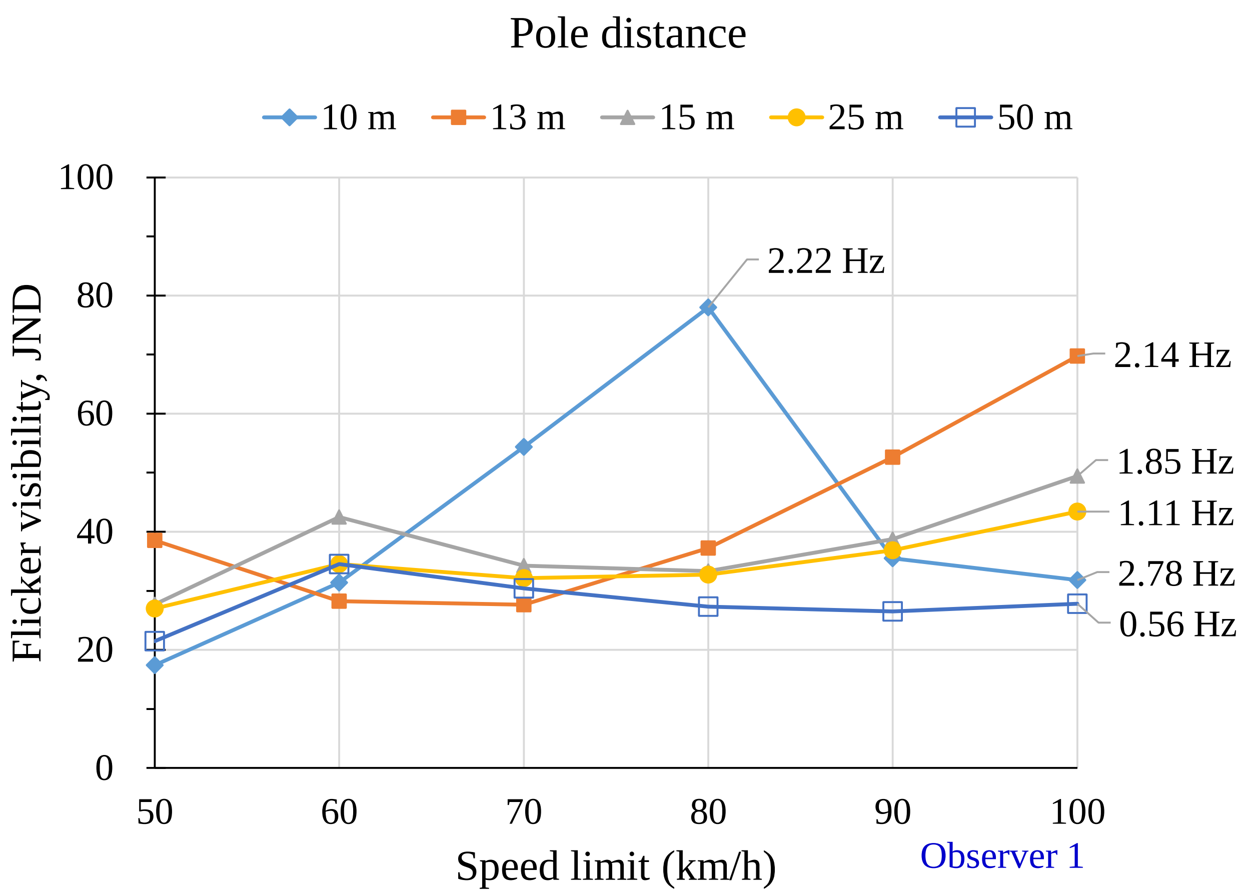
JEITA Flicker amount for observer 1

- Most occurrence between 2.5 Hz to 10 Hz
- For the pole distance 50m, all flicker values are above -10dB for varied speed limits. It means that drivers will be annoyed by flicker.



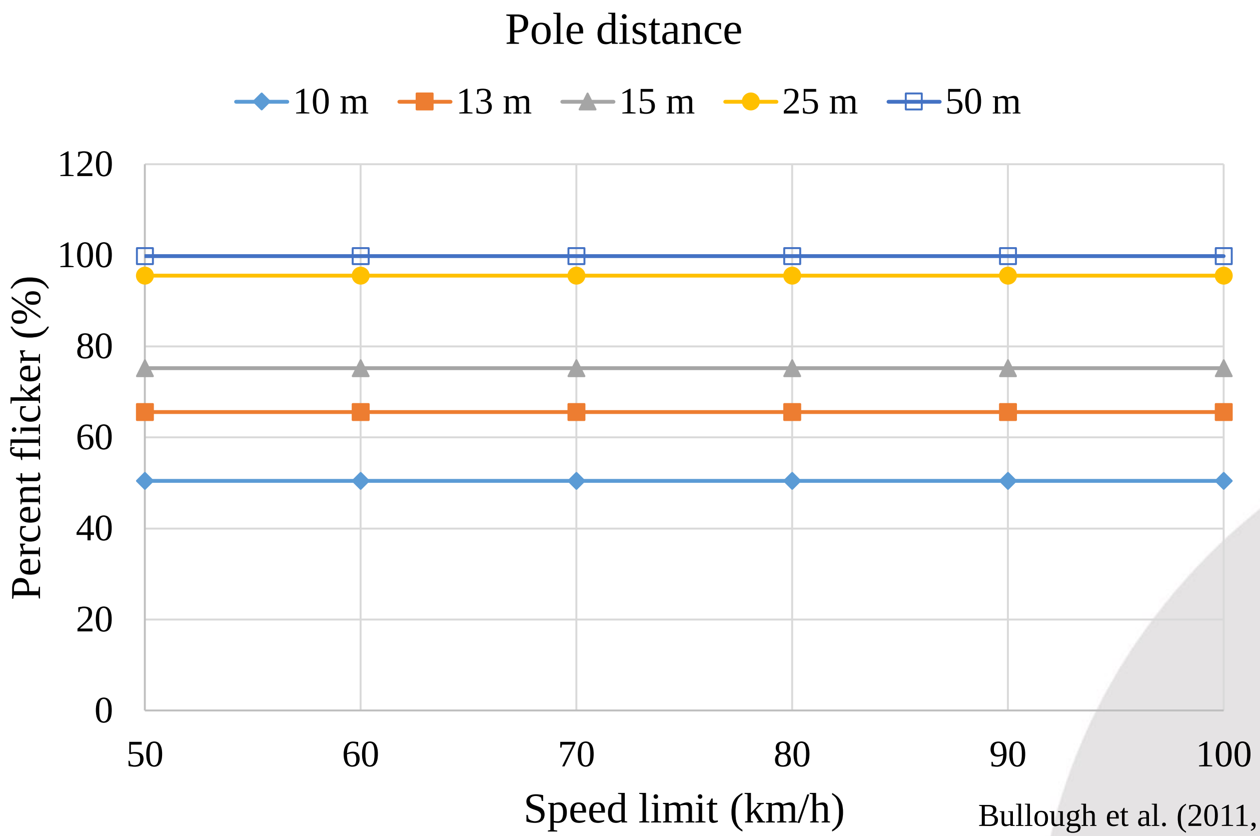
Flicker Visibility for observer 1

- The highest flicker visibility is occurrence as driving speed 80 km/h through the repetition range of pole distance 10 m.
- For pole distance 50 m, there is lower flicker visibility as speed fast than 80 km/h.



