International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

# ABSTRACT BOOKLET

## CIE2025 SCIENTIFIC CONFERENCE

*July 7-9, 2025*

# MIDTERM MEETING VIENNA, AUSTRIA

**CIE2025** July 4–11, 2025

# ABSTRACT BOOKLET

## CIE 2025 SCIENTIFIC CONFERENCE

*July 7-9, 2025, Vienna, Austria*

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# Contents

## About this Abstract Booklet

This Abstract Booklet compiles the abstracts of all oral and poster presentations to be delivered at the CIE 2025 Scientific Conference, taking place from July 7-9, 2025. The abstracts of the contributions accepted through double-blind peer review are included. Abstracts of invited keynotes and workshops selected by the ISPC are also included.

The abstracts are organized according to the order of presentations at the conference on Monday, Tuesday and Wednesday. The abstracts are arranged with the (Short Paper) ID numbers.

The abstracts have been organized in the following order:

**Monday, July 7, 2025**:
09:15 - 10:15: Keynote lecture 1
10:45 - 12:25: Oral Session 1, Oral Session 2 and Oral Session 3
13:25 - 15:05: Workshop Session 1, Workshop Session 2 and Workshop Session 3
15:35 - 16:20: Presented Poster Session 1, Presented Poster Session 2 and Presented Poster Session 3
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**Tuesday, July 8, 2025**:
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**Wednesday, July 9, 2025**:
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14:50 - 16:30: Oral Session 16, Oral Session 17 and Oral Session 18

## Monday, July 7, 09:15 - 10:15: Keynote lecture 1

# THE MULTIFACETED IMPACTS OF LIGHT-POLLUTION

**Dr. Dietmar Hager**
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Light-pollution, the excessive or misdirected artificial light in the environment, is a growing concern with profound implications across economic, ecological, health policy, and cultural dimensions. Economically, light pollution increases energy consumption, inflating costs for municipalities, businesses, and households. Inefficient lighting design exacerbates this waste, highlighting the need for more sustainable infrastructure. Ecologically, artificial lighting disrupts natural ecosystems, altering animal behaviors such as migration, reproduction, and predation. Nocturnal species, in particular, are vulnerable, facing habitat loss and population declines due to altered circadian rhythms. From a health perspective, light pollution poses risks to human well-being. Overexposure to artificial light, particularly blue light at night, interferes with melatonin production, leading to sleep disorders and increasing the likelihood of chronic illnesses such as obesity, depression, and cardiovascular diseases. Health policy must address these risks by promoting awareness and implementing guidelines for safer lighting practices. Culturally, light pollution diminishes humanity's connection to the night sky, erasing millennia of stargazing traditions and disrupting astronomical research. This loss of cultural heritage undermines our ability to understand and appreciate the cosmos. Addressing light pollution requires a multidisciplinary approach, combining technological innovation, policy reform, and public education. Solutions such as adopting energy-efficient lighting, enforcing dark-sky regulations, and raising awareness about its far-reaching effects can mitigate its impact. Tackling light-pollution is not only an environmental imperative but also a societal one, demanding collective action to restore balance between artificial illumination and the natural night.

## Monday, July 7, 10:45 - 12:25: Oral Session 1 (OS1): D3/D8 - Interior lighting

### ID173
### SPATIO-TEMPORAL DYNAMICS OF KOMOREBI LIGHT PATTERNS

**Zhujing ZHANG, Prof. Marilyne ANDERSEN**
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Komorebi, the dappled sunlight filtering through trees, offers restorative benefits in outdoor and indoor environments. While studies have examined its presence, movement, and changes in illuminance, a comprehensive understanding of its dynamic properties remains largely unexplored. This study develops a framework to quantify the spatial and temporal characteristics of Komorebi patterns. The methodology involves collecting Komorebi scenes, extracting their temporal and spatial features, and creating a multidimensional representation to capture these features effectively. The spatial feature analysis focuses on light pattern dispersion, intensity correlations, and spectral analysis of two-dimensional patterns; the temporal analysis, on the other hand, examines movement, directional changes, and brightness fluctuations. This study introduces a novel approach for categorizing and representing different typologies of Komorebi, and establishes a basis for examining people's responses to Komorebi patterns.

*Keywords:* Komorebi, Dappled Sunlight, Spatial Characteristics, Temporal Dynamics

### ID222
### EFFECT OF TARGET AND AMBIENT LIGHTING ON SPATIAL IMPRESSION AND SUBJECTIVE VISUAL PERFORMANCE

**Saori UENO, Masato FUWA, Kenji MUKAI, Dr. Tatsukiyo UCHIDA**
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Activity Based Working offices has gained attention, and various lighting design values for various activities are becoming more important. Target and ambient lighting (TAL), creating the diversity of illumination distribution, is expected not only to contribute to decarbonization but also to diversify spatial impressions compared to general lighting. This paper clarifies the lighting requirements diverse spatial impressions and subjective visual performance. Also, age-related differences for those were examined. The results suggest that the target/ambient illuminance ratio (TAIR) of approximately 2, coupled with a lower CCT, enhances a warm atmosphere. Conversely, a TAIR of 3 or higher, increases task immersion. No significant differences related to age were showed in terms of spatial impressions. On the other hand, subjective visual performance of over-40 group is low with narrow beam angle target lighting. Thus, lighting design values in workspaces should be adjusted based on demanding spatial impression and the age of workers.

*Keywords:* target illuminance, ambient illuminance, luminous intensity distribution, CCT

## ID273
## HOW LIGHT VARIES ACROSS DIFFERENT LEVELS: INSPECTING CONVERGENCE AND DISCREPANCIES IN MEASUREMENTS FROM FIXED OUTDOOR AND INDOOR MONITORING AND PERSON-WORN SENSORS

**Yunyi ZENG[1,3], Karin C.H.J. SMOLDERS[2], Yvonne A.W. DE KORT[2], Borong LIN[1,3]**
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This study conducted two field tests in offices to investigate the convergence and discrepancies of fixed and personal light measurements. Firstly, an open-plan office was monitored with sensors at various points from outdoor weather station to person-worn pendants for one week. Secondly, personal light exposure of an office worker was monitored with wearable sensors at multiple measurement points, including forehead, eyeglasses, pendant, and wrist. Data analyses involved time-series plots, Pearson correlations, linear regression, and Bland–Altman comparisons. Results indicate that window-side measurements could estimate workstation light levels but require caution regarding direct sunlight. As for personal light evaluations, fixed workstation measurements were incapable of capturing temporal fluctuations in individuals' light exposure. For wearable sensors, measurements from eyeglass-mounted devices were comparable to those from forehead-mounted sensors, while pendant/wrist sensors required calibration. These findings highlight the importance of measurement calibration and integrating wearable sensors in field studies for healthy lighting design.

*Keywords:* Light Measurement; Wearable Sensors; Time Series Data; Healthy Lighting

## ID358
## NOVEL APPROACH TO INTEGRATIVE LIGHTING DESIGN FOR DIFFERENT AGE GROUPS: A COMPREHENSIVE METHOD FOR PARAMETERIZING LIGHTING SITUATIONS

**Robert SUPRONOWICZ**
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This study introduces the novel "Comprehensive Lighting Situation Parameterization" (CLSP) method, which enables in-depth spectral analysis of entire lighting situations through a single simulation. At a room scale, CLSP accurately models the relationship between the spectral radiant flux of luminaires and compliance with task lighting and melanopic lighting criteria for users of various ages. The analysis integrates diverse parameters, including interior finish materials, photometric light distributions of luminaires, and the spectral power distributions (SPDs) of phosphor-converted LEDs (pcLEDs) commonly used in interior applications. By applying CLSP, 3015 SPDs were evaluated across 20 lighting situations to determine the required luminous flux for different age groups. Notably, the method eliminates the need for repeated simulations to analyse SPDs, significantly reducing computational time. This innovative approach provides a scalable and efficient framework for optimising integrative lighting systems tailored to diverse user needs while ensuring compliance with established lighting standards.

*Keywords:* Integrative Lighting, Melanopic Lighting, Sustainable Development Goals

# ID176
# TOWARDS AN ISO/CIE STANDARD FOR BSDF CHARACTERIZATION OF SHADING AND DAYLIGHTING SYSTEMS

**David GEISLER-MORODER[1], Eleanor S. LEE[2], Lars O. GROBE[3,4], Gregory WARD[5]**
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Shading and daylighting systems such as textiles, louvres, and prismatic glazings are used to modulate incident solar radiation. The scattering properties of these “complex fenestration systems” (CFS) determine the temporally-variant, spatial distribution of daylight and solar radiation and thus affect the energy, global warming potential, comfort, health, and qualitative performance of buildings and the urban environment. Angle-dependent, solar-optical properties of CFS (i.e., bidirectional scattering distribution function (BSDF) data), however, are often unavailable or inaccurate, hindering simulated evaluations of environmental performance. New general methods for characterizing BSDF properties have been developed and extensively validated. This article describes the ISO/CIE 25176 initiative (launched in July 2024) that aims to standardize these methods for any arbitrary CFS. Open questions such as the limits of applicability are discussed. Standardization will have immediate implications on building performance analyses, e.g., the recent adoption of ISO/CIE 10916 for lighting energy simulations now requires use of BSDF data.

*Keywords:* Bidirectional scattering distribution function (BSDF), complex fenestration systems (CFS), characterization, standardization, daylight simulation

## Monday, July 7, 10:45 - 12:25: Oral Session 2 (OS2): D2 - Photometry & radiometry 1

### ID253
### STABILITY OF INDUCED JUNCTION PHOTODIODES UNDER UV IRRADIATION

**Aarre Viljami KILPELÄINEN[1], Dr. Farshid MANOOCHERI[1], Dr. Fredrik EDHBORG[2], Dr. Stefan KÄLLBERG[2], Dr. Ozhan KOYBASI[3], Dr. Lutz WERNER[4], Dr. Jarle GRAN[5], Prof. Erkki IKONEN[1,6]**

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Induced junction photodiodes have shown unprecedented stability and predictability at visible wavelengths, but they may undergo responsivity changes when exposed to UV irradiation. When using induced junction photodiodes in a Predictable Quantum Efficient Detector (PQED) with operation range extended to UV, the irradiation hardness of photodiodes is of critical concern. Two different types of induced junction photodiodes were exposed to UV irradiation at 280 nm and 300 nm wavelengths. Their responsivity was monitored during the irradiation and the UV and visible spectral responsivities were compared before and after the irradiation. Our results show excellent stability for the first type of photodiode when irradiated at 300 nm, but clear degradation at 280 nm, whereas the second type of photodiode remained stable down to 280 nm. This significant outcome opens the way to extend the predictability of PQED to the previously inaccessible wavelength range from 280 nm to 450 nm.

*Keywords:* Stability, UV irradiation hardness, induced junction photodiode, PQED, Chipscale photodiodes, Qu-candela photodiodes

### ID268
### ENHANCING MEASUREMENT ACCURACY IN MICROSCOPE-BASED REFLECTOMETRY FOR THIN FILM OPTICAL CHARACTERIZATION

**Masoud RASTGOU[1], Aleksandr DANILENKO[1], Farshid MANOOCHERI[1], Juha PELTONIEMI[1], Erkki IKONEN[1,2]**

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Thin-film thickness characterization is important in the semiconductor and photonics industries. This study introduces for the first time an enhanced reflectance modelling method for microscope-based reflectometers with focused beams, aimed at achieving accurate thin-film thickness measurements for layers ranging from tens to thousands of nanometers. The proposed approach integrates angular distribution modelling, bandwidth correction, and thickness gradient analysis to improve the precision of modelling used to fit measured reflectance curves and extract the optical properties of the layers. Validation against a traceable gonio-reflectometer with a collimated beam shows excellent agreement across a wide thickness range, confirming the micro-reflectometer's reliability for high-accuracy, non-destructive characterization. The gonio-reflectometer's reliability was verified through an international comparison using ellipsometry method on the same samples. The advancements of this work enable more reliable thin-film analyses using microscope-based reflectometers, which offers the advantages of faster operation and suitability for measurements of small areas on semiconductor wafer samples.

*Keywords:* Micro-reflectometer, angle of incidence, thin film thickness, bandwidth

## ID235
## A MATHEMATICAL FRAMEWORK FOR COMPARING PHOTOMETRIC OBSERVERS

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The V(λ) function, a photometric observer representing the spectral luminous efficiency of human vision, has been the basis of photometry for 100 years. Cone fundamentals offer an alternative to V(λ), $V_F(\lambda)$, which is accepted as a better match to human vision. In addition, the framework of cone fundamentals allows parametrization of $V_F(\lambda)$ to account for the significant diversity among human populations, e.g. for changes as we age and also changes with respect to field-of-view. There is currently a debate about the potential benefits of changing the normative photometric observer, defining the photometric units, from V(λ) to a cone fundamental based observer, e.g. $V_F(\lambda)$. A change from V(λ) to any other reference observer would require good justification as it would have profound consequences for measurement technology, metrology and the photometric unit scale. This paper introduces a mathematical framework for comparing one observer against another observer, across observer populations and lighting applications.

*Keywords:* Photometry, Cone fundamentals, Photometric observers

## ID267
## PSYCHOPHYSICAL EXPERIMENT TOWARDS A MEASUREMENT SCALE OF SPARKLE

**Nathan David SLEMBROUCK[1], Alejandro FERRERO[2], Esther PERALES[3], Nina BASIC[4], Jan AUDENAERT[1], Frédéric Benedict LELOUP[1]**
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The visual appearance effect known as sparkle, defined as observed bright points of light contrasted with a darker surround, is frequently used to enhance modern product finishes. Existing commercial instruments measure sparkle using proprietary methods, lacking standardisation. To address this issue, CIE is working on the recommendation of a sparkle measurement scale based on luminance factor images. This paper presents the results of a study on the correlation between sparkle as optically quantified through luminance factor images and as visually assessed through a magnitude estimation experiment. To this end, 66 samples were selected, obtained from different manufactures and exhibiting different sparkle effects. The study demonstrates that the degree of correlation is strongly dependant on the sample type. This result illustrates that more research is needed for defining a general measurement and or processing procedure that is applicable to a wide variety of sample types.

*Keywords:* Visual Appearance, Soft Metrology, Sparkle

## ID199

# EXPLORING DAILY LIGHT EXPOSURE: DOCUMENTING REAL-LIFE DATA WITH PERSONAL LIGHTLOGGERS IN SPAIN

**Dr. Sofia MELERO-TUR, Dr. David BAEZA-MOYANO, Dr. Guadalupe CANTARERO-GARCÍA, Dr. María Concepción PÉREZ-GUTIÉRREZ, Dr. Roberto Alonso GONZALEZ-LEZCANO**

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The European Partnership of Metrology, on behalf of EURAMET, is conducting a global field campaign to quantify human exposure to visible and ultraviolet (UV) light, thereby supporting the future development of improved personal light dosimeters and guiding evidence-based luminaire design. This initiative leverages personal daily-light measurements collected both indoors and outdoors across six geographically diverse sites on multiple continents. By systematically capturing how much light reaches the human eye and identifying key spectral components necessary for optimal illumination, these data will inform refined practical recommendations for advanced indoor lighting solutions. Through ongoing field data collection, the project aims to raise awareness among manufacturers, designers, and end-users, ensuring the widespread adoption of adequate, well-balanced light environments. This paper presents the Spanish contribution to the consortium's overall goals, highlighting the methodology employed, preliminary insights, and the potential impact on future lighting practices.

*Keywords:* melatonin, light logger, visible light, circadian rhythms, melanopic EDI

## Monday, July 7, 10:45 - 12:25: Oral Session 3 (OS3): D4 - Exterior lighting

### ID225
### EFFECT OF FLUCTUATING EXTERIOR LIGHTING ON IMPRESSION: INFLUENCE OF THE NUMBER OF LUMINAIRES AND INSTALLATION INTERVAL

**Masayuki IKEBUCHI[1], Ayana TAKEI[2], Prof. Kazuto TAKASE[2], Toshiyasu TANAKA[1], Dr. Tatsukiyo UCHIDA[1], Kenji MUKAI[1], Prof. Nozomu YOSHIZAWA[2]**

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Dynamic changes in light, such as those produced by candles and fireflies, are known to provide a sense of comfort. Some luminaires recreate the changes. However, there are limited researches on the spatial impressions created by the installation of multiple luminaires with light fluctuation. In this study, we recreated the fluctuating light imitating candles and fireflies and evaluated the impressions under varying installation conditions. Results indicated that a smaller number of luminaires with greater interval contributed to a more comfortable atmosphere, while a larger number and shorter interval enhanced vitality. Furthermore, in experimental environment resembling actual usage conditions, we conducted impression evaluations separately during seating and passage. Compared to static lighting, significant differences were observed in “comfort” during seating, and in “visibility” during passage. This suggests that fluctuating light can create a pleasant spatial ambiance, although the evaluation of "vitality" may be influenced by the size of the installation space.

*Keywords:* Exterior Lighting, Fluctuating Light, Installation Interval, Impression

### ID263
### INTEGRATING EMOTIONAL AND VISUAL DIMENSIONS IN URBAN LIGHTING DESIGN: A HOLISTIC APPROACH USING THE PAD MODEL AND LIGHT FIELD METRICS

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Traditional urban lighting design emphasizes visibility and safety but often overlooks emotional and social responses. This study proposes an integrated triadic framework combining the PAD emotional modelling, Visual Light Field (VLF) theory, and cubic illuminance metrics to evaluate the affective impacts of spatial lighting. A pre-social survey and two controlled simulation experiments were conducted to examine perceptual and emotional effects under varied lighting configurations. Results show that greater horizontal illuminance asymmetry significantly elevates Arousal while reducing Pleasure and Dominance, while the richness of higher-order lighting components significantly enhances Pleasure and Dominance. These findings support experience-driven lighting strategies and provide actionable metrics for designing emotionally responsive public spaces.