Percent Flicker for observer 1

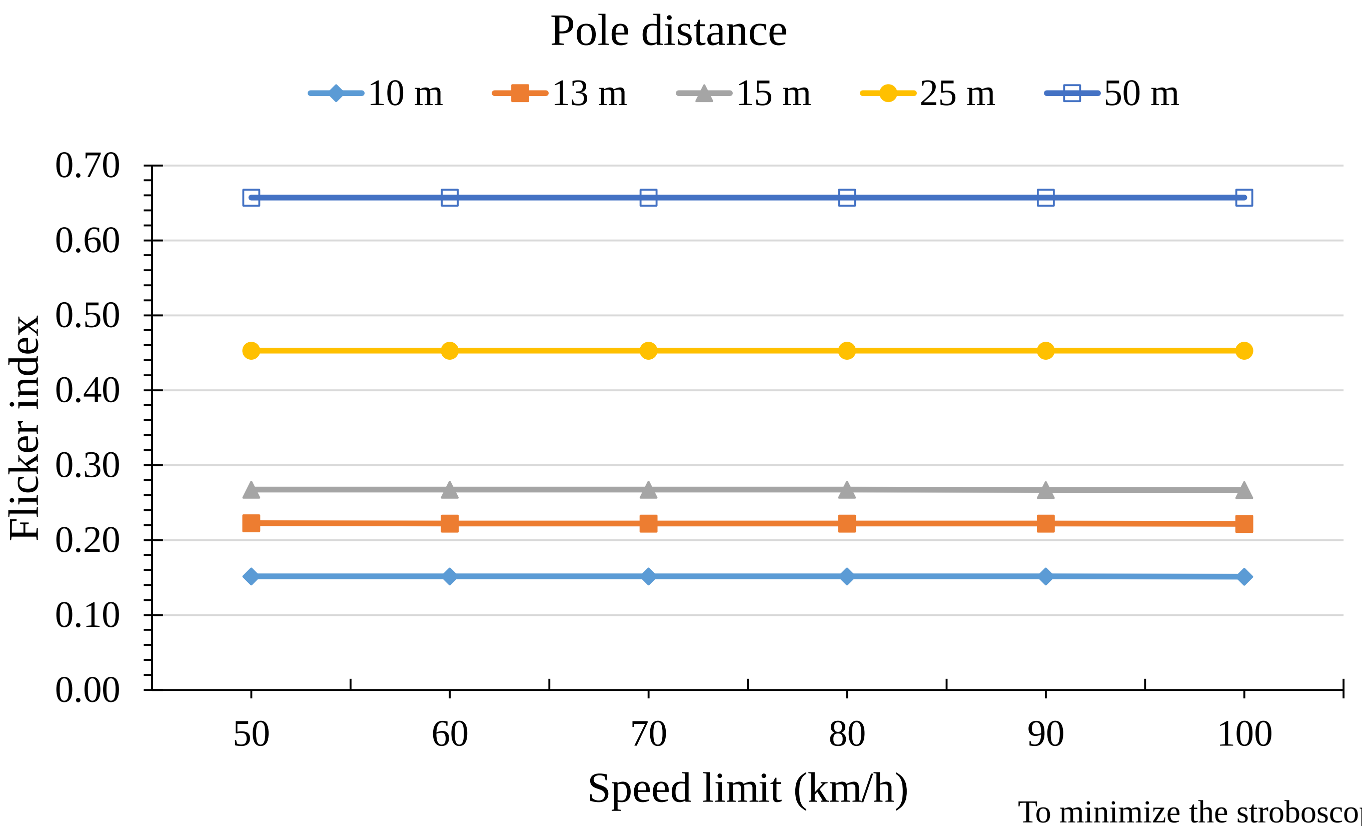
- There is identical percent flicker value for each pole distance.
- Percent flicker is not related to speed.
- For pole distance 50 m, the percent flicker is the highest 100%.



Bullough et al. (2011, 2012, 2013) reported that more than 10% flicker below 100 Hz could be noticeable and unacceptable to end user.

Flicker index for observer 1

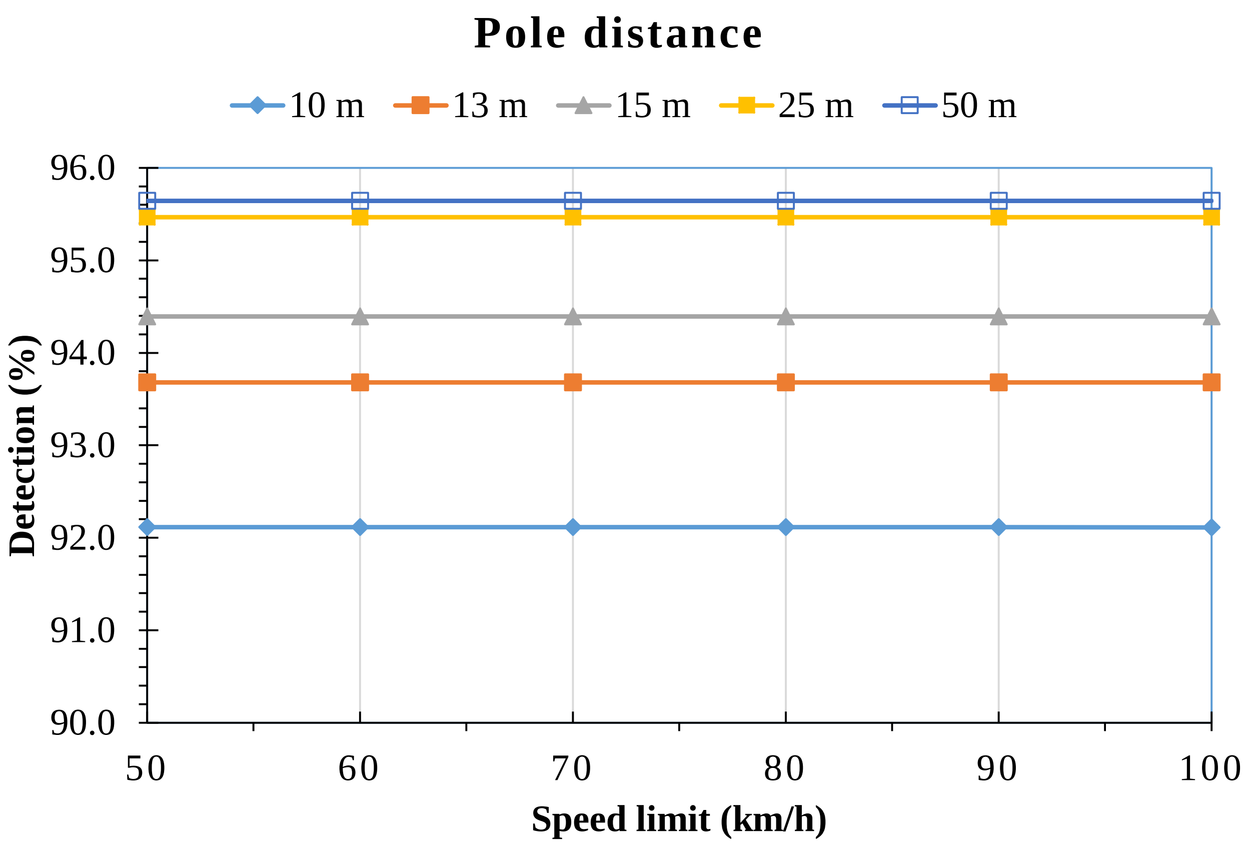
- There is identical flicker index for each pole distance.
- Flicker index is not related to speed.
- For pole distance 50 m, the flicker index is the highest 0.66.