*Keywords:* PAD Emotional Model, Visual Light Field, Cubic Illuminance Metrics, Lighting Asymmetry, Urban Public Space

## ID296
## IS THE COST 331 SOFTWARE STILL RELEVANT FOR CHARACTERISING THE VISIBILITY OF ROAD MARKINGS?

**Dr. Joffrey GIRARD[1], Dr. Laure LEBOUC[1], Dr. Valérie MUZET[2]**
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This study aims to evaluate the relevance of the daytime visibility distances of the road marking predicted by the software developed by COST 331. To do this, an experiment was carried out on a test track with two road surfaces (asphalt and concrete) on which new and worn discontinuous marking lines were applied. The visibility distance obtained with the software from static $Qd$ and horizontal illuminance measurements was compared to visibility distances calculated with the Adrian's model from luminance images acquired dynamically. The results show that the software systematically overestimates the visibility distance, in particular due to its failure to consider the variability of the perceived luminance as a function of the viewing distance. Moreover, the results question the fact that the standardized indicators of the visibility of road markings should really considered the contrast between the marking and the surrounding road surface.

*Keywords:* Visibility, Road Marking, Luminance

## ID218
## LUMINANCE CONTRAST THRESHOLD UNDER ROAD LIGHTINGS IN REVERSED SILHOUETTE VISION AND SILHOUETTE VISION

**Kazuki TSUKAGOSHI[1], Dr. Sho TAKAHASHI[1], Dr. Toru HAGIWARA[1], Dr. Miyoshi AYAMA[2], Hiroo KUNIYOSHI[3], Yoshiyuki SAGANE[4]**
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In Japan, low-position lighting systems have been proposed. Under these systems, the occurrence rate of obstacles visible as reversed silhouette vision is not negligible. Therefore, it is desirable to propose performance indicators combining reversed silhouette vision and silhouette vision. The present study investigates the luminance contrast thresholds of obstacles in reversed silhouette vision and silhouette vision under the same experimental conditions by conducting a laboratory experiment. The results show that the increase in luminance contrast threshold is greater in reversed silhouette vision than in silhouette vision as the average road surface luminance decreases. Furthermore, we compared the results of the laboratory experiments with the results of the field experiments using low-position lighting systems to verify the validity of the laboratory experiment. The results suggest that the luminance contrast thresholds obtained in the laboratory experiments could be used to assess the visibility of obstacles under arbitrary road lighting conditions.

*Keywords:* Visibility of Obstacles on the Road, Reversed Silhouette Vision, Silhouette Vision

# ID141
# STATIC AND DYNAMIC ASSESSMENTS OF LIGHTING QUALITY: A FIELD EXPERIMENT

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Evaluation of lighting quality of urban space at night can be collected in asking pedestrians at a specific place of the space while looking at it, or after walking, which is a more ecological behaviour. This study addresses this methodological issue in comparing static evaluations (free gaze in one direction; fixed position) and evaluations after a walk in the street (free gaze; ecological task) in three urban pedestrian pathways. Subjective assessments about the perceived luminous environment, discomfort from glare, perceived safety and the overall satisfaction were collected after a 15-m walk on a pedestrian path (dynamic) or standing at a static position at mid-distance of this 15-m path. Forty-three participants were involved in the experience. No difference was found between evaluations in static position or after walking, except for the perceived visibility and the item “I feel uncomfortable with the idea to walk into this street”.

*Keywords:* lighting quality, pedestrian, urban lighting, ecological task

## Monday, July 7, 13:25 - 15:05: Workshop Session 1 (WS1): D1

### PERSONAL COLOUR MANAGEMENT FOR DISPLAY DEVICES AND CONSUMER PRODUCTS

Convenor:
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The way we perceive colours varies significantly from person to person due to individual differences in the spectral sensitivities of short-, middle-, and long-wavelength cone photoreceptors. These variations can result in noticeable colour mismatches, known as metamerism failures, when viewing displays or consumer products. Addressing these discrepancies offers clear advantages for industry. Some products can be designed to minimise colour mismatches across diverse observers, while others, such as personal displays, can be tailored to optimise colours for individual users.

## Monday, July 7, 13:25 - 15:05: Workshop Session 2 (WS2): D3

### TAILORING INDOOR LIGHTING REQUIREMENTS TO MEET USERS' NEEDS

Convenor:
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Effective indoor lighting design requires interdisciplinary knowledge that extends beyond technical expertise. Lighting ensures safe usability, supports performance, and enhances visual comfort and well-being. Beyond functionality, it shapes the appearance of spaces, highlights details, and guides interpretation and use. A holistic approach is essential, integrating space, function, users, technology, and materials. Defining lighting requirements is a crucial step, balancing various influencing factors. While guidelines and standards offer criteria based on typical conditions, actual lighting needs may vary due to task-specific, personal, or contextual factors. This workshop explores a new decision-making framework for determining indoor lighting requirements. It will discuss an approach that goes beyond activity type, incorporating key influencing variables such as visual task characteristics, individual differences, and environmental context.

## Monday, July 7, 13:25 - 15:05: Workshop Session 3 (WS3): D6

# ELECTRIC LIGHT EFFECT ON INSECTS AND WILDLIFE

Convenor:
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With the significant uptake of LED lighting at night there have been increased concerns regarding the potentially adverse ecological impact upon animal and insect life. For example, baby sea turtles are sensitive to the spectrum typical of starlight and have been attracted away from nests by high colour temperature lighting at night. Likewise, outdoor lighting can disorient birds and fish. Many insects are attracted to shorter visible and near ultraviolet (UV-A) light may alter their normal behaviour. This topic may be particularly important for spectral distributions of outdoor lighting shifting to shorter wavelengths. Over the past century, insect light traps were developed to attract insect pests. However, many insects play important ecological roles, such as pollination of plants or as part of the food chain. Can higher CCT outdoor lighting disturb insects' normal nighttime behaviour? How much does the spectral composition of different sources attract different species, and how strongly or weakly?

## Monday, July 7, 15:35 - 16:20: PS1: Presented Posters (D2/D3)

### ID123
### POTENTIAL OF LED-BASED STANDARD SOURCE PROVIDING CIE STANDARD ILLUMINANT A

**Kenji GODO[1], Kenichi KINOSHITA[1], Yuri NAKAZAWA[1], Kohei ISHIDA[2], Ai FUJIKI[2], Mako NIKAI[2], Yumiko NIIMI[2], Hideki TERANISHI[2], Tetsuya NISHIOKA[2]**

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Illuminance meter calibration using incandescent standard lamps has long served the industry. However, the phase-out of incandescent lamps presents difficulties in maintaining the calibration schemes. The National Metrology Institutes have received strong addresses for an alternative light source. To address this, Illuminant A standard LED was developed to provide CIE standard source A. The standard LED realised a CIE illuminant A spectrum using a customised LED. The spectral distribution mismatch index was 2.5 %. In this study, the relation between $V$ (λ)-mismatch index ($f_1$') and the spectral mismatch correction factor (SMCF) was studied in detail using 144 illuminance meters data to demonstrate that the standard LED has the potential to replace for standard lamps. The findings demonstrated that for illuminance meters better than $f_1$' = 6, they had the SMCFs of better than 1.007. In practical calibration, Illuminant A standard LED was found to be sufficient to replace standard lamps.

*Keywords:* 2856 K, CIE standard illuminant, Illuminance meter, Planck radiation, Standard lamp

### ID137
### RESULTS OF THE JOINT LED AGING EXPERIMENT OF THREE UNIVERSITY LABORATORIES WITHIN THE AI-TWILIGHT PROJECT

**Dr. Gusztáv HANTOS[1], Dr. János HEGEDÜS[1], Dr. András POPPE[1], Dr. Alexander HERZOG[2], Dr. Alessandro CARIA[3], Dr. Matteo BUFFOLO[3], Dr. Carlo DE SANTI[3], Dr. Nicola TRIVELLIN[3], Dr. Enrico ZANONI[3], Dr. Matteo MENEGHINI[3]**

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In this paper, a detailed description of the mid-power LED aging experiment carried out within the AI-TWILIGHT H2020 ECSEL project shall be provided. This was a mitigation action, called the JointLab project to provide detailed LED aging data to allow the creation of even LED-age dependent multi-domain models with the timeframe of the 3 years of AI-TWILIGHT. This was an extended LM-80 test with the collaboration of the laboratories of three academic partners, during which a large space of stress conditions applied during the aging process was covered and a set of measurements more detailed than usual in a standard LM-80 lifetime test had been performed at the predetermined intervals, more frequently than in most LM-80 tests. The goal was to create a so-called multi-domain circuit simulation model that could also describe the effect of LED aging as a function of the elapsed operating time and operating conditions.

*Keywords:* LM-80 aging test of mid-power LEDs, AI-TWILIGHT, JointLab project

## ID138
## LIFETIME MULTI-DOMAIN MODELING OF MID-POWER LEDS

**Dr. Márton NÉMETH, Dr. János HEGEDÜS, Dr. Gusztáv HANTOS, Dr. András POPPE**
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This paper presents the LED modelling work carried out in the AI-TWILIGHT H2020 Ecsel project. The new multi-domain LED model was developed based on measurement results of a comprehensive aging test carried out by an international collaboration of three academic laboratories. In addition to elapsed operating time, the new model also considers past stress conditions, i.e. forward current and temperature profiles. The predictive power was tested by fitting the model to measurement results performed during a pre-defined minimum test time, then comparing the resulting simulation results with real measurement data obtained at later times. The power of modelling different stress conditions was also verified by swapping the stress conditions for 2 x 2 sets of LED samples under test and continuing the aging test in this manner, thereby mimicking a sudden change in the LED samples' mission profiles resulting also in a change of the consumption rate of their lifetime-budget.

*Keywords:* lifetime modelling, multi-domain modelling, mid-power LED, LED simulation, AI-TWILIGHT, JointLAB project

## ID158
## LED PHOTOMETRIC MEASUREMENT BASED ON LED STANDARD LAMPS

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The study of LED photometric measurement, which utilizes LED standard lamps as a complement to traditional incandescent standard lamps, has been undertaken. As a means to transition the photometric scale, LED transfer standards are crucial for LED photometry. This research investigates the development of LED lamps designed for luminous intensity and total luminous flux, which are intended to emulate their traditional counterparts and maintain compatibility with existing methods of lamp alignment and mounting. The characteristics of these LED lamps, including spectrum, warm-up duration, short-term stability, long-term stability, on-shelf effects, angular intensity distribution, the inverse square law performance, and temperature dependency, have been thoroughly examined. The LED lamps have demonstrated significant potential for photometric applications. Efforts are currently underway to employ LED transfer standards in LED photometric measurements to build traceability to the national primary scales at the author's institute.

*Keywords:* LED, Photometry, Transfer standards, Standard lamps

## ID242
## WAVELENGTH CALIBRATION WITH A TUNABLE MONOCHROMATIC SOURCE BASED ON A SUPERCONTINUUM SOURCE

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To evaluate spectral distribution of LED products accurately, a wavelength calibration method was developed using a tunable monochromatic source system based on a supercontinuum source. In this method, the peak wavelength and shape of the monochromatic light obtained from the developed system were characterized using an optical spectrum analyzer with a resolution of 0.01 nm. The wavelength range of the generated monochromatic light was from 430 nm to 900 nm, and a full width at half maximum of the light was better than 0.1 nm. As a results of a wavelength calibration of an array spectroradiometer using the developed system, it seems that the new calibration method can reduce the wavelength calibration uncertainty.

*Keywords:* Array spectroradiometer, Supercontinuum source, Wavelength calibration

## ID325
## HIGH DYNAMIC RANGE IMAGING METHODS FOR TRACEABLE OPTICAL MEASUREMENTS

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Imaging Luminance Measurement Devices (ILMDs) are increasingly used for optical measurements in applications like glare analysis and obtrusive light evaluation. However, the dynamic range of digital imaging sensors is often insufficient for typical scenes in these applications, requiring high dynamic range (HDR) imaging methods. HDR imaging typically involves capturing multiple low dynamic range (LDR) images at different exposures and combining them using an HDR merging algorithm. Most HDR imaging methods were established with the objective to produce aesthetic images, however, our objective is to understand how to best apply the methods to produce accurate and traceable measurements. This study reviews suitable HDR merging algorithms, considering the effects of the instrument, image acquisition method, and processing parameters, with the aim to draw attention to the parameters with the most impact on measurement quality.

*Keywords:* Imaging, HDR, Luminance, ILMD, Metrology

## ID357
## OUTDOOR INTERCOMPARISON OF HDR IMAGING LUMINANCE MEASUREMENT SYSTEMS USING A HIGH CONTRAST LUMINANCE SCENE

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This paper presents the concept, implementation and key results of a field intercomparison campaign on the measurement of a glare scene using High Dynamic Range imaging luminance measurement systems capable of measuring high contrast luminance scenes. Several participants took part in the intercomparison using various imaging systems, covering the majority of the system types used in practice for such measurement tasks. For the purpose of the intercomparison, the outdoor road lighting installation used as glare scene was extended by grey cards (as homogeneous reference targets) and by a specially designed high contrast luminance source offering several decades of luminance level difference. The main target of this comparison was to verify the proper use of the instrumentation and to reveal sources of measurement error and thus uncertainty linked to both the devices and the measurement procedure.

*Keywords:* Glare, Obtrusive light, High Dynamic Range, Imaging, Photometry, Metrology

## ID210
## STUDY ON CALCULATING LUMINANCE DISTRIBUTIONS BY INCORPORATING THE ESTIMATED MODELS OF DIRECTIONAL REFLECTANCE CHARACTERISTICS FROM SIMPLIFIED MEASUREMENTS INTO RADIANCE

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This study verifies the accuracy of the calculated luminance distributions of scaled models with directionally reflective surfaces by Radiance software. It compares them with the luminance distributions calculated by the luminous flux transfer method. The directional reflectance properties of the materials were modelled using data from simplified goniophotometer and used as inputs for the calculations. The Radiance calculations reproduced the maximum luminance and the distributions of the first reflection from the directionally reflective surfaces but not the second reflection. The calculated luminance distributions and Daylight Glare Probability (DGP) due to daylight reflection from the building materials exhibited considerable differences when the building materials were assumed to be ideal uniform diffuse, specular, or directionally reflective surfaces. This suggests that it is necessary to consider the directional reflectance properties of the building materials for glare assessment. Using directional reflectance data modelled from simplified measurements as inputs for luminance calculations is beneficial.

*Keywords:* Luminance Distribution, Calculation, Directional Reflection, Glare

# ID319
# EFFECTS OF CAMERA APERTURE ON STRAY LIGHT IN HIGH DYNAMIC RANGE LUMINANCE IMAGING

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The quality of luminance measurements performed using HDR imaging is significantly impacted by stray light, which manifest itself as diffused stray light, focused ghost images or diffraction. These effects vary with the camera lens aperture and the position of bright light sources both within and outside the field of view. This study investigates the influence of aperture settings on stray light in HDR imaging of high-contrast scenes. To quantify these effects, we captured HDR luminance images of a laboratory scene using a scientific camera at various apertures. We observe that a large aperture (small F-number) tends to increase diffuse stray light around bright sources, while a small aperture (large F-number) intensifies diffraction effects and the overall quantity of stray light in the image but creates less diffuse stray light around the bright source.

*Keywords:* HDR, Imaging, ILMD, Stray light, Photometry

## ID323
## FURTHER DEVELOPMENT OF THE CALCULATION MODEL FOR SPACIOUSNESS TO INCLUDE THE EFFECTS OF WINDOWS AND EXTERNAL SPACE

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Spaciousness is crucial in architectural design, because it affects comfort, productivity, and health. Currently, there exists a model that predicts spaciousness based on distance and luminance, developed through experiments conducted in spaces without windows. Expansion of the scope of application to spaces with windows was reported experimentally; however, the revision was insufficient because the distance to the objects outside the windows was not considered. This study aimed to improve this model to include the effects of windows and external views. Subjective experiments were conducted using both real and virtual reality spaces with different window configurations and variables, such as window position, external scene luminance, and distance to external objects. The results showed that the distance and luminance of external objects affected spaciousness. The model was revised to reflect the situation outside the window by employing modified distances for outside objects and weighting the internal and external parts differently.

*Keywords:* Spaciousness, Window, Brightness, 3D luminance mapping, Virtual Reality

## ID197
## DAYLIGHT PERFORMANCE OF PERFORATED SOLAR SCREEN FACADES IN OFFICES: A CASE STUDY

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The use of a Perforated Solar Screen (PSS), as a second layer of Double Skin Façades, is an effective strategy for controlling excessive sunlight, particularly in fully-glazed buildings, while also enhancing the aesthetic appeal of the facades. PSS systems are also a key factor for optimizing daylight conditions that affect occupants' visual comfort. However, there is a notable lack of studies focusing on the daylight performance of PSS facades in offices. For this reason, this study investigates the impact of daylighting on visual comfort conditions in offices with the use of PSS facades. This research evaluates the effects of various PSS design alternatives on visual comfort conditions in terms of daylight provision, glare, and view out as described in the EN 17037 standard. The results demonstrate the daylight performance of PSS systems regarding design alternatives that involve different PSS materials and positions in offices.

*Keywords:* Perforated Solar Screen, Daylight Performance, View Out, Glare, EN 17037, Office Building

## ID333
## ABILITY OF COMMON GLARE INDICES TO EVALUATE DISCOMFORT GLARE IN THE PRESENCE OF MULTIPLE ELECTRIC LIGHT SOURCES

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The Unified Glare Rating(UGR) was introduced by the CIE as a simpler alternative to the CIE Glare Index(CGI) for predicting discomfort glare from electric lighting, using background luminance(Lb) instead of vertical illuminance(Ev) for adaptation. With the rise of image-based luminance measurements, CGI's complexity is no longer a limitation, prompting renewed comparison between the two models. This study evaluated UGR and CGI under controlled electric lighting with multiple glare sources, building on findings that CGI outperforms UGR in daylight. A controlled experiment with 34 participants showed both models aligned similarly with subjective discomfort ratings. Notably, adding a second glare source did not consistently increase perceived glare, revealing limitations in the assumption of glare additivity. These findings highlight the need for further research into how the number and type of glare sources—particularly the interaction between electric and daylight—affect glare perception to improve prediction models for more realistic lighting environments.

*Keywords:* discomfort glare, metrics, adaptation level, multiple, electric glare sources

## ID338
## ENERGY-EFFICIENT LIGHTING DESIGN FOR HAGIA EIRENE: TAILORED SOLUTIONS FOR WORSHIP, CONCERT AND MUSEUM SETTINGS

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Throughout history, churches have served as central gathering places for various activities. This study aims to propose energy-efficient lighting design recommendations for the Hagia Eirene Museum considering its potential uses and adhering to the ISO/CIE 8995-1:2025 and the Society of Light and Lighting Guide 13: Lighting for Places of Worship (SLL LG13) standards. Three different utilization scenarios were chosen as the basis for these recommendations: the museum envisioned as a concert venue, a common use of the space throughout the building's history, a church for which it was originally built, and a museum, the actual utilization of the space as of 1800s. Different lighting design proposals were developed to meet the unique requirements of each scenario. To achieve this, the historic building's 3D model was created using DIALux evo. Recommendations and photometric calculations, including illuminance levels and glare, have been made based on this model.

*Keywords:* Lighting Design, Church Lighting, Concert Lighting, Museum Lighting

## ID362
## STUDY ON SPATIAL BRIGHTNESS EVALUATION USING OLED LIGHTING

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OLED (Organic Light Emitting Diode) lighting, expected to gain adoption as next-generation lighting, offers unique features like a thin, lightweight design and surface emission, enabling flexible lighting designs. Its low luminance allows exposed emitting surfaces to enhance energy efficiency, reduce glare, and ensure required illuminance. Current brightness prediction formulas exclude high-luminance regions, such as lighting fixtures, which could lead to inaccuracies in brightness predictions. The influence of high-luminance regions on perceived brightness remains unclear. This study examined the effects of differences in light source types (OLED or LED), luminance, and arrangement on spatial brightness. The results showed that LED lighting was rated brighter due to its higher luminance, while OLED lighting was associated with lower glare ratings. When OLED lighting was positioned in the peripheral view, increasing the solid angle tended to reduce glare and enhance brightness. These findings suggest that strategic light source arrangement can enhance brightness.

*Keywords:* OLED Lighting, LED Lighting, Spatial Brightness, Glare

## ID269
## DAYLIGHT REQUIREMENTS AND METRICS IN PRACTICE: A CLIMATIC ANALYSIS OF CURRENT CRITERIA

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Daylight is vital to human life. However, architectural reference documents often lack clear daylighting goals. This article investigates daylight requirements and metrics in such documents, focusing on a climatic approach. The methodology involved systematizing documents collected, classifying climate criteria, mapping daylight recommendations by climate zones, and analysing metric types and their applications. Findings show that 60% of the metrics are geometric and 37% are non-geometric. In this sample, most documents (72%) are from temperate climates, followed by 18% from tropical, and 5% each from dry/arid and continental; none were from polar regions. Similarly, 65% of daylight metrics apply to temperate climates, 16% to tropical, 10% to dry/arid, and 9% to continental. While geometric metrics are more commonly used in daily practice, those do not ensure proper daylighting indoors. Non-geometric metrics, though less applied in practice, are more closely linked to higher building performance.

*Keywords:* Daylight requirements, Daylight metrics, Standards, Rating Systems, Building and Urban Codes, Regulations, Guidelines, Climate

# ID348
# DEVELOPMENT OF PHOTON FLOW THROUGH PRACTITIONER DIALOGUES – DESIGNING EXHIBITION SPACES ENVELOPED IN DIFFUSE LIGHT

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Accurately capturing three-dimensional light distribution (Light Field) in architectural spaces with complex geometries and lighting environments is a significant challenge. This study focused on improving photon flow, a method for visualising the light field and examining its applicability in practice. Existing visualisation methods based on photon mapping algorithms capture the direction and intensity of light from the spatial distribution of photons. However, understanding the directionality of light remains challenging in spaces predominantly illuminated by indirect light. Using Rosanjin Hall at the Adachi Museum of Art, an environment primarily dominated by indirect lighting, we implemented improved methods and had practitioners observe the Photon Flow within the space. The results highlighted advantages such as enhanced visual clarity of light flows and evaluation of the practical utility of the method. Simultaneously, issues related to the parameter settings during photon flow creation were identified.

*Keywords:* Light Field, Photon Flow, Photon Mapping, Head-mounted display (HMD), Virtual Reality (VR)

## Monday, July 7, 15:35 - 16:20: PS3: Presented Posters (D1/D2/D6)

### ID394
### THE EFFECT OF LIGHT DIRECTION ON PUPILLARY LIGHT REFLEX: A PILOT STUDY

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Standard methods of measuring biological effects of light often disregard the varied spatial distribution of light in the environments because they are represented by a single measurement at the eye. However, the retina has a high spatial resolution, and the photoreceptors are not evenly distributed, implying that light fields with identical corneal irradiance and varying spatial patterns may elicit distinct retinal responses. This pilot study investigated how spatial light distribution across a wide field of view affects the pupillary light reflex (PLR). In a laboratory experiment each stimulus was calibrated to 80 lux near the cornea and the spectral power distribution was constant across scenes.

Time series plots demonstrate greater pupil sustained constriction when light is focussed in the central field of view compared to other spatial distributions, implying that PLR is dependent on spatial distribution and that light in the central field is more effective in eliciting pupillary constriction.

*Keywords:* Non-visual effects, lighting distribution, pupillary light reflex

### ID177
### THE VISIBILITY OF TARGETS: DISCS VS GRATINGS

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The CIE approach to target visibility is based on Blackwell's experimental data of contrast thresholds for uniform discs on uniform backgrounds. An analytical model of detection thresholds has been proposed by the CIE (1972; 1981) followed by Adrian (1989). Another line of research is based on the fact that the detection threshold of a periodic pattern can be derived from the detection thresholds of its Fourier components, using the Contrast Sensitivity Function (CSF) of the human eye. We use a computer vision algorithm to compare the two approaches: a bank of spatial filters is tuned in order to compute the visibility of edges in an image, in a way which is consistent with the CSF (Joulan et al., 2011a). It allows comparing the visibility computed from a CSF-based method to the visibility computed from Adrian's formula, on the same images.

*Keywords:* Visibility, Contrast sensitivity function, detection threshold

## ID359
## RELATION OF CONE FUNDAMENTALS TO UNITS, QUANTITIES AND SYMBOLS

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Photometry aims to measure physical quantities with high correlation to physiological properties of the human vision system. The spectral luminous efficiency function based on cone fundamentals provides a better description of the relative spectral responsivity of the human eye than the photopic $V(\lambda)$ function, which is widely used in photometric measurements. That situation has prompted a discussion on replacing $V(\lambda)$ with another weighting function and on the consequences of such a change. This paper is a contribution to the discussion, including a projection how such a change could take place over a long transition period. As a brief summary, the units would stay unchanged, new quantities would need to be defined, and symbols might have a more definite role than earlier.

*Keywords:* Photometry, human eye, luminous flux

## ID206
## ASSESSING VISUAL ATTENTIVENESS IN RETAIL ENVIRONMENTS USING A HUMAN SUBJECT-BASED TESTING PROTOCOL BASED ON JUST NOTICEABLE DIFFERENCES

**Prof. Diana Valeria ARAIZA SOTO[1], Dr. Siminovitch MICHAEL[2], Dr. Jae Yong SUK[2]**
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This study investigates visual attentiveness in retail environments using a developed human-subject testing protocol. Building on previous research into energy-saving lighting strategies for commercial spaces, this project explores whether dynamic lighting controls can enhance customer alertness while reducing energy consumption. The research focuses on the perceptibility of lighting changes, particularly in terms of dimming and ramping rates, by examining central and peripheral vision responses. A controlled laboratory experiment with 70 participants tested various light intensity adjustments under different ramp rates. The findings aim to inform lighting design protocols that minimize energy waste without compromising customer experience or visual attention. By developing a new experimental methodology for assessing alertness through lighting, this work contributes to sustainable retail lighting design practices and offers insights into how lighting systems can be optimized to boost customer engagement while lowering energy use.

*Keywords:* Lighting design, retail lighting, dynamic lighting controls

## ID341
## HETEROCHROMATIC BRIGHTNESS MATCHING AND RED-GREEN COLOUR VISION DEFICIENCY RECOGNIZING WITH A SOFTWARE BASED ON APPARENT MOVEMENT

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This article introduces software designed for heterochromatic brightness matching (HBM) and red-green colour vision deficiency (CVD) recognition, which operates by minimising apparent movement. Our study focuses on presenting measurements and results on two different displays and laboratory environments using the same concept and principles. To validate the accuracy of the tests' ability to determine both the presence and type of CVD, the results of the tests were compared with those from the Nagel (Type 2 Heidelberg Multi Color) anomaloscope and the Ishihara test (24 plate). Test subjects were categorized into three groups based on their CVD characteristics (normal colour vision, protan, and deutan). The results of the tests aligned with known CVD types in 67 % and 94 % of cases, showing the method's reliability and accuracy in identifying CVD. Additionally, HBM results revealed that distinguishing deutan vision from normal colour vision is considerably more challenging than identifying protan cases.

*Keywords:* Brightness Matching, Colour Vision Deficiency, Apparent Movement, Minimal Motion

## ID190
## ACCOUNTING FOR SPECTRAL CORRELATIONS IN UNCERTAINTY ANALYSIS OF SPECTRAL INTEGRALS

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Measurement errors of spectral irradiance, as an example, are usually highly correlated at neighbouring wavelengths. The key question for the purposes of uncertainty analysis is that how far this correlation extends. Quantities defined in terms of ratios of spectral integrals, such as chromaticity coordinates, are especially sensitive to the features of spectral correlations, because the assumption of uncorrelated spectral measurement errors produces, unrealistically, almost vanishing uncertainty. New insight into the problem of spectral correlations is given by the recent observation that harmonic deviation amplitudes in carefully performed comparison measurements are, on the average, inversely proportional to the harmonic order [Maham et al, 2024]. That observation is sufficient to solve the puzzle of how far the correlation of measurement errors extends at neighbouring wavelengths. Furthermore, it is interesting to note that such inverse proportionality is also observed in many other phenomena in science.

*Keywords:* Photometry, colorimetry, spectral integrals, measurement uncertainty, correlations

## ID343
## UNCERTAINTY EVALUATION OF COLOUR MEASUREMENTS

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Reflectance spectra of a large number of colour reference samples have been measured in d:8° geometry with two independent colour-measuring instruments. An uncertainty band can be associated with each of the measured spectra, but the problem is the unknown correlation of the reflectance values at neighbouring wavelengths, which hampers the propagation of reflectance uncertainty to the uncertainty of colour quantities. To address this problem, a novel spectral analysis of the deviations of reflectance values measured with the independent instruments was carried out. The power-law exponent of the harmonic amplitudes found from this analysis is −0,39. Then iterative Monte Carlo simulations were carried out to determine the corresponding power-law exponents of −0,55 and −0,45 for each instrument, describing spectral reflectance deviations from the unknown true value. With this information a proper account could be made on spectral correlations of reflectance values for propagating the uncertainty into colour quantities like *L**, *a** and *b**.

*Keywords:* Colour quantities, CIELab, reflectance, correlations, uncertaint

## ID390
## APPLICABILITY OF CIE SUPPLEMENTARY PHOTOMETRY FOR GLARE PREDICTION UNDER COLORED DAYLIT SCENES

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In this study, we examined the influence of daylight transmitted through colored glazing on discomfort glare by exposing 56 participants to four daylight conditions with the sun disc visible in their field of view. The conditions varied only in the glazing color (red, blue, green, and neutral) toward the sun while having similar transmittance and glare metric values. Results showed a strong influence of color on glare perception, with more participants reporting glare under red and blue conditions compared to green and neutral ones. These findings indicate that V(λ) is not an effective method for spectral weighting in colored lighting scenarios and that the Helmholz-Kohlrausch (H-K) effect may apply to glare similar to brightness perception. To incorporate this effect in glare model, we implemented the CIE200:2011 supplementary photometry system which integrates the H-K effect and results in better glare prediction in colored daylit scenes.

*Keywords:* Glare, Color, Visual comfort, Daylight, H-K effect

## ID383
# COLOUR ASSIMILATION EFFECTS ON FACES IN FOVEAL AND PERIPHERAL VISION USING CURVED DISPLAY SYSTEM

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Colour assimilation demonstrates how visual perception integrates spatial colour information, yet its effects on socially significant stimuli like faces remain underexplored. This study investigates colour assimilation in faces under foveal and peripheral vision using a curved display system. Psychophysical experiments measured the effect using a Colour Assimilation Index (AI), calculated from chromatic shifts on the CIE (u', v') chromaticity diagram. Five test images included four faces and a non-face, presented against striped backgrounds in red, green, or blue. A total of 11 subjects performed colour-matching tasks, adjusting test images to match references under both viewing modes. Results revealed no substantial overall differences between foveal and peripheral viewing; however, for the red primary, colour assimilation was stronger in peripheral vision. These findings suggest colour processing varies with stimulus features and viewing conditions, offering insights into perceptual integration and its implications for recognizing socially critical stimuli in everyday contexts.

*Keywords:* Colour Assimilation, Confetti Illusion, Face Perception, Peripheral vision

## Monday, July 7, 16:20 - 17:50: Poster session 1

### ID276
### LIMITING THE IMPACT OF LIGHTING AT NIGHT ON BIODIVERSITY: A MULTI-EXPERTISE METHODOLOGY FOR ADAPTING LIGHTING TO LOCAL CHALLENGES

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Growing awareness about the multiple impacts that artificial lighting at night has on natural ecosystems and the pressing necessity for protecting biodiversity is conflicting with the need for ensuring a safe and accessible nighttime environment for human beings and societies. In this project, the collaboration between multiple expertise among which ecology, sociology and lighting, has led to the elaboration of a methodology and an onsite measurement protocol for determining how the lighting characteristics could be tuned in order to limit the harm on the local biodiversity. Using the bats population as an umbrella species for nocturnal biodiversity assessment, the measurement protocol consists in mapping the lighting characteristics (illuminance, spectrum, light points height) versus the presence of various light-sensitive and opportunistic bats species, using dynamic onsite measurements that are repeated several times a year according to seasonality. This results in recommendations for the local lighting infrastructure adaptation to fit local biodiversity.

*Keywords:* Artificial lighting at night, biodiversity, collaboration, multi-expertise

### ID328
### A SHIFT TOWARDS WHITE – OBSERVING CHROMATIC ADAPTATION VIA ACHROMATIC SETTING

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LEDs' technological developments bring changes in lighting technology and the field of digital displays. Expanding and refining the chromatic adaptation models considering changes in the characteristic spectral contents is advisable. The methodological goal of the research involving the presented study is to build a framework for collecting data from different experimental settings, which leads to a universal chromatic adaptation model. In the presented study subjects had to adjust chromaticity on a tablet screen to set achromatic stimulus. Adapting environments were provided in a spectrally tuneable light booth, where subjects had to set achromatic stimulus on a tablet. The initial results indicate the relation between adapting colour shift and adapted white.

*Keywords:* Chromatic adaptation, adaptive colour shift, adapted white

## ID229
## CHARACTERIZATION OF HIGH-DYNAMIC-RANGE IMAGING MEASUREMENT SYSTEMS BY USING A HIGH CONTRAST LUMINANCE REFERENCE SOURCE

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High luminance contrast produces glare, a discomfort or reduction in the ability to see details or objects, and can be obtrusive, giving rise to annoyance and discomfort. The evaluation of glare or obtrusive light relies on measurement of scenes with high luminance contrast using imaging systems and the application of dedicated metrics. These metrics rely on both high levels of luminance of the light sources and low levels of the background or other objects. A method for the photometric characterization of high-dynamic-range imaging measuring systems with a specially developed high contrast luminance reference light source is presented in this contribution. The spatial configuration of this reference is defined, and methods proposed to obtain the relevant empirical parameters needed for evaluating the potential of these systems to provide a reliable luminance imaging measurement of high-contrast luminance scenes. These methods are tested in different cameras, and key results are shown and discussed.

*Keywords:* Glare, ILMD, Cameras, Photometry

## ID168
## TOWARD AN UNIFIED PROPOSAL FOR THE COLOURS OF THE FLAGS OF THE TWENTY-SEVEN MEMBER STATES OF THE EUROPEAN UNION

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We analysed the official regulations for the colours of the flags of the 27 member states of the European Union (59 colour samples) and compared them with the colours we measured (D65 illuminant, CIE 1964 standard observer) for commercial flags made by a Spanish manufacturer. Official regulations employed 7 colour systems, Pantone being the most common (78% of flags). These regulations used the CIE *x*,*y*,*Y* or CIELAB systems (specifying colour tolerances) for only 29% of flags. Colour differences between the official regulations and the colours measured with/without a reference plaque behind the fabric were very high: an average of 19/25 CIELAB units (standard deviation of 12/13 CIELAB units), respectively. Colours in the official regulations were spread over larger regions of colour space than the colours measured for the commercial flags, which were mainly located in 7 regions. A rigorous and unified quantitative specification of colours for these flags seems necessary.