To minimize the stroboscopic effect, systems with a flicker index of 0.1 or less are suggested. IES The Lighting Handbook, 10^{th} Ed., p.7.45.

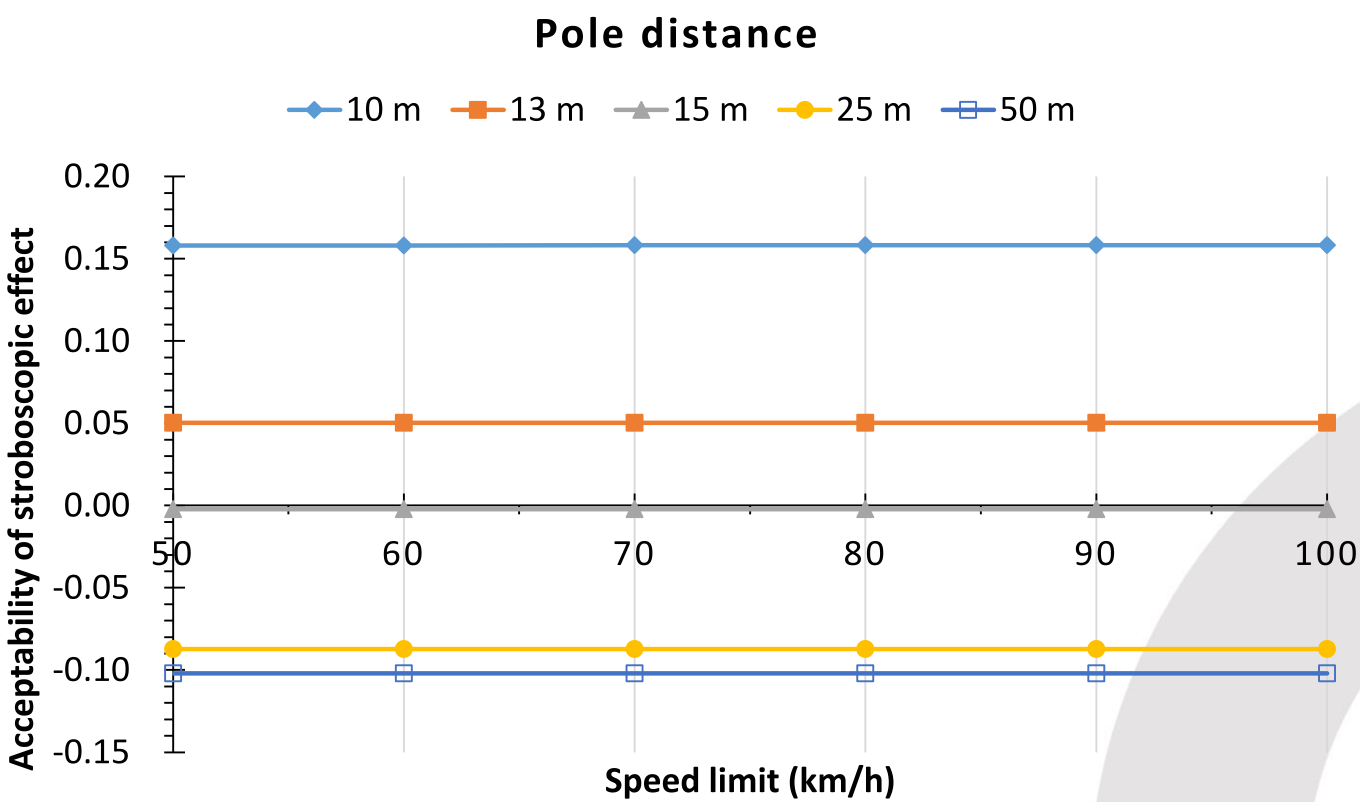
Detection of Stroboscopic (DoS) effect for observer 1

- There is identical DoS for each pole distance.
- DoS is not related to speed.
- For pole distance 50 m, the DoS is the highest 95.6%.



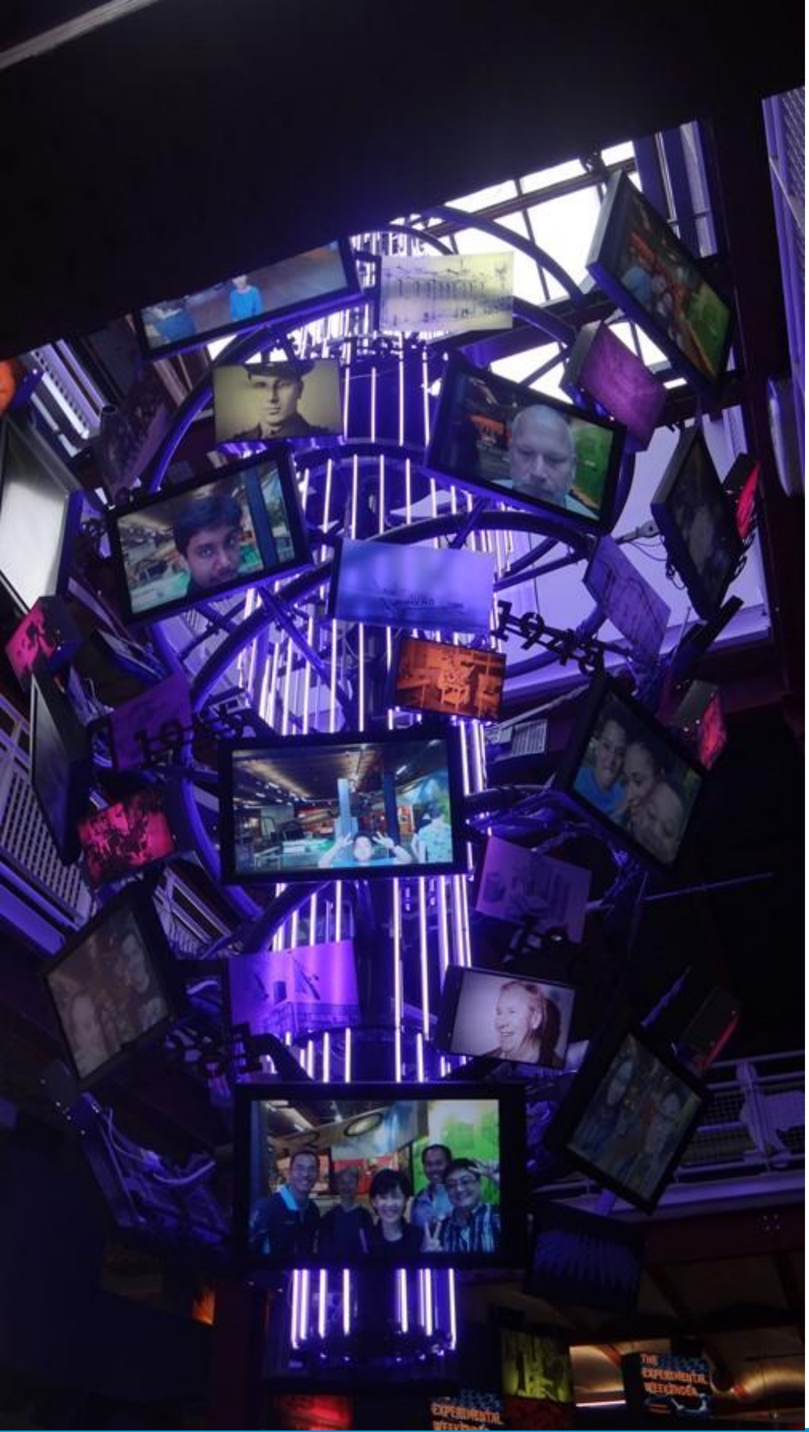
Acceptability of Stroboscopic (AoS) effect for observer 1

- There is identical AoS for each pole distance.
- AoS is not related to speed.
- For pole distance 50 m, the AoS is the lowest -0.1.



Summary

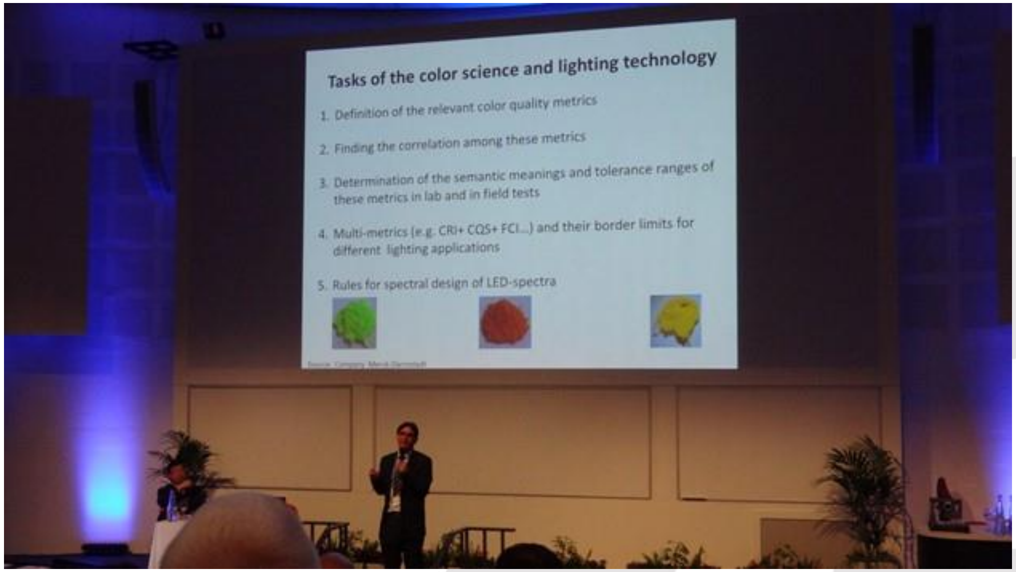
- Inconstant results of the current flicker metrics
- Irregular waveform of vertical illumination from the complicated real scenes.
- Take the duration account into the flicker metric
  - Transition for short time or very low frequency: glare issue
  - Transition for middle or long time: flicker issue



Colour Quality of LED Lighting

Tasks of the color science and lighting technology

1. Definition of the relevant color quality metrics
2. Finding the correlation among these metrics
3. Determination of the semantic meanings and tolerance ranges of these metrics in lab and in field tests
4. Multi-metrics (e.g. CRI+CQS+FCI….) and their border limits for difference lighting applications
5. Rules for spectral design of LED-spectra