*Keywords:* Colour difference, CIELAB, Vexillology, Flag

## ID388
## VARIABILITY OF SPECTRAL DISTRIBUTIONS OF LED

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This paper investigates the variability of spectral characteristics among LED light sources with similar correlated colour temperature (CCT), using a dataset of 1752 measured spectral distributions. We evaluate how well CCT predicts two widely used metrics: the melanopic daylight efficacy ratio (MDER), relevant for human-centric lighting, and the G-index, proposed for regulating blue light emissions. While both metrics correlate with CCT to some extent, substantial variability remains. MDER can vary by up to 40% within narrow CCT bands, and the G-index shows strong sensitivity to its division wavelength — a 20 nm change can alter compliance outcomes for most products. These results suggest that CCT, although convenient, is insufficient as a proxy for biologically or ecologically relevant effects. We call for greater attention to metric robustness, the use of physiologically grounded indicators, and the development of shared, high-quality spectral datasets to support more transparent and reproducible lighting evaluation and regulation.

*Keywords:* Photometry, Spectral distribution, Correlated Color Temperature, Colour Rendering, G-index, impact measurement, integrative lighting

## ID360
## IMPROVED UNCERTAINTY ESTIMATION PROCEDURE FOR SPECTRAL MEASUREMENTS USING THE COMBINED MONTE CARLO METHOD AND BOOTSTRAP

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Array spectroradiometers are increasingly being used to determine basic photometric quantities such as illuminance or CIE xy. Proper interpretation of these results requires the determination of uncertainties. Examples of the random component of uncertainty could be a power disturbances or changes in the radiation source. Due to the nature of spectral measurements, the method for estimating the uncertainty of these results recommended by GUM Supplement 2 is the Monte Carlo method. For measurement series characterized by large scatter or asymmetry of distribution, resampling with the Bootstrap method can improve the uncertainty estimation by refining the probability distribution of random errors. The paper presents the results of a comparison of a Monte Carlo uncertainty assessment for illuminance and CIE xy, obtained from series of spectral measurements deviating from the normal distribution, using two random error modelling methods: based on the standard deviation of the measurement series and those using the Bootstrap method.

*Keywords:* uncertainty, spectral measurement, Monte Carlo method, Bootstrap

## ID340
## ANALYSIS OF ENVIRONMENTAL LIGHTING ZONES AND THEIR EFFECTIVENESS FOR PROTECTED AREA CONSERVATION IN SWEDEN

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Environmental lighting zones (E0-E4) in CIE 150:2017 were developed primarily to address human needs and gave limited consideration to ecological impacts. This study analysed light pollution patterns in relation to protected areas across Sweden using satellite-derived metrics. Analysis of 55 roadside sites revealed that the ratio of artificial brightness to natural background brightness is the most ecological relevant parameter. A new multi-criteria classification system for ecological environmental lighting zones (EcoLZ) is proposed, integrating ratio classes with ecosystem light sensitivity, topographical features, and temporal variations. The framework includes a matrix approach combining biotope and species sensitivity to determine appropriate lighting restrictions. Implementation guidelines outline a step-by-step process for applying these ecological lighting zones in practical roadside management. This preliminary framework requires further field testing and case studies to refine zone-specific lighting specifications.

*Keywords:* Light pollution, Nature conservation, Transportation infrastructure, Environmental zoning, Ecological impact

## ID127
## LOW-COST OPTION FOR ADAPTING CURRENT PHOTOMETERS TO A NEW SPECTRAL LUMINOUS EFFICIENCY FUNCTION

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As calls grow to revise the $V(\lambda)$ function to better match the human visual response, there is concern that the resultant need to replace existing broadband photometers could pose substantial economic and environmental costs. A practical alternative is introduced here as a possible first step: a decadic conversion filter kit, with a specialized spectral transmittance function that retrofits a current photometer so that its spectral responsivity matches the new spectral luminous efficiency function with readings that are 10 % of the intended reading. Users simply fit the new filter onto their existing photometer and multiply its reading by 10 to get the correct value. Each filter is tailored to a corresponding instrument type (luminance meter or illuminance meter), with optical transmission properties that enable an accurate result with the required directional sensitivity. This scalable solution can extend device lifespan, reduce waste, and support a smooth transition to updated lighting standards.

*Keywords:* Cone fundamentals, photometer, $V(\lambda)$ function, spectral luminous efficiency function, filter, adaptor

## ID227
## EFFECTIVENESS OF LIGHT IN ENHANCING WORKING MEMORY THROUGH MELANOPSIN STIMULATION VARIES WITH AGING

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Light is essential for vision but also regulates functions unrelated to image formation such as circadian rhythm, mood but also cognition. Short wavelengths of visible light have been shown to modulate alertness and working memory by activating intrinsically photosensitive retinal ganglion cells through a photopigment called melanopsin. Here, we investigated how this memory-enhancing effect of light varies with aging. We compared short wavelengths of visible light (blue) exposition and long wavelengths of visible light (red) exposition impact on short term and working memory and found that the most effective exposition light in enhancing working memory depended on aging (blue light for young individuals and red light for older individuals). In addition, electrodermal activity was found to be a possible good indicator of the amount of light perceived and received on the retina.

*Keywords:* Photometry, Light, Melanopsin, Working Memory, Electrodermal activity

## ID129
## CHROMATICITY POINTS OF REAL SPECTRA OUTSIDE THE CIE CHROMATICITY DIAGRAM

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When an expert of colorimetry is asked whether the chromaticity point of a real spectrum can fall outside the CIE xy chromaticity diagram, the immediate answer will probably sound like 'No! This is not possible!' However, regular spectra generated with a mathematical model function for substituting those of real amber LEDs led to an unexpected fact. Their chromaticity points were close to the boundary, yet outside the CIE xy chromaticity diagram. Deeper investigations discovered that there are several parts of the chromaticity diagram where the concept of convexity is violated. The results have no consequences for most calculations or practical measurements, hence the deviations are only visible in the 5$^{th}$ decimal place. Yet, they may imply a need for revising the colour matching functions, hence an axiom-like property – convexity – of the chromaticity diagram, relevant to the theory of colorimetry, has been disproved.

*Keywords:* chromaticity diagram, convexity, axiom, LED

## ID393
## A RESEARCH ON WORK PRODUCTIVITY AND VISUAL ATTENTION UNDER HUMAN CENTRIC LIGHTING SYSTEM

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Human-centric lighting has gained attention for its potential to enhance mood, cognitive performance, and productivity in work environments. This research investigates how LED-based dynamic lighting (with tunable CT ranges from 2700K to 6500K and adjustable illuminance control) operates relative to reference office lighting (static scenario) under laboratory environment. Repeated measures were obtained to achieve reliable time-based data. Momentary Affect Scale for mood evaluations, Digit Span Test for measuring short-term memory, Spatial Cueing Task for assessing visual attention were used. The findings highlight the interplay between lighting conditions, task type, and cognitive performance, particularly focusing on reaction times and accuracy in the context of the digit span task. Specifically, participants responded about 3.13 seconds faster in the backward digit span task when exposed to static lighting compared to human-centric lighting. Similar patterns were observed for the forward task, underscoring the impact of task complexity on cognitive processing speeds.

*Keywords:* Human-centric Lighting, Work Productivity, Visual Attention, LED, Indoor Lighting

## ID125
## EXPLORING THE IMPACT OF CORRELATED COLOUR TEMPERATURE OF LED GLARE ON PUPILLARY DYNAMICS

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This study investigated the impact of commercial light-emitting diodes (LED) lamp Correlated Colour Temperature (CCT) on pupillary dynamics. Using a pupilometer embedded in a two-channel Maxwellian view optical system, we measured pupillary diameter dynamics under various luminance levels and glare conditions. Nineteen young participants were exposed to LED light sources glare of 2700 K and 6500 K. Results showed a significant effect of luminance on pupillary diameter variation for both CCTs. Increased background luminance reduced both maximum pre-glare and minimum glare-induced pupil size, while LED lamp CCT showed no impact on pupillary behaviour across luminance levels. The lack of CCT influence on pupillary diameter was attributed to spectral distribution similarities between the lamps. This suggests that CCT may not be a reliable parameter for predicting pupillary response to LED-induced glare. These findings may have important implications for LED lighting design in road networks and visual performance assessment.

*Keywords:* Correlated Colour Temperature, Pupil Size, LED Lamp

## ID144
## INVESTIGATING FACIAL EMOTION RECOGNITION: TWO FIELD EXPERIMENTS

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The objective of this paper is to explore the use of the Facial Emotion Recognition (FER) task (inspired by a laboratory task) on field experiments to assess lighting quality for pedestrians in urban space and to investigate the relationship with reassurance after dark. The task consists in identifying a facial emotion from a given distance during a given observation time. Two field experiments were conducted with different experimental designs, protocols and panels. One experiment also involved elderly people. The results show a luminance plateau above 0.1 cd/m² on average, *i.e.* the rate of correct responses did not increase above a sign luminance of 0.1 cd/m². For elderly participants, the proportion of correct responses increases when the sign luminance was greater than 0.5 cd/m². The results also show that the rate of "I don't know" responses may discriminate the darkest lighting conditions and may be related to perceived safety.

*Keywords:* outdoor lighting quality, pedestrians, FER task, field experiments

## ID317
## HYPERSPECTRAL IMAGING IN AGRICULTURE – EVALUATING THE SPECTRAL DEPENDENCY OF VEGETATION INDICES

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Vegetation indices have been in active use for over five decades. They are remote sensing indicators derived from surface reflectance data to highlight various vegetation-related properties. Their popularity stems partly from their simplicity. Each index is computed by simple formulas using the pixel values of a handful of multispectral bands. However, the loose definition of spectral bands introduces a device-specific discrepancy to the results as the spectral sensitivity can vary significantly between different systems and slightly even between different units of the same model. This paper uses hyperspectral aerial images to investigate the cross-instrument differences of some popular vegetation indices. The spectral characteristics of various multispectral instruments are reconstructed from the much narrower hyperspectral bands, creating the device-specific projections of the dataset. The differences between devices are presented using these transformed values.

*Keywords:* Hyperspectral Imaging, Remote Sensing, Agricultural Imaging, Vegetation Indices

## ID351
## ON THE COMPARABILITY BETWEEN DAYLIT AND ELECTRICALLY LIT EXPERIMENTAL CONDITIONS FOCUSED ON NON-VISUAL RESPONSES TO LIGHT

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Daylight has long been recognized for its positive effects on human health and well-being, yet empirical evidence is still missing regarding the specific optical properties driving these benefits. In our effort to bring a more fundamental understanding of the mechanisms governing our non-visual response to daylight, the present paper describes a workflow and its application to an experimental setting to ensure “a priori equivalence” (i.e. comparability) of light exposure between daylit and electrically lit conditions, where “equivalence” (or comparability) is based on the latest findings from the literature regarding expected non-visual effects. By combining environmental and personal light exposure monitoring with ad hoc calculation methods, the proposed approach allows to design an experimental setting in which non-visual responses from participants exposed for prolonged periods to either uncontrolled and inherently dynamic conditions (daylight) or controlled and mostly static ones (electric lighting) can be “fairly” compared.

*Keywords:* Non-visual effects, temporal and spectral dynamics, equivalence

## ID166
## REFINING THE CMC COLOUR-DIFFERENCE FORMULA BASED ON THE COM-CORRECTED DATASET

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Colour difference is widely applied in various industries. Currently, the CMC colour-difference formula is well liked by the textile industry though CIEDE2000 is the latest recommendation from CIE/ISO. In this paper, a modified and a symmetric-modified CMC formula (MCMC and SMCMC respectively) are developed by optimizing both the original CIELAB and CMC colour-difference formulas together using the corrected combined colour-difference dataset (COM-corrected) used to develop CIEDE2000 (DE00). Performance tests show CMC(1:1), MCMC(1:1), SMCMC(1:1) and DE00(1:1:1) have STRESS values of 30.5, 26.9, 26.9, and 27.5 tested using the COM-corrected dataset, and 30.6, 27.7, 27.8, and 29.6 tested using the BFD-P dataset. Both MCMC and SMCMC are statistically significantly better than the CMC colour-difference formula and DE00(1:1:1) tested using the COM-corrected and BFD-P datasets. Furthermore, the BFD-P dataset consists of textile samples. Hence, it is to be expected that both the MCMC and SMCMC formulas can find applications in the textile industry.

*Keywords:* CMC Colour difference, STRESS value, CIEDE2000 colour difference, COM-corrected dataset, CIELAB

## ID286
## THE PHANTOM ARRAY EFFECT EXPLAINED USING SIMPLE FORMULAS

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The phantom array effect is a visual effect perceived by a human observer when making rapid eye movements across a light source exhibiting temporal light modulation at frequencies between about one hundred Hz and a few kHz: a series of multiple spurious images of the light source is seen in the direction of the eye saccade. This phenomenon may create discomfort when accomplishing visual tasks involving eye movements, such as driving or walking. In this paper, we provide a simple description of the phantom array effect by deriving formulas predicting its spatial and temporal features perceived in the field of view. This approach provides a framework to study how the visibility of the phantom array effect is influenced by the shape of the source, its luminance, the surrounding and background luminance, the modulation frequency and waveform, and the individual visual acuity.

*Keywords:* Temporal Light Modulation, Phantom Array Effect, Modelling, Visibility, Contrast Sensitivity Function, Eye Tracking, Saccade, Light Source

## ID339
## LIGHT EXPOSURE OF OLDER ADULTS LIVING ALONE: A PILOT STUDY

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Ocular light exposure is essential for regulating circadian rhythms, influencing sleep-wake cycles and several physiological and psychological processes. Inappropriate light exposure can impair sleep, mood, cognition, and overall well-being, posing particular risks for older adults experiencing age-related sleep disturbances and cognitive decline. However, objective data on the light exposure of older adults remain limited. In this observational study, we monitored the winter and summer light exposure of 16 older adults living alone using wearable spectral sensors. We derived the Circadian Stimulus and Melanopic Equivalent Daylight Illuminance (mEDI) for each data point and analyzed their light exposure during the daytime, evening, and nighttime. Our results indicate that older adults tend to have relatively low daytime exposure, with a median daytime mEDI of 31,2 lux, but did not experience light pollution at night. Furthermore, an analysis of building characteristics revealed only a modest association between light exposure and the window-to-wall ratio.

*Keywords:* Light, Older Adults, Circadian Rhythms, Non-visual Effects, Wearable Sensors

## ID318
## EFFECT OF ILLUMINANCE ON PERCEPTION OF THE STROBOSCOPIC EFFECT

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A study deals with the stroboscopic effect that occurs during the perception of pulse width modulated light. The aim was to investigate whether and how illuminance influences the stroboscopic effect. The study was based on a test setup with a rotating black circle as a visual object on a bright background. The test field was illuminated with different illumination levels (1000 lx, 250 lx, 63 lx). The LED illumination varied in frequency, duty cycle and modulation depth. 12 test subjects took part. The hypothesis that the perception of the stroboscopic effect depends on the illuminance could not be confirmed.

*Keywords:* Stroboscopic Effect, Time-Modulated Light

## ID112
## SUNGLASSES STANDARD ISO 12312-1. A NEW PROPOSAL BASED ON NON-IMAGE EFFECTS OF LIGHT

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The standards for general purpose sunglasses classify them into five categories according to the transmission of light they send in the UV, visible and NIR ranges. The visible information transmitted by each category is given without specifying the proportion in each visible range. The effects of light on the mood and functioning of our organs depend on the time of day it is received, amount of light at each time of day and night, history, proportion of light in each part of the visible and intensity in each of them. Eye care professionals should be aware of the non-visual effects of light and from that, recommend different categories of sunglasses and different color shades of lenses depending on the season, latitude, phototype and chronotype of the person. A future classification system should differentiate categories based on the amount of light transmitted to each photoreceptor for different tints of lenses.

*Keywords:* sunglasses, circadian rhythms, visible light, melatonin

## ID304
## MEASUREMENT OF OBTRUSIVE LIGHT EMISSION FROM RESIDENTIAL BUILDINGS

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This paper presents a comprehensive framework for evaluating obtrusive light emissions from residential buildings by integrating field measurements, statistical analysis, and simulation. The approach includes direct luminance measurements of windows and buildings, time-lapse photometry to capture temporal lighting behavior, and simulation of spatial light distribution using software-based goniophotometry. The results highlight the role of shading devices and characteristic timing of residential lighting use. Based on these findings, a scalable simulation workflow was propsed, allowing for the construction of time-dependent models of obtrusive light emissions at the level of individual buildings or entire urban blocks. The proposed framework captures both spatial and temporal dimensions of residential light leakage and provides a methodological basis for future modeling efforts. It addresses the current gap in this area and offers a practical basis for assessing light pollution from residential buildings in urban settings.

*Keywords:* Obtrusive Light, Residential Buildings, Windows, Luminance Analysis, Spill Light

## ID162
## THE INFLUENCE OF THE CORRELATED COLOUR TEMPERATURE CALCULATION METHOD ON THE ACCURACY OF COLOUR RENDERING INDEX MEASUREMENT

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Work investigates the impact of different correlated colour temperature (CCT) calculation methods on the accuracy of the Colour Rendering Index (CRI) measurement. As the choice of CCT calculation method influences the reference illuminant used in CRI computation, discrepancies in CRI values may arise. Nine CCT calculation methods were analyzed using 18 spectral power distributions (SPDs) selected from the EMPIR 15SIB07 PhotoLED database. The results indicate that, despite variations in CCT values, the CRI index is largely unaffected by the choice of calculation method, with minimal discrepancies observed across the methods. The findings suggest that, for most practical applications, the CCT calculation method has negligible impact on CRI accuracy, and other factors, such as performance, should guide the selection of the optimal CCT calculation approach.

*Keywords:* Colour Rendering Index, Correlated Colour Temperature, LED

## ID354
## A VALIDIATION STUDY OF THE CIE CORRECTION METHOD FOR NON-UNIFORM LIGHTING CONDITIONS

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The International Commission on Illumination (CIE) introduced a Unified Glare Rating (UGR) correction method for non-uniform source luminance. However, its validation under realistic office conditions involving visual tasks remains limited. This study configured 21 lighting conditions (UGR ranging from 15 to 28) using 9 LED linear tracks, both with and without diffusers. A full-scale experiment was conducted with 40 participants in a within-subject design under controlled office-like conditions. The experimental design included both sequential and alternating exposures, incorporating pairwise assessments as well as absolute assessments of discomfort glare. Additionally, UGR values derived from the correction method were compared with those obtained directly from fisheye-lens luminance images. Results show small deviations between the fisheye-based image analysis and the correction method for UGR calculation. While UGR corresponds well with glare levels when only fixture intensity varies, it fails to match perceived discomfort between moderate and highly non-uniform sources, regardless of calculation method.

*Keywords:* UGR, ILMD, Pairwise comparison, Discomfort Glare, Nonuniform light source

## ID264
## DEVELOPMENT AND VERIFICATION OF A LIGHTING CONTROL SYSTEM IN A LOW-TRAFFIC TUNNEL

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A lighting control system in low-traffic tunnels (hereinafter referred to as “the system”) is a system to reasonably reduce power consumption while providing necessary lighting conditions for drivers. In Japan, the Standards for the Installation of Road Lighting Facilities and a Commentary (2007) are applied to the planning and operation of tunnel lighting. Those Standards prescribe lighting control in accordance with the brightness outside of a tunnel but do not mention lighting control depending on whether vehicular traffic is present or absent. The system actively reduces tunnel lighting when there is no vehicular traffic, in addition to controlling tunnel lighting in accordance with the brightness outside the tunnel. This paper reports on the development of a lighting control system (the system) and the results of verifying its reduced energy use. In addition, several points to consider when installing a lighting control system are proposed.

*Keywords:* tunnel lighting, dimming control, carbon neutrality

## ID118
## REAL-LIFE CHARACTERIZATION OF EYE EXPOSURE TO LIGHT USING A NEW INSTRUMENTED EYEWEAR: A PROOF-OF-CONCEPT STUDY

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New and convenient devices for continuously monitoring eye light exposure levels in real life are needed to address current knowledge gaps. This two-week study, involving 10 participants, assessed the real-life reliability and usability of a device developed to meet this need: newly instrumented eyewear containing four calibrated sensors (an illuminance ambient light sensor, an irradiance spectrometer with eight channels, and two proximity sensors). The eyewear provided reliable, objective data on light dose and spectral composition, and enabled analyses according to time of day, light environment (indoor/outdoor; different light sources), and weather conditions. Feedback on aesthetics, comfort, and usability was positive. These data support the larger-scale use of this new instrumented eyewear in future studies involving real-life characterization.

*Keywords:* light exposure, wearable, light, sensors

## ID133
## POTENTIAL OF USING LUMINOUS COLOUR IN WORKSPACES WITH DIFFERENT TYPES OF TASKS

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Recently, different types of places other than the office have been used for office work. The aims and values for office workers to gather in office spaces are being reconsidered. There is needed for offices to have spaces that can be used for multiple purposes as needed, rather than spaces that are specialised for a specific purpose only. The lighting design of office spaces should not only ensure visual workability, but also enhance the productivity of both the individual worker and the organization. In this study, a subjective experiment was conducted to identify the potential of luminous colour to create workspaces where different types of tasks coexist simultaneously or over time. The effects of luminous colour which gently divides the space into zones with different types of tasks are being performed on the subjects' workability, visual fatigue, and visual comfort are examined.

*Keywords:* Workspace, Luminous colour, Work efficiency, Subjective experiment

## ID398
## EXPLORING THE ROLE OF THE FALL OF DARKNESS ON LONDON'S THEFT AND ROBBERY INCIDENTS BETWEEN 2013 - 2019

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This study investigates criminal behaviour in London after dark by using Metropolitan Police Services (MPS) crime records from 2013 to 2019 and calculating solar altitude at the time the crime took place. The data was filtered to identify crimes where the time was known to have taken place in a window of 5 minutes or less, and only these were analysed in the study. “Darkness” is defined in this study as the condition when the solar altitude is less than –6 degrees. Findings indicate that robbery and theft from the person increased significantly after dark ($p<0.0001$). The percentage of theft that takes place after dark, increases in Central London, compared to the whole of London. Further analysis found that robbery and theft occurrences have a significant correlation with darkness.

*Keywords:* Darkness, safety, crime, London, solar altitude

## ID330
## CLAPP – A NEW FRAMEWORK FOR LIGHTING DESIGN EDUCATION AND PRACTICE

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Educators, practitioners, students of architecture and lighting design face the challenge to include, in education and practice, aspects related to psychological and physiological impact of light, which are stated in the CIE definition of integrative lighting. Therefore, this paper introduces a new framework that combines features from multiple categories: Context, Light(ing) conditions, Action (behaviour), Perception and Person (CLAPP). The proposed framework intends to be a glossary for terms that relate to high level aspects of features and responses, which can be used as guidance by lighting design students, researchers and practitioners, to navigate through the complexities of the aspects concerning the impact of light on health and well-being.

*Keywords:* Integrative lighting, architectural lighting design, practice, education, research

## ID391
## A SIMPLE METHODOLOGY FOR ASSESSING LIGHT POLLUTION ISSUES USING FREE SATELLITE DATA AND AN INVENTORY OF ROAD LIGHTING INSTALLATIONS

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Limiting the pressure exerted by night-time lighting is a key issue in preserving biodiversity. In this study, we propose a simple methodology for tackling the issue, based on satellite data and knowledge of road lighting installations. We rank an urban area according to the likelihood of impact from artificial light in the form of heat maps generated pragmatically. By comparing the heat map obtained from a satellite image with that generated from the inventory of road lighting installations, we can identify particularly bright private lighting or modulations of road lighting. The proposed approach can be a first means of action for local authorities wishing to take up the challenge of light pollution, but whose resources are limited or whose territories are very large.

*Keywords:* Light Pollution, Satellite Imagery, Road Lighting, Private Lighting

## ID302
## SIXTEEN YEARS OF ALPINE LIGHT - TRENDS, SOURCES, STABILITY, ACCURACY

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We present new results of day- and night light-monitoring in Austria, obtained with Lightmeters[1] over 16 years. We offer additional urban light-data for the main Austrian source, the city of Vienna.

1) We extend the time series of horizontal irradiance at mountain sites near the “Alpine artificial light minimum”, to the end of 2024,

2) we review a direction-complete photometric assessment of the sources of Vienna (with up to ~100 Mcd), from two Helicopter campaigns (2016, 2022),

3) we estimate the accuracy and stability of the Lightmeter time-series by comparison to simultaneous total irradiance-monitoring at two nodes of the Austrian Radiation Monitoring Network, and,

4) we synthesize the above to sketch possible conventions for standards and procedures for “round the clock” radiation-monitoring to support light quantification of contributions to the Outstanding Universal Value of UNESCO’s world heritage programme.

1 https://lightmeter.at , A. Müller. et al., 2011, Hähnel et al.., 2018

*Keywords:* Global radiation monitoring, long term monitoring, night-time radiation monitoring, city light sources, light and World Heritage, aerial photometry and radiometry

## ID161
## STUDY ON LIGHTING CONTROL SYSTEM LINKED TO WEATHER FORECAST

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This study aims to develop a weather-linked lighting control system that optimizes office lighting by adjusting dimming rates and CCT based on weather forecasts. Existing lighting systems with fixed schedules or light sensors often fail to adapt to changing daylight. The proposed system predicts daylight an hour in advance and compensates for brightness imbalances using simulations. Weather forecast is categorized as SUNNY, CLOUDY, and RAINY based on cloud cover and rainfall data. Illuminance simulations using Rhinoceros and Climate Studio model both artificial and daylight illuminance under various weather conditions. It is experimentally demonstrated that the proposed system can effectively prevent brightness excesses and shortages, evaluated under constant dimming rate and CCT on sunny and cloudy days, by adjusting these settings accordingly. This approach demonstrates the potential for enhanced lighting environments and will benefit from advancements in weather forecast accuracy and simulation technology, laying the foundation for smarter, feedforward lighting solutions.

*Keywords:* Lighting control system, Weather forecast, Daylight, Simulation, Office

## ID365
## DEVELOPMENT OF AN APPROXIMATE FORMULA FOR ESTIMATING SPATIAL BRIGHTNESS FOR PLANNING AND EVALUATING THE LIGHTING ENVIRONMENT WITH WINDOWS

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Spatial brightness is a crucial factor in designing lighting environments; however, few methods exist for evaluating spatial brightness during the planning stage. Additionally, the estimation of spatial brightness in spaces with windows has not been sufficiently validated. This study aims to develop an estimation formula for the spatial brightness of spaces with windows, applicable during both the planning stage and after construction. A large LED display was used to replicate the size and luminance of real spaces during the planning phase. Participants evaluated the lighting environment in the real spaces and the corresponding LED display images. The proposed estimation formula considers the window surface and the 180° field of view, excluding the window. The product of average luminance and solid angle was used as the explanatory variable.

*Keywords:* Spatial Brightness, Luminance, Light Emitting Diode Display, Subject Experiment、Method of Adjustment

## ID203
## AN EXAMINATION OF PRACTICAL METHODS FOR PERFORMING CONE-FUNDAMENTAL-BASED PHOTOMETRY

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Since the publication of two CIE Technical Reports, CIE 170-1:2006 and 170-2:2015, cone-fundamental-basedphotometry and/or colorimetry has attracted much attention in related communities, including the CIE. This study reports several methods available to measure a photometric quantity based on a novel spectral luminous efficiency function, $V_F(\lambda)$. An evaluation by spectral weighting revealed that a change in the function from $V(\lambda)$ to $V_F(\lambda)$ results in an overestimation of photometric quantities by about +5 % on average for white LED and fluorescent lamps. The analysis based on the spectral responsivity data of a commercial illuminance meter showed that the spectral mismatch correction of a maximum of +3 % allows us to convert the output to a $V_F(\lambda)$-weighted photometric value. Furthermore, a $V_F(\lambda)$-corrected interference filter was designed and prepared for the purpose of constructing the so-called $V_F(\lambda)$ photometer.

*Keywords:* Photometry, Spectral Luminous Efficiency, Cone Fundamentals, Illuminance Meter, Spectral Mismatch Correction

## ID256
## EFFECT OF IPRGC STIMULATION ON CONTRAST SENSITIVITY IN CENTRAL VISION

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Since the discovery of the intrinsically photosensitive retinal ganglion cells (ipRGCs), their roles have been investigated by vision researchers around the world, and their effects on non-image-forming functions, such as circadian rhythm and pupillary light reflex, are now being evaluated. Furthermore, it has been suggested that the ipRGCs are also involved in contrast sensitivity, a fundamental function of the human visual system. Therefore, the purpose of this study is to clarify whether the high luminance ipRGC stimulation affect contrast sensitivity in central vision. In this study, a silent substitution method was applied using a multichannel variable wavelength light source to create background stimulus that stimulates only ipRGCs. The test stimulus was a Gabor stimulus presented on the display. The results showed that the higher the amount of stimulus given to the ipRGCs, the lower the contrast sensitivity, and the lower the amount of stimulus, the higher the contrast sensitivity.

*Keywords:* ipRGC, Contrast sensitivity, Central vision, Silent substitution

## ID167
## UNIFORM FLAT PLANE SPECTRAL RADIANCE SOURCE BASED ON BROADBAND LED

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Integrating sphere sources are commonly used for calibrating spectroradiometers, photometers, and image sensors due to their uniform radiance. However, achieving field homogeneity typically requires limiting the open fraction of the integrating sphere to less than 5%, resulting in bulky dimensions. This study presents a compact flat plane uniform radiation source comprising an array of broadband LEDs and a king of optical nano-diffusion film. The flat plane source exhibits a luminance variation of less than 1% over a 56mm(W)×58mm(H) subsection, with adjustable luminance ranging from 800 to 11000 cd/m². The broadband LED has enhanced the spectral radiance in the red band region compared to typical white LED sources. This novel flat plane radiance source offers advantages in compactness, ease of fabrication, low cost and improved spectral performance, making it a promising alternative to conventional integrating sphere sources in some case.

*Keywords:* spectral radiance; integrating sphere source; broadband LED; light homogenizer; luminance

## ID366
## TLM EFFECT ON VISUAL PERCEPTION ON LANDOLT C

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Temporal Light Modulation (TLM) can induce Temporal Light Artifacts (TLAs) such as flicker, the stroboscopic effect, and the phantom array effect, all of which may influence visual perception. However, it remains unclear which types of TLAs have the most impact and how they affect visual tasks. This study examined the accuracy of Landolt C orientation identification under various TLA conditions across three experiments. Results showed that phantom arrays reduced accuracy of Landolt C orientation identification and stroboscopic visibility ratings unexpectedly increased at 500 Hz, possibly due to phantom arrays triggered by micro-saccades. While Landolt C accuracy is related to known metrics such as flicker and stroboscopic visibility, our results did not fully align with existing models like the Stroboscopic Visibility Measure (SVM). These findings suggest the need to refine current TLM metrics by accounting for dynamic viewing behavior and individual perceptual differences under realistic lighting conditions.

*Keywords:* Temporal Light Modulation, Visual Perception, Phantom Array Effect, Stroboscopic Effect, Flicker

## ID278
## TOWARDS ESTABLISHING A PRIMARY STANDARD FOR SPECTRAL RESPONSIVITY

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Pursuing improvement in measurement capabilities through improving uncertainty and delivering this to calibration and testing services is very consistent with our unique work as a national metrology institute (NMI). Currently, the Photometry and Radiometry Metrology Group of the Korea Research Institute of Standards and Science (KRISS) has installed a new mechanically-cooled absolute cryogenic radiometer (mACR) and is conducting research to improve the accuracy of primary standards based on it. Starting this year, we prepared for normal operation of mACR and conducted uncertainty analysis on our lab-assembled transfer standard. Here, we would like to discuss how to secure a high-accuracy primary standard scale through recent uncertainty component analysis.

*Keywords:* ACR, primary standards, photometry and radiometry

## ID259
## FROM CALCULATION TO EVALUATION: ASSESSING UGR AS AN INDICATOR OF VISUAL DISCOMFORT

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Evaluation of visual conditions in buildings typically relies on the measured or calculated values of various performance indicators, including, for example, illuminance level, luminance level, daylight factor, and daylight autonomy. The present contribution deals with one of these indicators, namely UGR (Unified Glare Rating), an indicator of glare intensity in the visual field. In this context, we present results of a case study, which involved the comparison of four sets of data, namely, *i)* UGR calculations, *ii)* UGR simulations, *iii)* UGR measurements, and *iv)* subjective evaluations of glare intensity. The study explored the level of agreement between UGR computations on the one side and UGR measurements on the other side. Moreover, the study investigated the correlation between people's evaluation of glare intensity with UGR-based expectations. The analysis of this data can contribute to efforts regarding the assessment of UGR's fitness and dependability of as a visual performance indicator.

*Keywords:* Glare, UGR, calculation, measurement, perception

## ID126
## DRIVING DISABILITY GLARE IN MIDDLE AGE: EFFECT OF CORRELATED COLOR TEMPERATURE (CCT)

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This study examines the impact of the correlated colour temperature (CCT) of commercial light-emitting diode (LED) glare sources on visual performance during simulated nighttime driving in middle-aged drivers. Participants were exposed to LED glare at two CCT levels (2800 K and 6500 K) for 3 s. Foveal reaction time (RT) was measured for a 2° circular stimulus with a Weber contrast of 0,1 within a 10° circular field, under background luminances of 0,1 cd/m² and 1 cd/m². Results show that mean RT with glare is significantly higher at the lower luminance level (0,1 cd/m²). The CCT of the glare sources did not have a significant influence on RT. These results suggest that, under the conditions of this study, the CCT of LED sources has an uncertain impact on the visual performance of middle-aged drivers during night driving, while background luminance plays a more critical role in reaction time.

*Keywords:* Glare, Visual Reaction Time, Correlated Colour Temperature, Driving, Middle-aged

## ID247
## ESTABLISHMENT AND APPLICATION STRATEGIES OF THE QUANTUM COMMUNICATION AND SENSOR EVALUATION TECHNOLOGY CENTER

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We introduce the quantum testing center built to evaluate quantum technologies, especially in the fields of quantum communication and sensing. Our focus is on testing single-photon detectors, which are key components in quantum key distribution (QKD) systems. A testing setup is built utilizing a 1550 nm diode laser and transfer standards to measure important properties such as detection efficiency, after-pulsing, dead time, quantum efficiency, dark count rate, and timing noise. We are also planning to provide research support, development tools, and calibration services to support the quantum industry.

*Keywords:* Quantum Communication, Single-Photon Detector, Detection Efficiency

## ID291
## THE EFFECT OF RADIATION PATTERNS ON VEHICULAR VISIBLE LIGHT COMMUNICATION

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Vehicular Visible Light Communication (V-VLC) offers a compelling alternative communication technology for Intelligent Transportation Systems, leveraging its license-free spectrum, wide bandwidth, energy efficiency, and existing transmitters. Accurate optical channel modelling is essential for evaluating V-VLC feasibility and performance in vehicular environments. For this, accurate transmitter representations are required. Low beam headlights and daytime running lights are primary candidates for VLC transmitters, yet simplified light source models often lack photometric realism compared to actual vehicle headlights. A comparison of a Lambertian and a measured low-beam emission patterns reveals that Lambertian models underestimate communication range while overestimating mobility. A narrow beam better reflects the low beam irradiance but requires careful design considerations for an optimal representation. This study examines the differences between the source models commonly used and suggests alternative modelling approaches depending on the communication range.

*Keywords:* Photometry, Vehicle Lighting, VLC, Channel Modelling

## ID172
## SUPPORT AND SUPPRESSION OF ANALOGUE NIGHT VISION DEVICES USING IR LEDS

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Each generation of analogue night vision devices has significant technical differences. Basically, all parameters have improved on average during the generation changes. However, the significant difference in the wavelength-dependent characteristics of the sensitivity of photocathode materials represents a gap through which an active radiating source can be created with the help of an appropriate design process, which can even put the newer generations at a disadvantage compared to the old ones. For an active radiant source, infrared LEDs may be an obvious choice. Their operation is strongly temperature-dependent and even device aging may have to be taken into account, but nowadays suitable and fast circuit-simulation modelling solutions already exist to deal with such issues. The proposed device for supporting and suppressing analogue night vision devices requires system-level simulations with an Industry 4.0 approach. This paper discusses the design steps and theoretical results of such a procedure.