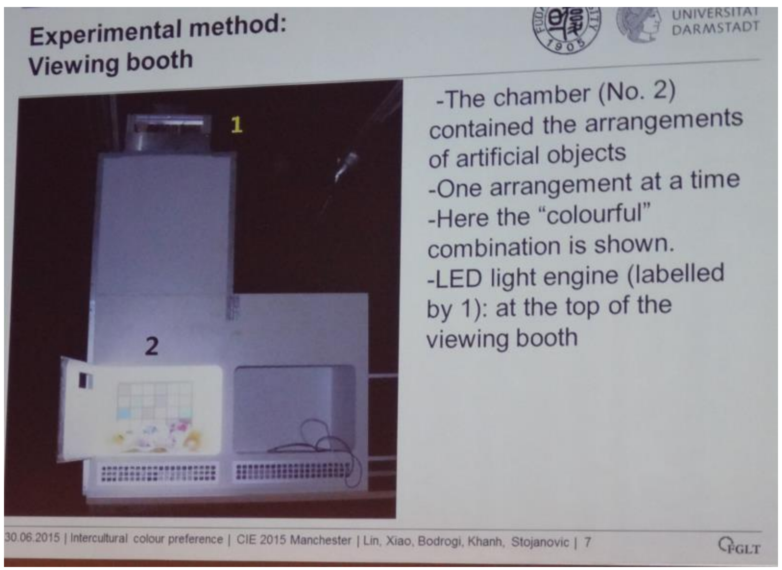


Conveners: Ronnier Luo & Tran Quoc Khanh

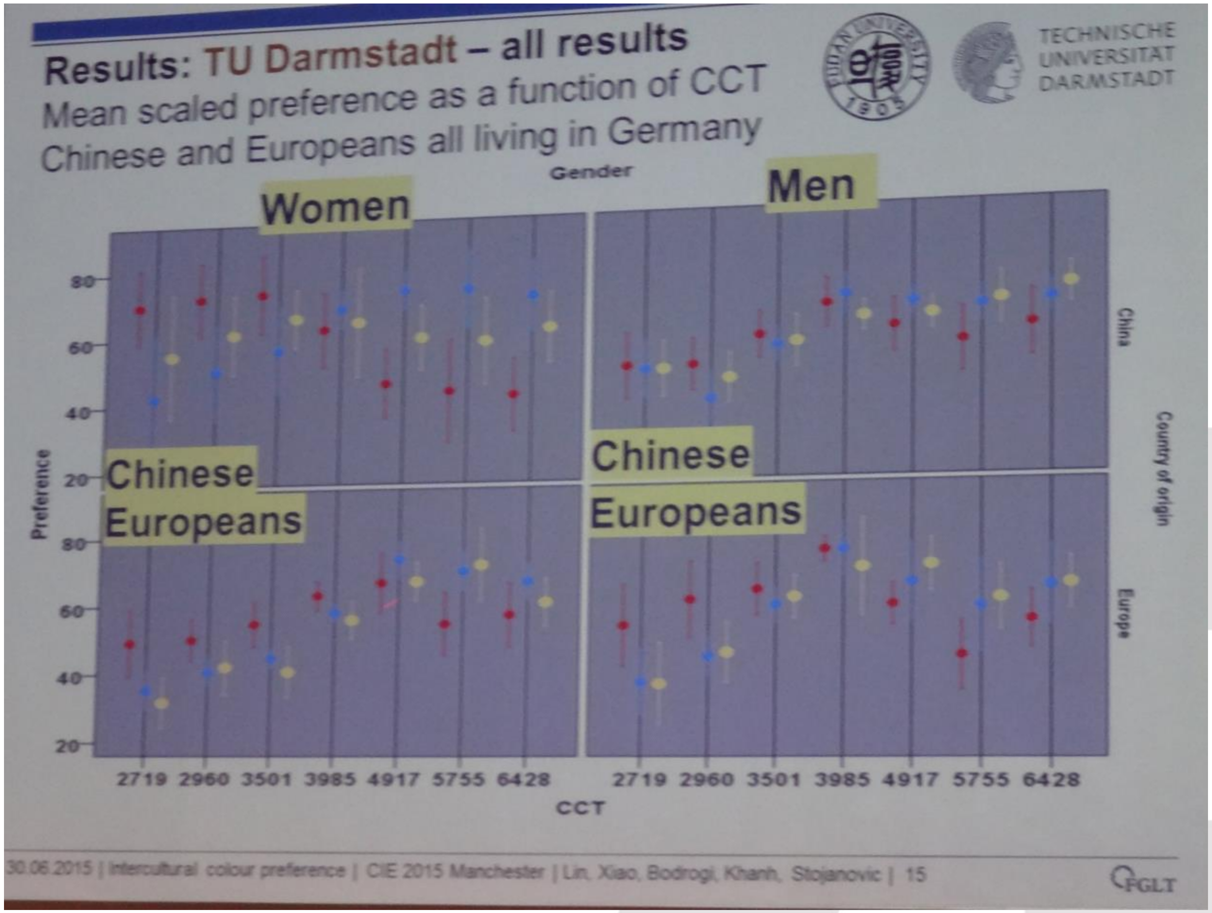
Intercultural Colour Preference

- Intercultural Colour Temperature preference of Chinese and European Subjects Living in Germany (p.618 ~ 622)
  - Technische Universität Darmstadt, Darmstadt, GERMANY
  - Fudan University, Shanghai, China

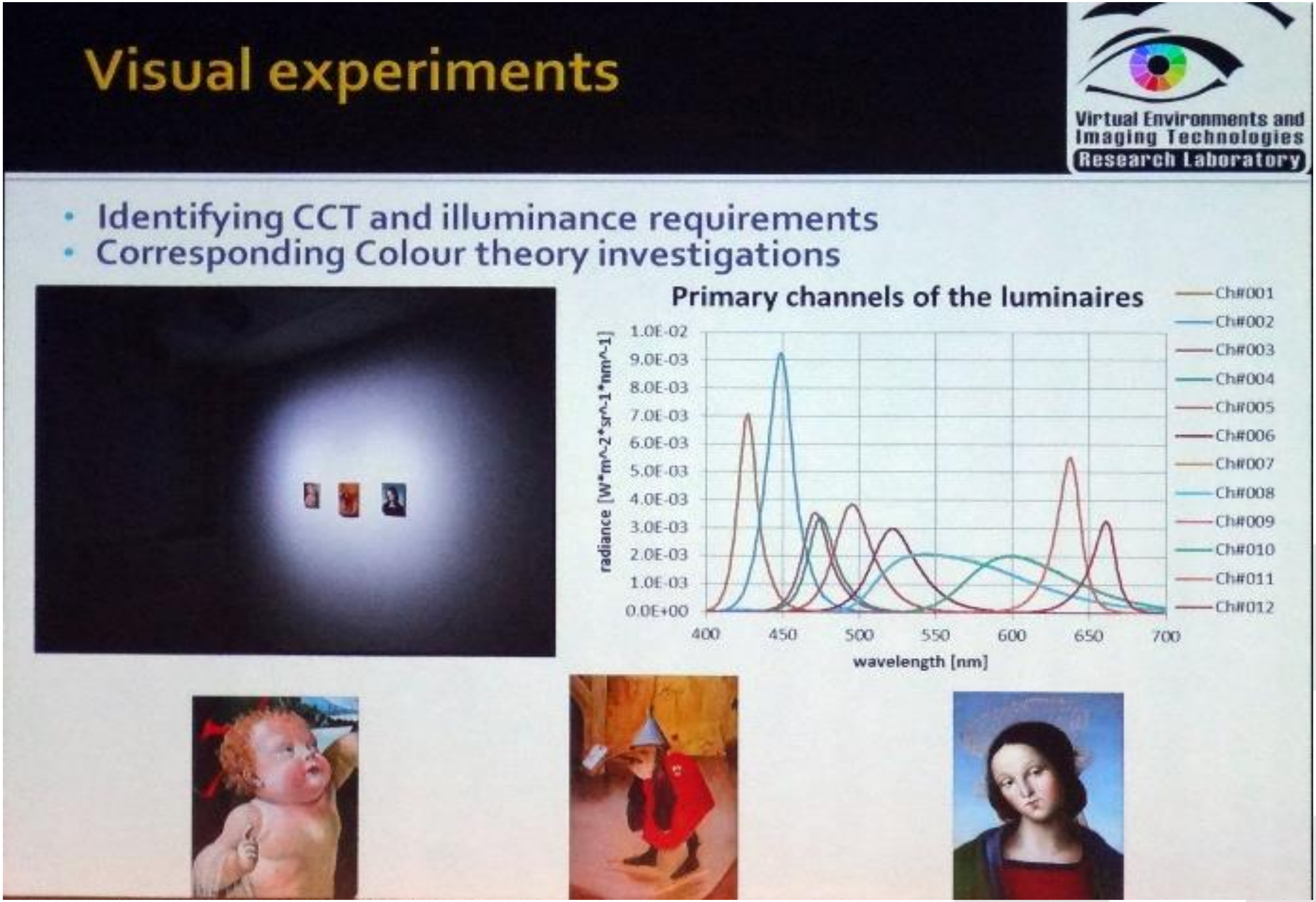
Artificial objects used in the experiment