*Keywords:* night vision devices, infrared LED, LED modelling and simulation, constant image brightness

## ID151
## THE INFLUENCE OF SPECTRAL POWER DISTRIBUTIONS ON THE GROWTH OF RED SPINACH (AMARANTHUS DUBIUS)

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Red spinach is a leafy vegetable with high nutritional value widely grown in subtropical and tropical regions, it appears to be an ideal candidate for production in large scale protected environments. Red spinach plants have been exposed to various LED arrays to establish the influence of the spectral power distribution on the growth of the plants up to harvesting. The LED arrays were classified as white, white with enhanced red content, white with enhanced blue content and a combination of predominantly red plus blue radiation. Detailed measurements of plant growth parameters: stem height; number of leaves; leaf length; leaf width; fresh weight after harvesting, allowed the plants' progress to be compared. These measurements showed the most effective light source for producing the highest fresh plant weight was the red plus blue combination.

*Keywords:* Horticultural lighting, Photoperiod, Photosynthetic photon flux density, Red spinach

## ID332
## LIGHTING CONDITIONS IN THE HOMES OF OLDER ADULTS: ARE THEY SUITABLE FOR HEALTHY AGING IN PLACE?

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Many people in industrialized countries would prefer to remain in their own homes for as long as possible. Remaining healthy while aging in place will depend on maintaining suitable indoor environmental quality. This paper reports preliminary online survey results concerning lighting conditions in the homes of older Canadian adults. Older adults who spend close to 24 hours daily in their homes might not receive the recommended daily light exposure of minimum 250 lx melanopic equivalent daylight illuminance from morning until three hours before bed. Those who spend time outdoors might receive an adequate total exposure if shorter or intermittent very high illuminance exposures are equivalent to long periods at a lower level. Survey participants were generally satisfied with their lighting. Regression analyses revealed small but statistically significant effects of light exposures and satisfaction with lighting on sleep and quality of life, which require validation with light logger data.

*Keywords:* residential lighting, aging, quality of life, lighting satisfaction, light exposure

## ID146
## RESEARCH ON EXTREMELY HIGH-RESOLUTION WIDE-BAND ARRAY SPECTRORADIOMETER

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This paper introduces an extremely high-resolution wide-band array(EHRA) spectroradiometer that can achieve ultrahigh spectral resolution within a wide wavelength band and has the full-band blazed characteristics. It uses a grating and a prism for cross dispersion, and the obtained spectrograms are no longer simple one-dimensional images, posing new challenges for spectrogram reconstruction and wavelength calibration. A spectrogram-reconstruction algorithm and wavelength-calibration method is further proposed. A theoretical spectrogram model is firstly established based on the crossed-dispersion theories, and the model is then mapped onto an actual reference spectrogram by leveraging the abundant characteristic spectral lines in different orders of a Hg-Ar lamp, further using an intelligent spectrogram-recognition algorithm, a high-precision spectrogram reconstruction was achieved. Experimental results demonstrated that within the wavelength range from 380 nm – 1000 nm, its spectral resolution, spectral accuracy, and wavelength repeatability are better than 0.1 nm, 0.025 nm, and 0.005 nm respectively.

*Keywords:* Cross-dispersion, Array spectroradiometer, Extremely high-resolution

## ID370
## CAMERA SPECTRAL SENSITIVITY MEASUREMENT AND UNCERTAINTY EVALUATION

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This paper describes a spectral sensitivity calibration procedure for a camera and evaluates the measurement uncertainty. A narrow wavelength band radiance source based on a monochromator and a standard spectroradiometer traced to the National Metrology Institute are used. As the uncertainty associated with the standard spectroradiometer is easily obtained from the calibration certificate, we mainly consider the uncertainty associated with the radiance source and the camera. The repeatability, stability, wavelength accuracy, bandwidth, non-uniformity and stray light are carefully examined. The relative extended uncertainty of the spectral responsivity of the red, green, and blue channels of the camera in the range from 410nm to 680nm is approximately 4%($k$=2).

*Keywords:* Camera, Spectral sensitivity, Uncertainty

## ID272
## TOWARDS MORE ENERGY-EFFICIENT ROAD TUNNEL LIGHTING - A COMPARISON OF LIGHTING INSTALLATION DESIGN METHODS

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This article aims to compare the energy consumption of various methods used for the design of road tunnel reinforcement lighting. The Belgian, French, and Italian methods, as well as those presented in the appendices of CIE 88 2004 and the latest version of CEN 14380 (16 October 2024), are studied. The French and Italian methods, along with the simplified traffic-weighted L20 method, achieve the most energy-efficient road luminance profiles (with consumption between 51% and 56% less than for the most energy-intensive method). It is important to note that the results do not account for the safety aspects of the methods and to a large extent depend on the design hypotheses.

*Keywords:* Tunnel Lighting, Design Methods, Energy Savings

## ID143
## COMPACT TYPE OF ILLUMINOMETER CALIBRATION SYSTEM USING INTEGRATING SPHERE

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The conventional lux meter calibration system utilizes a 1 kW tungsten halogen lamp and a 6-meter bench to produce illuminance levels ranging from 50 lx to 5,000 lx. Expanding this range requires the use of alternative lamps (e.g., 10 W or 2 kW), which demand a cooling and stabilization period, an inefficient and costly process. To address this, a compact calibration system has been developed using a 400 W lamp and an integrating sphere. This design reduces system size and eliminates the need for large-scale movement. The new system achieves an extended illuminance range from 0.1 lx to 2,000 lx, with a uniformity of ±0.1 % and a colour temperature stability within ±20 K. The range is adjusted by controlling the distance between the lamp and the integrating sphere using an automated stage. Additionally, a 2 kW lamp can be used to extend the illuminance range up to 20,000 lx.

*Keywords:* Illuminance, Integrating sphere, Colour temperature standard lamp, lux meter calibration system

## ID238
## POTENTIAL IMPACT OF DAYLIGHTING ON VISUAL ENVIRONMENTAL SATISFACTION IN SMALL HOUSES WITH RESTRICTED VIEW

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In urban areas, high land prices often lead to the construction of small, densely packed houses. Consequently, in these densely populated residential areas, the distance between neighbouring walls is typically minimal, making it difficult to secure adequate views. In this study, we explored the potential to improve residents' visual environmental satisfaction during their stay by ensuring sufficient indoor brightness through daylighting, even with restricted views. Experiments using head-mounted displays were conducted under varying experimental conditions such as window size, position, and elements within the visual field. The results revealed that sufficient daylighting can enhance visual environmental satisfaction, even when views are obstructed.

*Keywords:* Small House, Daylighting, View, Environmental Satisfaction

## ID364
## OPTIMIZATION OF PERSONAL LIGHT DOSIMETRY: CONSIDERATION OF THE BINOCULAR FIELD OF VIEW

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Light exposure plays a crucial role in non-visual light effects, demanding accurate measurement technologies. Traditional laboratory and light dosimetry methods measure illuminance, alpha-opic irradiance, or spectral irradiance. However, these methods do not account for anatomical limitations such as the human binocular field of view (FOV), resulting in measurement bias. To address this, a novel field-limiting aperture was developed to integrate the binocular FOV into light dosimetry measurements using a LiDo (Light-Dosimeter). In a study, participants wear two LiDos – one with the special field-limiting aperture – along with additional dosimeters and complete questionnaires on mood, activity, and sleep. The results allow a direct comparison of the measurement methods and provide insights into the relevance of the FOV in real-world lighting scenarios. This approach enhances our ability to describe light stimuli in field studies and deepens our understanding of non-visual light effects.

*Keywords*: non-visual light effects, personal light dosimetry, field-limiting aperture, field of view

## ID250
## OPTIMIZATION OF URBAN LIGHTING EVALUATION METHOD BASED ON MULTI-SOURCE DATA MUTUAL VERIFICATIONS

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Excessive energy consumption and interference towards human health caused by urban lighting have attracted widespread attention and the optimization of evaluation methods is important. ArcGIS Pro were used to analyze the Visible Infrared Imaging Radiometer Suite (VIIRS) data of Dali City (China) to obtain distributions of lighting intensity and high radiation areas. By comparing identified areas with point of interest (POI), typical categories were found. Unmanned aerial vehicle(UAV) and panoramic images were then used to make site verifications, it was found that constructional works is highly related to lighting intensity, buildings which caused high radiation are mostly consistent with POI conclusions, meanwhile, facade lighting, outdoor advertising and customized lights are key factors causing obtrusive lights. By combining VIIRS, POI, UAV and panoramic images, the evaluation efficiency can be significantly improved which also provide great convenience in lighting intensity distribution analysis, typical object recognition, specific problem discovery, etc.

*Keywords:* multi-source data, Urban lighting evaluation, Satellite imagery, Point of interest, unmanned aerial vehicle imagery, panoramic imagery, Geographic information system

## ID346
## MELANOPIC EQUIVALENT DAYLIGHT ILLUMINANCE AT HOME OF JAPANESE TELECOMMUTERS

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In this study, the lighting environment at home used for telecommuting in Japan was assessed from the viewpoint meet the recommended melanopic equivalent daylight illuminance (melanopic EDI). The horizontal and the vertical illuminance levels in the spaces used for telecommuting, such as living-dining room and study room were analysed. The results show that spaces with daylight from windows are likely to retain the melanopic EDI higher than 250 lx during the daytime. However, the melanopic EDI during the nighttime mostly exceeds 10 lx. The findings emphasize the importance to consider the local lifestyle and various ethical visual characteristics when integrating non-visual light effects into the design of lighting.

*Keywords:* melatonin, melanopic EDI, Illuminance level at home

## ID216
## INVESTIGATION OF THE MEASUREMENT ERROR DUE TO THE POSITION OF THE BAFFLE ON THE 2Π GEOMETRY INTEGRATING SPHERE PHOTOMETER

**Mitsuhiro AOYAGI[1,2], Dr. Kazuaki OHKUBO[2], Prof. Yasuki YAMAUCHI[1]**
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The integrating sphere has been used to measure the total flux of various types of light sources, but the measurement error caused by the optical design was not negligible. In this study, the measurement error with respect to the lamp beam angle was investigated based on a 2π geometric integrating sphere photometer model with the spatial response distribution function (SRDF) in the sphere was calculated by optical simulation. This study investigates two distinct types of sphere model (A and B), and the SRDF exhibited unique behaviours depending on each model. Moreover, the evaluation of each sphere utilising a variety of light distribution sources indicated that sphere type should be employed depending on purpose. Type A demonstrated the capacity to measure overall beam angle with decent accuracy. In contrast, Type B showed to achieve near-perfect accuracy for angle exceeding 50°, but their performance deteriorates significantly for angle narrower than this angle.

*Keywords:* Integrating sphere, Total luminous flux, Reflectance, SRDF, 2π geometry

## ID150
## PROPOSITION FOR A NEW TEXTURE DEFINITION AND ASSOCIATED METROLOGY

**Dr. Noël RICHARD[1], Dr. Hermine CHATOUX[2]**
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Over the last 60 years of research and development in the field of texture assessment or discrimination, no standard or recommended definition has been adopted. This study proposes to extract from the state of the art the existing definitions and the important elements to be retained. A proposed definition and two required properties are suggested. They constitute the first step in an international discussion on the definition of non-uniform surface metrology.

*Keywords:* Texture, Non-uniformity, metrology, image

## Tuesday, July 8, 08:30 - 09:30: Keynote lecture 2

# APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN THE COLOUR INDUSTRIES

**Prof. Stephen Westland**
School of Design at the University of Leeds, GREAT BRITAIN

Since the introduction of the term artificial intelligence in 1956, the last 70 years have seen increasing sophistication and speed for machine-learning algorithms. This presentation will review the main advances that have been made by describing several applications of AI in the colour-using industries. The talk will cover applications using supervised and unsupervised machine learning and will discuss the possibility of software achieving artificial general intelligence and what impact this might have on computational practice in colour, colorimetry and colour imaging. The reasons for the current interest in AI will be discussed and some possible outcomes for the next 5-10 years will be presented.

## Tuesday, July 8, 10:00 - 11:40: Oral Session 4 (OS4): D3 – Daylight

### ID179
### A ROUND ROBIN FOR A WORLDWIDE DAYLIGHT MEASUREMENT CAMPAIGN: INSIGHTS, CHALLENGES, AND LESSONS LEARNED

**Dr. Martine KNOOP[1], Prof. Laura BELLIA[2], Prof. Urszula BLASZCZAK[3], Dr. Dominique DUMORTIER[4], Prof. Mehlika INANICI[5], Dr. Paul KENNY[6], Prof. Shuying LIANG[7]**

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The aim of CIE TC 3-60 is to evaluate geographical and seasonal variations in daylight's spectral power distribution to refine the CIE reconstruction method for practical applications. Measurements include global, diffuse and direct spectral irradiance as well as spectral radiance from diverse locations. To address differences in instrumentation, configurations and operating procedures, the committee adopted a Round Robin (RR) approach using a travelling spectroradiometer to ensure data comparability. Challenges encountered during the RR include measurement obstructions and interferences, instrument tilt, and temporal discrepancies, which are being addressed through smaller studies and workflow refinements. The RR will continue in 2025 to further improve data quality through device alignment. Along with dataset alignment, this will support the creation of a comprehensive spectral dataset from various sites for the CIE TC 3-60 reconstruction work. A refined reconstruction method will enhance the understanding and use of daylight's spectral properties in lighting design and research.

*Keywords:* Daylight, Reconstruction Procedure, Round Robin, Spectral Power Distribution

### ID353
### ESTABLISHING A FRAMEWORK FOR COLLECTION OF COLORIMETRIC CHARACTERISTICS OF DAYLIGHT WITH AFORDABLE FISH-EYE ACTION CAMS

**Prof. Matej Bernard KOBAV[1], Prof. Martine KNOOP[2], Moritz Christian DÖLLE[2]**

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This research aims to establish a robust and innovative methodology for studying the colour of the sky. It focuses on exploring the potential use of small, portable action cameras equipped with fisheye lenses to capture comprehensive data on the colour of sky, its spatial distribution across the sky hemisphere and temporal changes of both. By employing these compact devices, the research envisions a globally scalable system for data collection, drawing inspiration from the CIE's luminance distribution models for various sky types. The study emphasizes the creation of a comprehensive framework to standardize data collection processes, ensuring accuracy and reliability. A key aspect of the research involves the detailed characterization and calibration of the cameras, as well as addressing variability in environmental and geographical conditions in the set-up, to enable consistent measurements across diverse global locations. This work could significantly advance our understanding of skylight colour distribution.

*Keywords:* CCT, CCT sky models, sky types

## ID367
## DAYLIGHT AND VIEW OUT: A COMPARATIVE STUDY BETWEEN BRAZILIAN AND EUROPEAN CONTEXTS

**Prof. Cláudia Naves David AMORIM[1], Dr. Julia Teixeira FERNANDES[2], Amanda Moura PINHEIRO[1]**
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The evaluation of quality of daylight indoors is a complex matter. Research about quality of view is increasing, with the European and the new Brazilian standard also addressing this aspect. This paper evaluates the quality of view and gather data concerning the Brazilian context, evaluating and comparing users' satisfaction with some European data. The method involves the creation of a database of Brazilian views and questionnaires to collect occupants' preferences. 34 representative Brazilian views were listed — within those, 15 views of 7 buildings in Brasilia, all evaluated by an assessment sheet based on approved methods. Users' perception consists in a in person (429 respondents) and online questionnaires (1301 respondents). There was a clear preference for natural elements, such as sky, water and vegetation, consistent with European results. As for Brazilian specificities, historical architecture is not a unanimous preference and there is a preference for modernist buildings.

*Keywords:* Daylighting, View out, User preferences, Brazilian context

## ID193
## EVALUATING WINDOW VIEWS: INSIGHTS INTO PERCEPTUAL DIFFERENCES BETWEEN OWNERS AND OBSERVERS

**Prof. Barbara MATUSIAK[1], Dr. Mandana SAREY KHANIE[2], Dr. Aicha DIAKITE-KORTLEVER[3], Dr. Jemima UNWIN TEJI[2], Dr. Natalia SOKOL[4]**
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This study investigates the assessment of window views by comparing the perceptions of long-term view owners with those of external observers. The research emphasizes the importance of views as a key attribute of daylight exposure and their impact on human perception and well-being. Conducted at four European universities, 145 students participated in workshops, evaluating their window views through a four-level process: static imagery, interior and exterior contextual analysis, and narrative accounts. Findings revealed that view owners rated their views significantly higher, influenced by long-term emotional adaptation, while external observers' evaluations remained unaffected by additional contextual and narrative details. These results highlight the limitations of static imagery in capturing experiential qualities and the intricate relationship between daylight, view content, and personal experiences. The study offers valuable insights for optimizing window design and fostering improved human-environment interactions in architectural practice

*Keywords:* Window View, View Appraisal, Long-Term View Exposure, Workshops

# ID202
# DEVELOPMENT OF AN EVALUATION METHOD FOR VIEW QUALITY IN OFFICE BUILDINGS

**Dr. Chikako OHKI[1], Dr. Yasuko KOGA[2], Dr. Yoshikane KOJIMA[1], Akito WATANABE[2]**
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Windows that provide daylight and a view are fundamental for creating comfortable and healthy office spaces. This study aims to develop an evaluation method for window view quality for application at the design stage of office buildings. A series of experiments were conducted in several real offices and virtual office spaces. The results confirmed that the quality of a view can be evaluated by the sky view factor, the near view factor indicating the proportion of buildings included in the foreground, and by the presence of greenery, such as roadside trees. Moreover, greenery was found to act as an additional factor in view satisfaction. As a view quality evaluation method, three-dimensional graphs were proposed to express view satisfaction based on the sky view and near view factors, considering the effect of greenery.