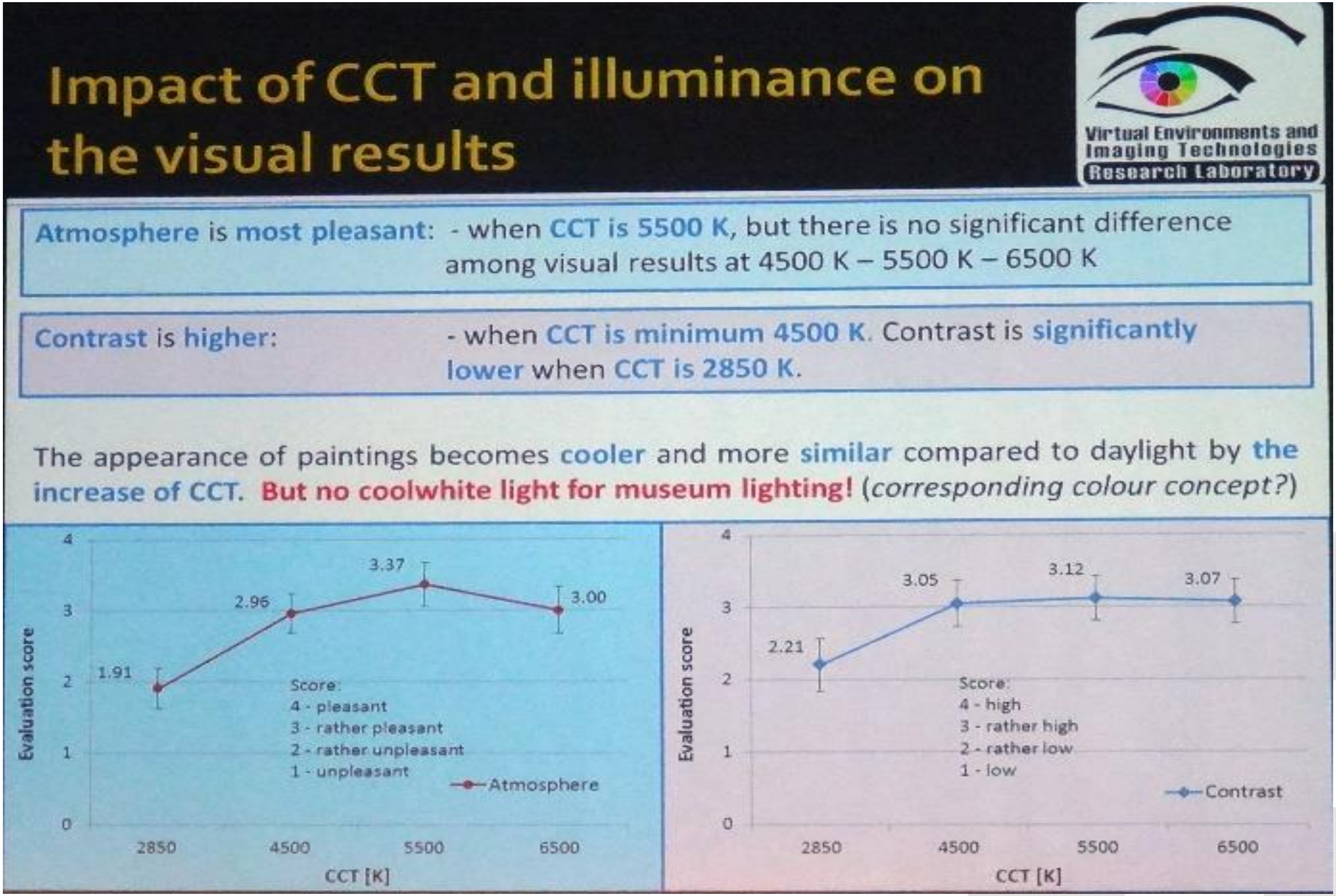


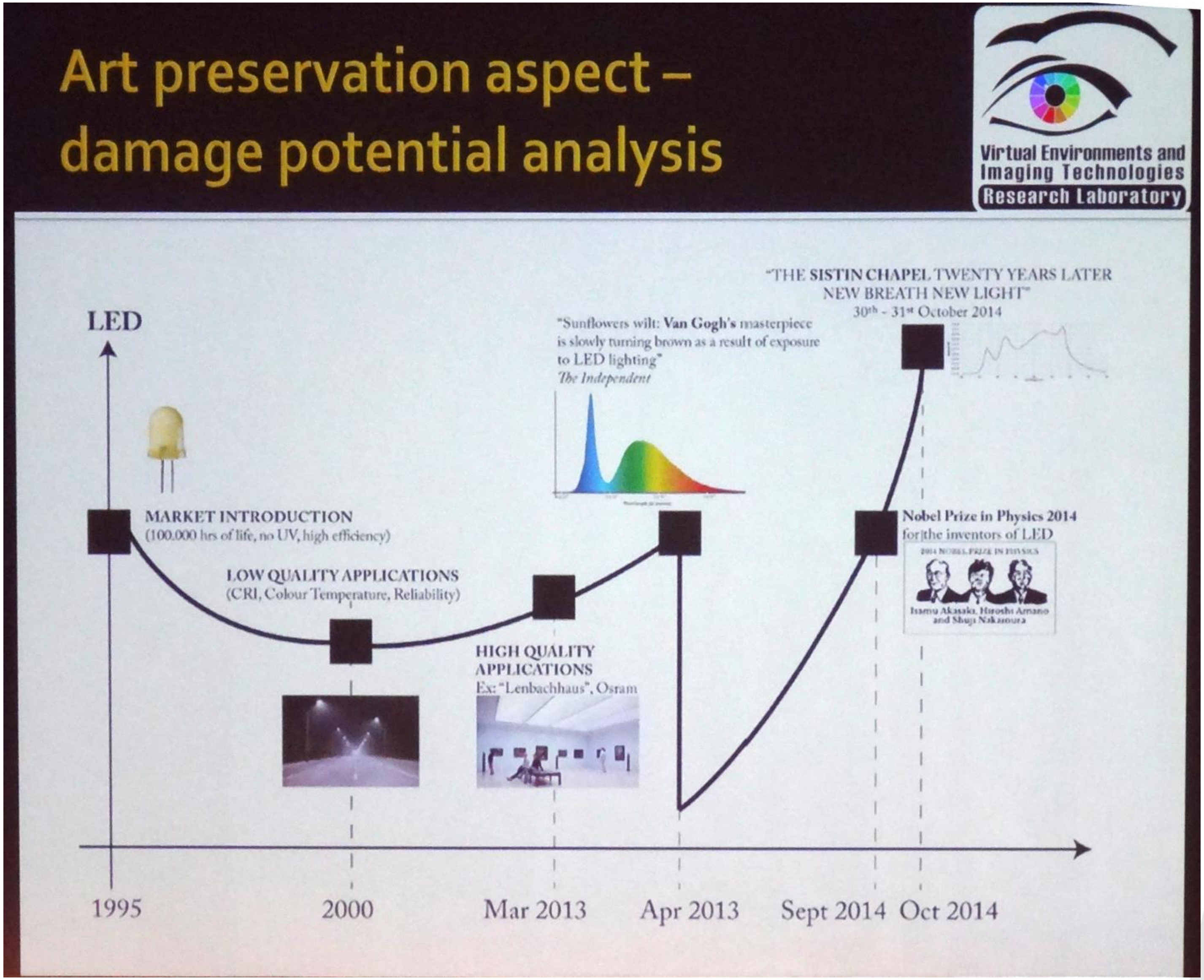
LED viewing booth with Ra>97 & R9>97




CIE 2015
MANCHESTER UK
Human centric intelligent lighting for museum applications
Ferenc Szabó, Péter Csuti, János Schanda
Virtual Environments and Imaging Technologies Research Laboratory University of Pannonia, Veszprem, Hungary
szabof@szafeonline.hu
Virtual Environments and
Imaging Technologies
Research Laboratory


Visual experiments
Virtual Environments and
Imaging Technologies
Research Laboratory
• Identifying CCT and illuminance requirements
• Corresponding Colour theory investigations
Primary channels of the luminaires
radiance [W*m^-2*sr^-1*nm^-1]
1.0E-02
9.0E-03
8.0E-03
7.0E-03
6.0E-03
5.0E-03
4.0E-03
3.0E-03
2.0E-03
1.0E-03
0.0E+00
400
450
500
550
600
650
700
wavelength [nm]
Ch#001
Ch#002
Ch#003
Ch#004
Ch#005
Ch#006
Ch#007
Ch#008
Ch#009
Ch#010
Ch#011
Ch#012