*Keywords:* View, Window, Office, Sky view factor, Near view, Greenery

## Tuesday, July 8, 10:00 - 11:40: Oral Session 5 (OS5): D4 - Revision of CIE 115

### ID119
### OPTIMAL ILLUMINANCE FOR PEDESTRIAN REASSURANCE

**Prof. Steve FOTIOS, Dr. Jim UTTLEY, Shahab GORJIMAHLABANI**
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The need for revision of CIE115:2010 is widely acknowledged and is currently a focus of activity in CIE Division 4. The first stage of this task is intended to be a rapid revision based on what we already know rather than waiting for new research to be completed. This article concerns lighting for pedestrians, the key road user for P class roads in CIE115. CIE 236:2019 indicates that pedestrian reassurance is a suitable focus for establishing optimal lighting conditions for the P class, and hence this article aims to support rapid revision of the P class through analysis of the results from previous field studies of pedestrian reassurance, these included for their use of the day-dark method proposed by Boyce et al. This analysis suggests an optimal average illuminance of around 7,5 lx: higher illuminance brings negligible increase in reassurance.

*Keywords:* road lighting, pedestrians, reassurance

### ID260
### DARKNESS INCREASES RISK OF SPECIFIC CRIMES

**Dr. Jim UTTLEY[1], Prof. Steve FOTIOS[1], Sarah FALCONER[2]**
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While road lighting is assumed to reduce crime, the supporting evidence is mixed. One factor is crime type – not all may be affected by the lit environment. This paper extends knowledge of lighting and crime through an analysis of crime conducted in collaboration with the local police. Of 15 crime categories, seven were associated with an increased risk after dark, including Burglary and Vehicle Offences; others, such as Violence Without Injury, showed a higher risk during daylight. These results confirm that darkness increases the likelihood of certain crimes and thus suggests a benefit of road lighting.

*Keywords:* Crime, Darkness, Road Lighting, Reassurance, Perceived Safety

## ID153
## ON SITE CHARACTERISATION OF ROAD SURFACES REFLECTION PROPERTIES FOR SEVERAL OBSERVATION ANGLES

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It has been proven that the use of CIE standard *r*-tables, instead of in-place stabilised pavement photometry, almost systematically leads to non-compliance with EN 13201 standard, particularly in terms of uniformities. Furthermore, the conventional observation geometry of 1° does not represent the preferred observation geometries of different urban road users in cities. In this paper, we present the device COLUROUTE2 that can be used to measure the road surface *r*-table on site for observation angles between 1° and 10°. Our first experimental campaigns on 10 different pavements confirm that the CIE road photometric indicators S1, Q0 and Qd generally decrease as the observation angle increases. Our results show that the assumption of equivalence of Q0 and Qd measurements between 1° and 2,29° in the CIE144 report is not valid, but that there are strong correlations between the different observation angles.

*Keywords:* Road surface, Photometry, r-table, Observation angle, Portable gonioreflectometer, Light reflection properties, Lighting design

## ID236
## MACHINE LEARNING BASED REAL-TIME PREDICTION OF LIGHTING CLASSES IN ADAPTIVE ROAD LIGHTING SYSTEMS

**Prof. Sermin ONAYGİL[1], Dr. Mustafa Berker YURTSEVEN[1], Sinem FEYZİ[2], Prof. Önder GÜLER[1], Serdar ERDOĞAN[2], Göktuğ OKTAY[2]**
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This study presents a machine learning-based framework for real-time prediction of road lighting classes in adaptive lighting systems. A pilot implementation was conducted on Büyükdere Street in Istanbul using two years of traffic and meteorological data. Lighting scenarios were developed in line with EN 13201 standards, and simulations with dimmable LED luminaires ensured compliance with lighting quality requirements. Hourly traffic flow and vehicle speed were predicted using Extreme Gradient Boosting and mapped to appropriate lighting classes via a rule-based matrix. The system was validated over six months, capturing seasonal and daily variations. The models achieved $R^2$ scores of 0.864 and 0.822 for flow and speed predictions, respectively. Predicted lighting classes reached 92.1% and 89.7% agreement with actual classes in two directions. Compared to non-adaptive M2-level lighting, the proposed system provided up to 32.1% energy savings. Results confirm the feasibility of data-driven adaptive lighting for energy-efficient and safe urban road environments.

*Keywords:* Energy Efficiency, Road Lighting Class, Adaptive Road Lighting, Control and Automation, Road Lighting Automation Algorithm, LED, Machine Learning

# ID315
# COMPARATIVE ANALYSIS OF INTERNATIONAL LIGHT POLLUTION GUIDELINES IN ECOLOGY: TOWARDS EVIDENCE-BASED MITIGATION STRATEGIES AND ECOLOGICAL THRESHOLDS

**Prof. Annika JÄGERBRAND**
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This review synthesizes practical lighting guidance from three major frameworks of international light pollution guidelines and identifies specific light thresholds for species protection. The analysis evaluates current international guidelines from a perspective of evidence-based recommendations for lighting professionals and managers to minimize ecological impacts while maintaining necessary lighting function. Results reveal three distinct but complementary approaches to light management: detailed technical specifications focused on species protection, implementation strategies, and protected area management principles. The comparison demonstrates how these different approaches complement each other and highlights critical gaps where additional research is needed to strengthen the evidence base for ecological light pollution mitigation.

*Keywords:* Light management, Species and area protection, Lighting design, Implementation strategies, Best practices, Light thresholds

## Tuesday, July 8, 10:00 - 11:40: Oral Session 6 (OS6): D1/D3/D8 - Vision & colour 1

### ID113
### ALGEBRAIC & ELECTROMAGNETIC MODELLING OF L, M, S CORNEAL SPECTRAL SENSITIVITIES USING A SINGLE PHOTOPIGMENT TEMPLATE

**Dr. James POND[1], Dr. Kees TEUNISSEN[2], Dr. Lorne A. WHITEHEAD[3]**
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Corneal spectral sensitivity functions (often called cone fundamentals) relate spectral power distributions of light to human colour perception. We modelled the corneal spectral sensitivity functions with a single algebraic function-based spectral photopigment template, with an adjustable peak wavelength, guided in part by numerical electromagnetic field modelling of the retina. In a first step, we relate the logarithm of sensitivity ratios at different frequencies to the logarithm of the ratio of those frequencies. A second step converts those results, according to common colour engineering practice, into discrete values of relative sensitivity for a discrete set of vacuum wavelength values. We incorporated two retinal effects not previously accounted for: (i) interaction of the uneven spatial distribution of macular pigment with the uneven spatial distribution of foveal S-cones, and (ii) cross-screening, whereby some of the light absorbed in a cone cell has first been filtered slightly by the pigment in adjacent cone cells.

*Keywords:* Cone Fundamentals, Electromagnetic Modelling, Photopigment Template

### ID156
### HOW WELL DO HUMAN PERCEIVE NON-UNIFORM SURFACE NOISE VARIATION?

**Dr. Hermine CHATOUX[1], Dr. Noël RICHARD[2], Dr. Susan FARNAND[3]**
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Since 1976, the CIELAB colour space is used to measure the perceptual difference between uniform patches. Several updates improved the measurements, but they generally focus on uniform colour patches. In this article, we consider the impact of non-uniform aspect (also called texture), on human perception. This paper provides information regarding on how much variation is needed to be perceived. The first step is to define the non-uniform image to use. We focus on non-semantic images: 3D Gaussian noise. Then, a psychophysical experiment was conducted presenting two images. The observer needed to choose the more textured one. The results show that on average, humans are sensitive at the smallest variation of noise in the image.

*Keywords:* Psychophysical experiment, texture, non-uniform perception

## ID171
## ESTIMATION MODEL OF VISIBILITY BASED ON THE CHROMATIC MECHANISM IN NEUROPHYSIOLOGY

**Suzu TAYAMA, Hikaru SHIDA, Dr. Kazuto TAKASE, Prof. Nozomu YOSHIZAWA**
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Visibility is a fundamental factor for explaining the visual environment and quantitative evaluation methods are being developed. Previously, as a model for estimating visibility, the edge detection algorithm that creates an edge image from a luminance image by imitating the perception of the boundaries of objects and surfaces (hereafter referred to as “edges”) in human early vision has been developed. In this study, we incorporated chromatic mechanisms into the algorithm using the responses of long-, middle-, and short wavelength-sensitive (L-, M-, and S-) cones in the retina as input data. This algorithm detects edges based on chromaticity that were not detected by the previous algorithm. We confirmed the efficiency of the algorithm by comparing the results of a subjective evaluation experiment using a display with the calculated values of the algorithm.

*Keywords:* Visibility, Edge Detection, Neurophysiology-Based Model, Colour Vision Mechanism

## ID191
## STUDY ON PERCEIVED WHITE POINT OF WIDE COLOUR GAMUT DISPLAY

**Dr. Xinyuan GAO, Dr. Shining MA, Dr. Weitao SONG**
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The white point, representing neutral white on the chromaticity diagram and crucial for display colour calibration, is typically set to D65. However, its suitability for wide colour gamut (WCG) displays with narrowband spectral characteristics remains underexplored. This study examined three different primary spectra WCG displays and one sRGB reference display. Using individual colour matching functions (CMFs), we estimated the spectra of visual matches on the WCG display to reference points with varying correlated colour temperatures (CCT) and *Duv* values. The results revealed chromaticity mismatch in white points between the reference and WCG displays, characterized by shift of the matched colour from the reference in the *+u′-v′* direction, which became increasingly pronounced as the display’s colour gamut widened and the primary spectra narrowed. Additionally, it is found that the CIE 2006 CMFs outperformed the CIE1931 2° and CIE1964 10°CMFs in reducing chromaticity mismatches, demonstrating their superior applicability for WCG displays.

*Keywords:* Wide color gamut, white point, colour matching functions

# ID196
# COLOURED SUNGLASS SIMULATION USING HYPERSPECTRAL IMAGING AND ICAM06

**Dr. Aiman RAZA[1,2], Marie DUBAIL[2], Dr. Dominique DUMORTIER[1], Dr. Sophie JOST[1]**
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Sunglasses offer protection against UV rays but can also improve the colour contrasts at wavelengths that matter for specific activities (sports, driving, etc.). Currently, the sunglass industry does not have comprehensive characterization methods for quantifying such innovations. This work validates a protocol to assess sunglass filtered vision via hyperspectral imaging and an image colour appearance model (iCAM06) with the help of psychophysical experimentation. This work also tested the chromatic adaptation transform (CAT) of iCAM06 (CIECAT02) against CMCCAT97 and its modified version. Simulations of sunglasses were compared for colour reproduction accuracy for a complex scene visualized through the actual sunglasses. CIECAT02 was found to reproduce the colour perception of the original scene with the highest accuracy when visualized with or without sunglasses. The non-linear CATs didn't improve the colour accuracy of the simulations, and thus validated the use of iCAM06 as a robust tool for filtered and unfiltered images in general.

*Keywords:* iCAM06, colour accuracy, hyperspectral imaging

## Tuesday, July 8, 12:40 - 14:20: Workshop Session 4 (WS4): D2

### HDR IMAGING FOR ASSESSMENT OF GLARE AND OF OBTRUSIVE LIGHT

Convenors:
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High Dynamic Range (HDR) imaging for glare evaluation lacks standardization, while uncertainty statements are usually absent. Together, these issues make it nearly impossible to fully explore the potential and limits of these systems. This workshop will provide a brief overview of the latest advancements in HDR imaging for evaluating glare and assessing the environmental impact of obtrusive light. By exploring technical aspects and real-world applications, it will set the stage for an in-depth discussion. Participants will be encouraged to engage in an open exchange on the challenges faced, lessons learned, and key research needs, fostering a collaborative dialogue that drives future advancements in the field.

## Tuesday, July 8, 12:40 - 14:20: Workshop Session 5 (WS5): D4

### RAPID REVISION OF CIE 115 LIGHTING OF ROADS FOR MOTOR AND PEDESTRIAN TRAFFIC

Convenor:
**Steve FOTIOS**
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The 2025 Division 4 workshop will focus on revision of CIE 115:2010 Lighting of Roads for Motor and Pedestrian Traffic. This revision is required because the data are incomplete, they are outdated, and because in most cases the basis of the recommendation is unknown. While it is acknowledged that this document is in need of revision, it has been delayed whilst we wait for further research. At the 2023 Division 4 meeting it was proposed that we first target a rapid revision, using data we already have: planning for this rapid revision will also recognise the ongoing or further research needed for a later, more substantial revision. This workshop will highlight the need for revision. It will focus on key topics where revision is needed, and it will encourage debate about how the revision is carried out.

## Tuesday, July 8, 12:40 - 14:20: Workshop Session 6 (WS6): CIE SP Education

### ACADEMIC & PROFESSIONAL LIGHTING EDUCATION

Convenor:
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This workshop aims to strengthen CIE's role in advancing education and fostering collaboration between academia and industry through its platform. Featuring three experts from academia and industry, invited by the CIE Standing Panel on Education, the session will explore interdisciplinary approaches to lighting education and professional training. Designed for educators, researchers, and students, the workshop encourages active participation in CIE's academic initiatives and professional training efforts. It seeks to bridge the gap between theoretical knowledge and practical application, promoting industry-academia partnerships. By facilitating dialogue and exchange, the workshop supports innovative educational strategies, best practices in teaching and training, and collaborative research. Participants will network with global experts, explore emerging trends, and help shape the future of lighting education and industry collaboration.

## Tuesday, July 8, 14:50 - 16:10: Oral Session 7 (OS7): D3/D6: Lighting for health and well-being

### ID198
### METROLOGY FOR NEUROPIC RESPONSE TO LIGHT: A CASE STUDY IN A NEONATAL INTENSIVE CARE UNIT

**Mehlika INANICI[1], James M GREENBERG[2,4], Richard A LANG[3,5], Jaime STRUVE[2], Katherine A GRUNER[2]**
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The inclusion of ocular and extraocular photoreceptor pathways in lighting studies represents a significant step forward in addressing the broader effects of light on human health and well-being. Building upon established metrics for ocular photoreceptors, this paper demonstrates metrology for neuropsin. Neuropsin is a violet (380 nm $\lambda_{max}$) sensitive photoreceptor present in both ocular and extraocular tissues and plays a role in eye development, circadian clock entrainment, and energy homeostasis. Outdoor measurements of photopic, melanopic, and neuropic ratios provide benchmarks for setting time-specific indoor lighting targets. Built environments modify the intensity and spectral quality of light sources due to the transmissive and reflective properties of materials and architectural geometry. The neuropic metrology is explored through a case study in a healthcare setting using in-situ measurements and multispectral simulations. The findings underscore that informed design choices can effectively enhance α-opic responses in built environments.

*Keywords:* opsins, Opsin5, neuropsin, N-EDI, violet light, built environment

### ID321
### INDIVIDUAL DIFFERENCES IN PHOTOBIOLOGICAL EFFECTS: A COHORT STUDY APPROACH

**Dr. Dandan HOU[1,2,3], Dr. Shixuan ZHANG[1,2,3], Dr. Hao YANG[1,2,3], Kanglong XIAO[1,2,3], Yang WANG[4], Prof. Yandan LIN[4], Prof. Bangsang ZHUOMA[5], Prof. Jiucun WANG[1,2,3]**
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Photobiological effects play a critical role in regulating circadian rhythms, mood, and cognitive function. In recent years, models quantifying photobiological effects have been developed, enabling predictions of light-induced melatonin suppression and circadian phase shifts. However, the simplifications in current models regarding individual characteristics limit their predictive accuracy at the individual level. This study aims to investigate the impact of Age, long-term light exposure history and ethnicity on human photobiological effects. We collected data from over 150 participants across representative light-climate zones in China, where the annual average illuminance varies by two times (<30,000 lx ~ >45,000 lx). For each participant, we measured physiological phenotypes (e.g., core body temperature, ECG) before and after nocturnal light exposure, biochemical phenotypes (e.g., salivary melatonin), and multi-omics data (e.g., genomics). These results could help elucidate the individual differences of human photobiological effects, providing novel insights for optimizing photobiological effects models and advancing healthy lighting strategies.

*Keywords:* Individual Differences, Photobiological Effects, Long-term Light History, Cohort Study

## ID211
## LIGHT EXPOSURE AND SLEEP QUALITY IN ICU PATIENTS: PRELIMINARY PILOT FINDINGS

**Iza Karen LINDERS[1,2], Dr. Veronica GARCIA-HANSEN[1], Dr. Francisca RODRIGUEZ[1], Oystein TRONSTAD[2]**
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Environmental factors in the Intensive Care Unit (ICU), such as lighting, play an important role in patients' sleep and recovery. However, ICU lighting is often suboptimal, and existing hospital lighting standards do not fully account for the non-visual effects of light, resulting in unfavourable conditions for critically ill patients. This paper presents preliminary findings from a clinical pilot study examining lighting conditions and sleep quality in ICU patients. Field measurements will be collected to describe patients' light exposure and sleep patterns and explore the relationship between these factors. Continuous light measurements will be obtained using a mini spectral sensor near patients' eye level. Simultaneously, objective sleep data will be continuously collected through single-channel electroencephalogram (EEG) devices and polysomnography. The findings will guide future research, potentially contributing to the development of ICU lighting standards and ultimately to optimising the ICU environment to enhance sleep and support recovery for ICU patients.