Impact of CCT and illuminance on the visual results
Virtual Environments and Imaging Technologies Research Laboratory
Atmosphere is most pleasant: - when CCT is 5500 K, but there is no significant difference among visual results at 4500 K – 5500 K – 6500 K
Contrast is higher: - when CCT is minimum 4500 K. Contrast is significantly lower when CCT is 2850 K.
The appearance of paintings becomes cooler and more similar compared to daylight by the increase of CCT. But no coolwhite light for museum lighting! (corresponding colour concept?)
Evaluation score
4
3
2
1
0
1.91
2.96
3.37
3.00
Score:
4 - pleasant
3 - rather pleasant
2 - rather unpleasant
1 - unpleasant
Atmosphere
2850
4500
5500
6500
CCT [K]
Evaluation score
4
3
2
1
0
2.21
3.05
3.12
3.07
Score:
4 - high
3 - rather high
2 - rather low
1 - low
Contrast
2850
4500
5500
6500
CCT [K]



Szabo博士報告自從LED應用在各個領域後，在博物館應用上一直受到一股阻力，主要是LED對畫作或藝術品的傷害，但藉者近幾年的研究與LED配方的改善，加上諾貝爾獎頒發給LED發明者，推測未來將是LED應用在博物館應用的爆發時代。

工業技術研究院
Industrial Technology
Research Institute

History of Colour Quality

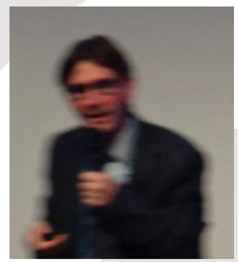
History of colour quality:
selected items of a long development

TECHNISCHE UNIVERSITÄT DARMSTADT

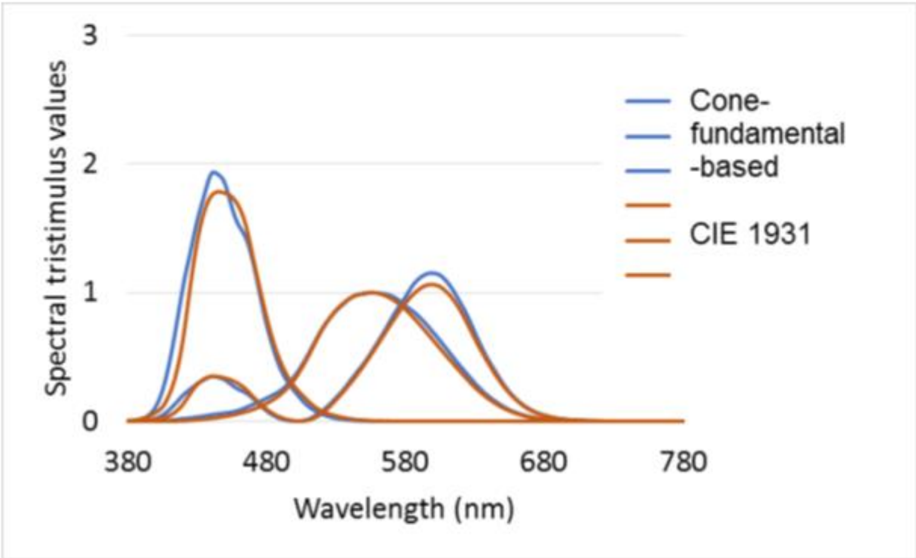
Colour quality (CQ) parameter	Year
Thornton's Color Discrimination Index	1972
Colour rendering index, CIE Publ. 13.3	1995
CIE R96, CIE Publ. 135/2, 1999	1999
CQS (NIST, Yoshi Ohno et al.)	1999
FCI (Feeling of Contrast Index, Hashimoto et al.)	2007
Gamut Area Index (GAI, Rea et al.)	2008
Memory Colour Rendering Index (Smet et al.)	2010
CRI-CAM02UCS (University of Leeds)	2012
CRI2012	2012
IES color rendition method	June 2015

30.06.2015 | Future LED lighting | CIE 2015 Manchester | Bodrogi, Khanh, Stojanovic | 3

FGLT



Cone Fundamentals: Past, Present and Future

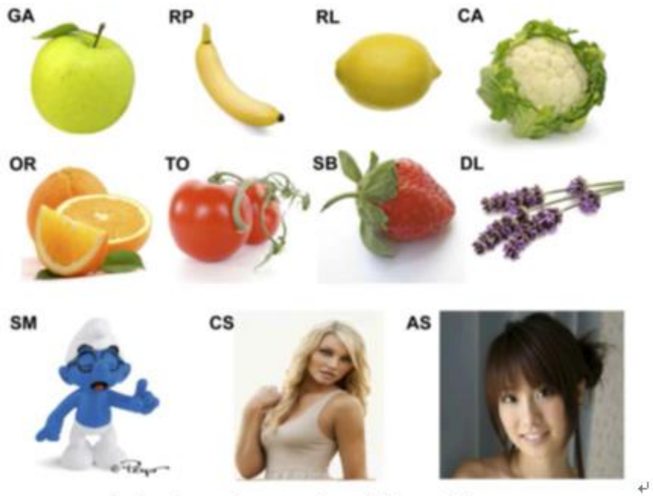


Comparison of the cone-fundamental-based spectral tristimulus values $\overline{x}_F(\lambda)$, $\overline{y}_F(\lambda)$, and $\overline{z}_F(\lambda)$ with the CIE 1931 standard colorimetric observer.

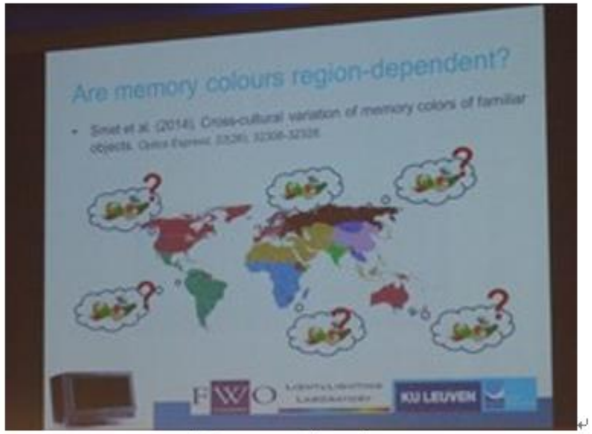
Prof. Françoise Viénot (MNHN, FR)

- 其團隊近期研究發現過去CIE於1931年發表色彩匹配函數與用人類錐狀細胞的光反應頻譜存在一些差異。
- Viénot教授建議未來可以使用以生理學上設計的色度圖（MacLeod-Boynton chromaticity diagram）和cone-fundamental-based chromaticity diagram可以作為更精準和正確的色彩應用

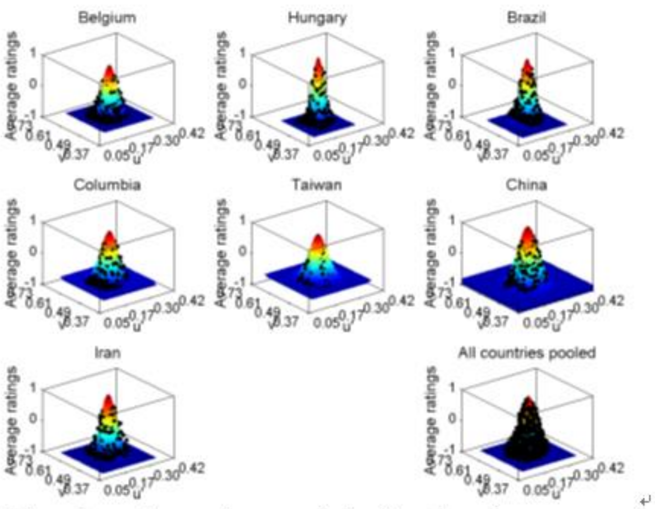
Geographical effects on memory colors



(a) The eleven familiar objects



(b) Introduction



(c) Bivariate Gaussian models for the observer rating data of a ripe banana

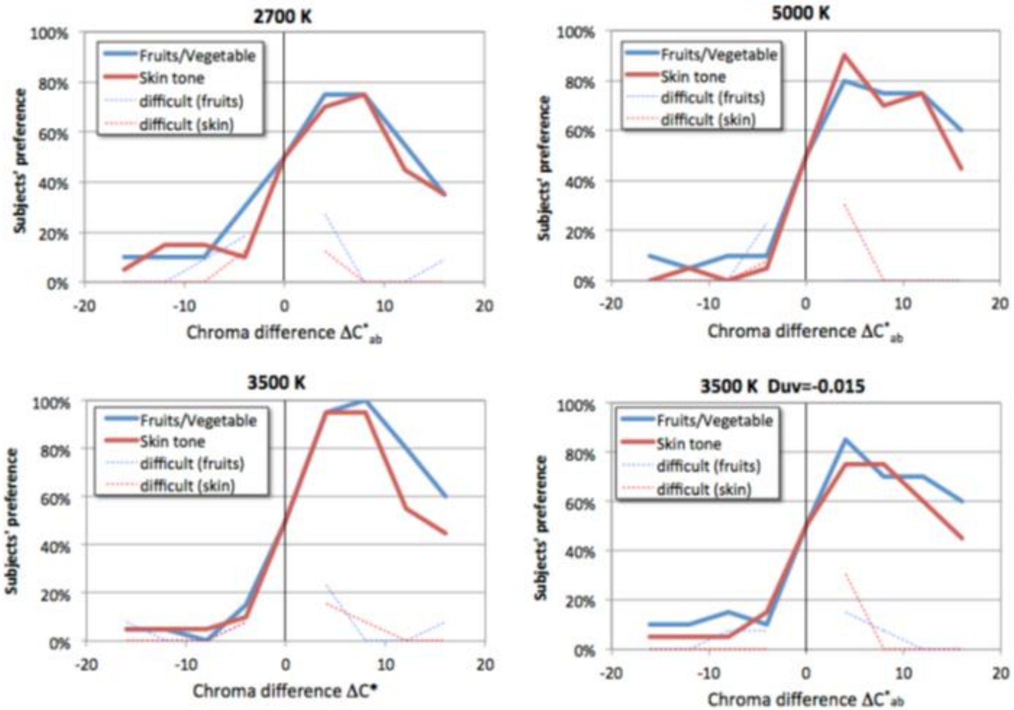
(d) Smet, K.A.G (KU Leuven, Light & Lighting Laboratory, Belgium)

- 此研究來自全球7個地區：Belgium, Hungary, Brazil, Colombia, Taiwan, China和Iran，實驗分析此7個地區對11種熟悉物體色的色外貌評價和記憶色，如圖(a)和(b)所示。
- 結果發現以色外貌評價為基礎的記憶色描述中，雖然地區間呈現統計上的顯著差異，但其影響效果不高，如圖(c)所示，
- 事實上區域的平均值和整體平均值的差異還小於在一地區的受試者內的變異。
- 故該研究建議地域內的變異似乎是不太重要的。

Vision Experiment on Chroma Saturation for Color Quality Performance

(a) View of the two cubicles of NIST Spectrally Tunable Lighting Facility

(b) Yoshihiro Ohno (NIST, USA)



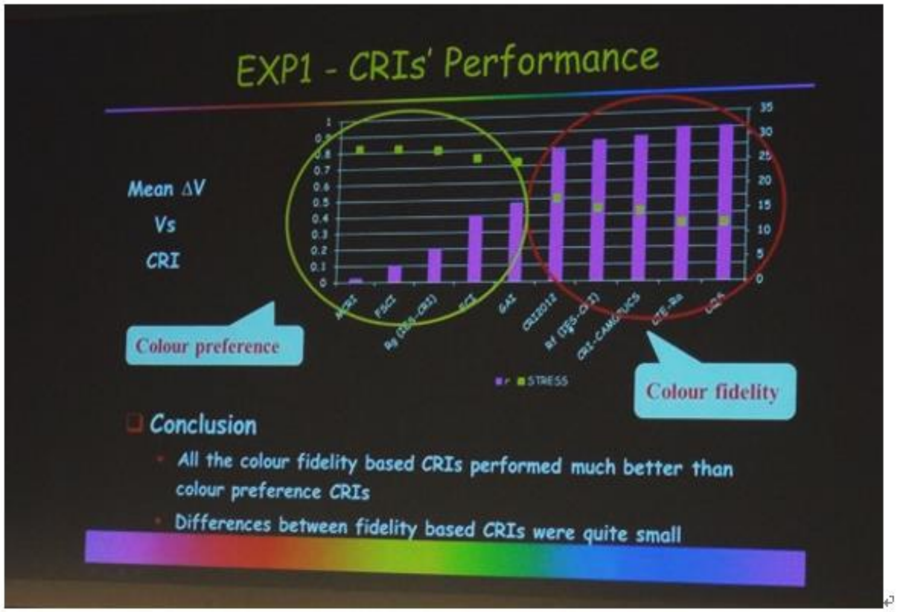
(c) Results

- 由於傳統CRI往往無法與真實照明場景下的視覺色彩評價有好的關聯性。主要理由是CRI量測色彩忠實度(color fidelity)，而一般使用者常常判定演色是以物體色外貌的喜好為基礎。
- 物體彩度的飽和度是主要影響色彩喜好度的因素之一，所以此研究利用NIST的可調變頻譜光源來模擬室內情境，如圖(a)所示，在3種相對色溫下(2700K, 3500K, 5000K)之各種飽和度照明，對水果、蔬菜和真實人臉膚色進行辨別。
- 結果發現受試者的喜好度一致在所有色溫下的彩度差異約為$\Delta C^*_{ab} \approx 5$，如圖(c)所示，這結果可應用於色彩喜好度的量測上。

Testing Colour Rendering Indices Using Visual Data under Difference LED Sources

(a) Experimental setup

(b) Luo, M.R. (Leeds, UK)



(c) CRIs' performance

- 此研究執行2項心理物理實驗，如圖(a)所示，比較各種均勻色彩空間(UCSs)和演色性指數(CRIs)用於光源的色彩忠實度評價上。
- 結果發現CAM02-UCS與視覺評價的關聯性比其它均勻色彩空間高。
- 對CRI指數而言，各種CRI指數顯示對色彩忠實度分析上具相當高的正確性，也優於色喜好度指數，值得注意的是傳統Ra的結果也呈現和其它CRI指數類似好的結果，如圖 (c)所示。
- 這項推論顯示近年來雖然許多學術與研究機構投入相當多的資源發展新的CRI指數，但結果卻呈現傳統CRI對光源照明色彩忠實度的評價還是具有相當高的準確度。

THANKS FOR YOUR ATTENTION