*Keywords:* Critical Care, Intensive Care Unit, Light, Sleep Quality

## ID374
## A CONTROLLED EXPERIMENT ON THE EFFECTS OF ARTIFICIAL LIGHTING ON PUERPERAE SLEEP, FATIGUE AND MOOD

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Postpartum women predominantly stay indoors and are more reliant on artificial lighting than during the prenatal stage. Consequently, their daytime mental state and nighttime sleep are influenced by the home lighting environment. To investigate the effect of the family dynamic lighting mode on postpartum women's mood and sleep, 30 Chinese postpartum women were recruited and randomly allocated to a control group and an intervention group (15 households each). In the lighting intervention phase, the control group maintained the usual living room lighting, while the intervention group adopted a dynamic lighting mode with morning wake-up, evening, bedtime, and nocturia modes. The four-week experiment comprised a one-week baseline, a two-week intervention period, and one-week observation period, during which sleep, daytime fatigue, and mood were measured. The results indicated that the dynamic lighting had a beneficial impact on sleep, fatigue, and mood in the experimental group.

*Keywords:* Dynamic light mode, Nonvisual effect, Postpartum mood, Sleep, Maternal

## Tuesday, July 8, 14:50 - 16:10: Oral Session 8 (OS8): D2/D4: Anthropogenic light at night

### ID279
### SPILL LIGHT IN A SENSITIVE COASTAL AREA: COMPARING TWO DIFFERENT LIGHTING INSTALLATIONS

**Stefan KÄLLBERG[1], Maria NILSSON TENGELIN[1], Annika JÄGERBRAND[2], Carsten RIECK[1]**
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Spill light, or unintended outdoor illumination, poses ecological threats, particularly in protected urban areas where photo-sensitive species are at risk. This study evaluates the environmental impact of spill light by comparing two lighting systems on a pedestrian and bicycle path in a sensitive coastal area. The original 6 m poles with LED luminaires were replaced with 1 m bollard luminaires emitting light with a lower color temperature. Using ground- and aerial based measurements, the study assessed spill light, general light pollution, and path illumination uniformity. Results revealed that the new bollards significantly reduced spill light towards the sea, decreasing vertical illuminance near the coastline by nearly tenfold. However, the horizontal illuminance uniformity on the path was reduced by a factor of five, potentially impacting user safety perception. The findings demonstrate the effectiveness of drone-based measurements and highlight the trade-offs between reducing ecological impact and maintaining user satisfaction in lighting design.

*Keywords:* Light pollution, Spill Light, Outdoor Lighting, Drone-based Measurements, Ecological Mitigation

### ID334
### DETERMINATION OF NATURAL REFERENCE LEVELS OF ILLUMINANCE AND EXPOSURE IN THE NIGHT ENVIRONMENT FOR THE ASSESSMENT OF LIGHT POLLUTION LEVELS

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The paper is focused on the mathematical description of the moonlight, namely the values of horizontal and normal illuminance from the Moon and the corresponding exposure values for any time and place on Earth. The aim of the research was to determine an algorithm for simulating the Moon as a light source and then using it to generate values for the Czech Republic and the year 2024. The values thus determined were then statistically analysed to determine the histogram of their occurrence as well as the median and mean. The data were then used to determine the theoretical exposure (in lux-hours) for the individual lunar cycles of 2024. The calculations assume that the Moon is a completely dominant light source in the natural nighttime environment, but its luminance and therefore the illuminance on the Earth's surface varies greatly during the year and on individual days of a cycle.

*Keywords:* Moonlight, light pollution, ALAN, natural light, reference, luminance analysis

## ID301
## METROLOGY OF OUTDOOR LIGHT EMISSIONS AT NIGHT USING UNMANNED AERIAL PLATFORMS

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The obtrusiveness of light at night can be met in forms of upward, spill, and reflected light, high intensity or hight contrast light sources, intrusive light or light escaping from building structures and as elevated sky radiance. All these sources and effects are also commonly referred as light pollution with the common characteristic that light propagates to the three-dimensional space directly or through various means. To quantify and assess light pollution it is essential to introduce dedicated measurement methods and instrumentation. This paper presents the first results of a research project on the development of a drone-based measurement system for quantifying light emissions in the outdoor space. The presented work includes the development of the flight platform, the specialized mission planning, the development of the measurement instrumentation, some measurement results from the verification flights as well as future developments. The research results will be submitted to the relevant CIE TC2-95.

*Keywords:* Obtrusive light, Light pollution, Photometry, Metrology, Drones

## ID342
## THE OBTRUSIVE LIGHT MEASUREMENT WITH UNMANNED AERIAL VEHICLE

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This paper is dedicated to inform a reader about the new research about the reconstruction of luminous intensity distribution of illuminated buildings or large outdoor objects that significantly contribute to disturbing light at night. The obtrusive light is highly discussed topic recently. However, there is lack of measuring equipment capable of characterising the contribution of individual illuminated objects to total obtrusive light. The proposed method uses unmanned aerial device with calibrated luminance camera to remotely and autonomously collect the luminance data around the object. With sufficient number of luminance images from different viewing positions and accurate GPS coordinates it is possible to indirectly calculate the luminous intensity distribution of that object and therefore evaluate total luminous flux that is irradiated in upper part of hemisphere and cause obtrusive light. These data can be used to determine the extent of the contribution of this object to obtrusive light in local region.

*Keywords:* Obtrusive light measurement, luminance camera, luminous intensity distribution, unmanned aerial devices

## Tuesday, July 8, 14:50 - 16:10: Oral Session 9 (OS9): D3/D4: Glare

### ID275
### TOWARDS RESILIENT LIGHTING DESIGN FOR DISASTER REFUGES PART 2: LIGHTING CONDITIONS OF JAPANESE GYMNASIUMS USED DURING ACTUAL DISASTERS

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During disasters, the safety, visibility, and comfort of evacuees must be ensured. However, poorly designed lighting can lead to excessive glare and inadequate brightness for essential activities like movement. The final goal of our research is to guide the development of future lighting designs for refuges and shelters that meet diverse needs during emergencies while supporting evacuees' safety and well-being. This study examined the lighting environments in gymnasiums used as shelters in Japan, focusing on short-term shelters opened during Typhoon Hagibis in 2019 and long-term shelters established after the Noto Peninsula Earthquake of 2024. Field measurements, interviews with shelter operators, and evacuee surveys were conducted to evaluate lighting conditions and identify key challenges. This study highlights the limitations of ceiling lighting, its tendency to produce glare, and explores practical solutions involving indirect lighting and portable lamps. These findings emphasise the importance of flexible lighting systems that balance visibility and comfort.

*Keywords:* Resilient Lighting, Gymnasium Shelters, Safety and Security, Sleep, Japan Case Study

### ID145
### DISABILITY GLARE FROM PHOTOVOLTAIC PANELS IN AIRPORTS

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The recent development of renewable energies leads to an increasing number of photovoltaic panels (PVPs) deployed worldwide, including around airports. However, solar ray reflections on PVPs may produce glare, both for pilots on approach and for air traffic controllers (ATCs), impairing their visibility of, respectively the runway threshold and objects along the runway. Regulation standards on PVPs around airports vary across countries but unexpectedly, the visibility of relevant targets has not been considered so far as a rationale in order to control the glare from PVPs in airports. In this paper, we compute the visibility of targets we defined for pilots and ATCs in a few reference scenarios, using Adrian's formula and a Contrast Sensitivity Function. Then, we assess, from the CIE formula of the equivalent veiling luminance, the impairment of the visibility in presence of disability glare, as a first tentative step towards regulating PVPs around airports regarding disability glare.

*Keywords:* Disability Glare, Visibility, Contrast Sensitivity, Photovoltaic Panel, PVP

## ID257
## COMFORT VIEW ZONE: MEASURING DISCOMFORT GLARE

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Measuring discomfort glare is a notoriously difficult task. Many physiological measures (like pupil response) and psychophysical measures (like subjective rating scales) have been proposed. Two important complicating factors are the large individual variability in glare sensitivity and the strong influence of the observer's gaze direction. Instead of attempting to fixate the gaze direction, we propose a method where respondents are free to determine the range of comfortable viewing directions: the "comfort view zone". This range is individual and depends on the context of the experiment. Variations in lighting conditions will then lead to relative individual variations in the comfort view zone, which is used as a measure of discomfort glare. Pilot tests in outdoor and indoor lighting setups shows promising results: the measure is sensitive to modest variations in light output, and to variations in luminance distribution of the glare source.

*Keywords:* Discomfort glare, Methodology, Viewing direction, Position index, Outdoor lighting, Indoor lighting, Glare source uniformity

## ID335
## DO CIE-RECOMMENDATIONS FOR PROPER LIGHT AT THE PROPER TIME CONFLICT WITH GLARE?

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CIE recently issued a position statement advocating for appropriate lighting at the right time, specifically recommending a melanopic EDI of 250 lx at eye level during daytime. However, the statement also cautions that avoiding glare from windows requires "advanced lighting design guidance", implying a conflict between achieving healthy lighting and managing daylight-induced glare. This study examines whether such a conflict is justified. Both a theoretical analyses and results of a user study conducted at six locations suggest otherwise: recommended illuminance levels for healthy lighting are significantly lower than typical glare thresholds. In fact, vertical illuminance levels between 250 and 1000 lx from daylight typically reduce perceived glare from façades. A supporting simulation study across three European climates, using typical shading devices and controls, further confirms this finding. The results demonstrate that healthy daytime lighting through daylight does not inherently increase glare risk and can be achieved without compromising visual comfort.

*Keywords:* Lighting recommendations, discomfort glare, daylight

## Tuesday, July 8, 16:10 - 17:40: Poster session 2

### ID142
### CHARACTERIZATION OF PHOTORESPONSE NON-UNIFORMITY AND NON-LINEARITY OF MULTISPECTRAL CAMERAS FOR RADIANCE AND LUMINANCE MEASUREMENTS

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Multispectral cameras provide both spatial and spectral information and they can be used for radiance and luminance measurements. These measurement systems must be characterized to be used as radiance or luminance meters, and that includes the evaluation of their main sources of error. Two of them are photoresponse non-uniformity (PRNU) and non-linearity. In this study, a single experimental system for characterizing non-uniformity and non-linearity of multispectral cameras for radiance and luminance measurements are described. The evaluated measurement system consists of a CCD (charge coupled device) based camera and a liquid crystal tunable filter (LCTF). A setup based on an integrating sphere, which provide identical radiant conditions for all pixels simultaneously, is proposed to characterize non-uniformity and non-linearity errors.

*Keywords:* Multispectral camera, non-uniformity, non-linearity, luminance measurements

### ID224
### CHARACTERIZATION OF THE NONLINEARITY OF ARRAY SPECTRORADIOMETERS FOR IRRADIANCE MEASUREMENTS

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Nonlinearity in a spectroradiometer refers to deviations from the ideal proportional relationship between the signal and the irradiance. In an ideal system, the signal should increase linearly with irradiance and integration time. However, for various reasons deviations from proportionality occur, which must be corrected for reliable measurements, or characterized to be taken into account in the uncertainty estimation. This work presents a methodology to characterize the nonlinearity of array spectroradiometers designed to perform spectral irradiance measurements with metrological quality, within the visible range. This methodology allows to identify the different sources of nonlinearity in relation to different variables: integration time, direct response of the instrument and irradiance to which the instrument is exposed.

*Keywords:* Array spectroradiometers, Nonlinearity, Irradiance

## ID243
## USE OF STELLATED APERTURES TO MINIMISE INTERNAL FORWARD REFLECTIONS IN STRAY LIGHT BAFFLES

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An important aspect of photometry is the use of baffles to block stray light, such as light reflected of the walls and floor, or light from other sources, from reaching the detector. The detector will often be placed in a baffle tube to limit the field-of-view of the detector to a narrow field around the optical axis, and the tube itself will usually have internal apertures to block reflections from the sides of the tube. The inside edges of the internal apertures can forward-diffract light onto the detector. In most cases this may be negligible, but for highest-accuracy applications may be significant. This paper describes a method to use stellation, i.e. introducing “teeth” to the inside edge of the internal apertures of a baffle tube, to reduce the forward diffraction by as much as 50 %.

*Keywords:* Photometry, stray light, baffle, additive manufacturing, baffle tube

## ID293
## SPECIFYING LUMINAIRE CUTOFF IN LIGHT POLLUTION REGULATIONS

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This paper examines different approaches used to specify the cutoff, or shielding, properties of luminaires in light pollution regulations, with a focus on the G* classification defined in the European road lighting standard, and the CIE flux code FC3, used in the French regulation. To compare the G* and FC3 rating schemes, a simple parametric model is introduced to generate typical luminous intensity distributions used in road lighting. In addition, these rating schemes are applied to a dataset of 145 measured luminous intensity distributions of outdoor luminaires with different characteristics. The results show that the G* classification yields more robust ratings than requirements based on FC3. However, neither FC3 nor G* can correctly predict the cutoff angle of the luminous intensity distributions, a parameter linked to the visibility of a luminaire at long distance.

*Keywords:* Light Pollution, Road Lighting, Regulation, Standard, Visibility, Glare, Luminaire, Cutoff, Shielding, Luminous Intensity Distribution, G* class, BUG rating, CIE Flux Code, ULR

## ID324
## UNSUPERVISED END-TO-END FEED-FORWARD NEURAL NETWORK FOR COLOUR DISCREPANCY ADJUSTMENT IN DISPLAY CAMERA COMMUNICATION SYSTEMS

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Human visual system's sensitivity to screen flickering necessitates innovative approaches for data embedding that do not compromise visual quality. This paper presents an unsupervised end-to-end feed-forward neural network (E2E-FNN) designed for colour discrepancy adjustment in display camera communication systems. Our method leverages differential modulation in the chrominance plane of the L-a-b colour space and Manchester encoding to embed data bits into video frames. FNN is employed to learn and predict the nonlinear colour space transfer features from display to camera reception, enhancing colour rendering accuracy. Experimental results demonstrate a significant reduction in bit error rate for approximately 50% for varying video clips, showcasing the effectiveness of our approach. The E2E-FNN based framework is lightweight for mobile deployment, enabling outdoor screens to simultaneously broadcast visual content and device-readable data streams, while smartphone cameras capture and decode information seamlessly, pioneering dual-channel synchronization in Internet-of-Everything environments.

*Keywords:* end-to-end feed-forward neural network, chrominance modulation, colour rendering, Manchester encoding, display camera communication

## ID208
## A PRELIMINARY FIELD-TEST OF LIGHTING WITHIN A GERIATRIC AND REHABILITATION UNIT: INFORMING A LARGER STUDY ON SLEEP QUALITY

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Hospitalised patients often experience insufficient, poorly timed light within clinical environments. Although international circadian-lighting guidelines exist, their application in geriatric and rehabilitation environments remains underexplored. This preliminary field test conducted within the local Geriatric and Rehabilitation Unit (GARU), Australia, measured horizontal and vertical Melanopic Equivalent Daylight Illuminance (M-EDI), illuminance (lx), and Correlated Colour Temperature (CCT) measurements, which were recorded at patient eye-level across multiple lighting conditions at noon and evening in two four-bed bays. Daytime M-EDI never approached the recommended 250 lux M-EDI, even under maximum artificial lighting, while evening illuminance remained consistently ≤10 lux M-EDI, but with cooler spectra than ideal. These preliminary findings will shape the subsequent seasonal sleep, light, and sound measurements of a larger study, and inform environmental interventions aimed at improving sleep quality and patient well-being.

*Keywords:* Geriatric Rehabilitation, Circadian Lighting, Melanopic Equivalent Daylight Illuminance (M-EDI), Hospital Environment, Sleep, Illumination Standards, Correlated Colour Temperature (CCT), Environmental Intervention, Preliminary Field Test

## ID389
## LUMINOUS AND SPECTRAL RESPONSIVITY OF PHOTOMETERS FOR MEASUREMENTS OF HIGH ILLUMINANCE LEVELS

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Photometers measuring high illuminance levels, ranging up to 200 000 lux, often undergo significant heating during operation in high illuminance measurements, i.e. by more than 10 °C. This namely affects the spectral matching filter, altering the luminous responsivity but also the spectral mismatch of the photometer, and leads to significant measurement errors. This effect depends on the photometer design and on the angular and spectral distribution of the irradiation. An active temperature stabilization significantly reduces the sensitivity to this measurement conditions, but high illuminances anyway affect internal temperature gradients while the stabilization is limited to a certain range of ambient temperature and illuminance. This paper demonstrates its significance by the differential responsivity regarding an RGBW LED spotlight and a bias irradiation generated by a while LED or incandescent lamps. The differential spectral responsivity of photometer heads reveals a significant decrease by several percent in the spectral range below 550 nm.

*Keywords:* Photometry, spectral responsivity, spectral mismatch, reference spectrum L41

## ID350
## INTERDISCIPLINARY INSIGHTS: OPTIMIZING LIGHTING FOR HORMONAL HEALTH IN INDOOR ENVIRONMENTS

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This study introduces a novel methodology to investigate how lighting conditions influence hormonal responses in human occupants within inner built environment, combining advanced measurement techniques (e.g., wearable sensors for light exposure, salivary melatonin, and pupillary responses) with machine learning to develop a predictive model for spectrally tunable lighting systems. By analyzing real time physiological data, the model forecasts hormonal outcomes under specific lighting scenarios while enhancing prediction transparency through interpretable AI techniques. Additionally, the research integrates non-image-forming (NIF) lighting effects-such as circadian regulation and melatonin modulation-into Building Information Modeling (BIM) frameworks. This standardization improves interoperability for lighting evaluations enabling data-driven decisions that prioritize occupant health. The study bridges lighting design with human well-being by linking spectral composition (e.g., cool vs. warm white light) to measurable biological outcomes, offering actionable insights for architects, engineers, and health researchers.

*Keywords:* Non-Image Forming Effects, Wearable Sensors, Circadian Rhythms, Lighting Conditions, Health and Well-Being, Machine Learning, BIM

## ID215
## ROAD SURFACE LUMINANCE OF THE TUNNEL INTERIOR LIGHTING WITH SOOT AND SMOKE EXHAUSTED FROM VEHICLES

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Under any tunnel interior lighting conditions, the required road surface luminance taking into account the effect of soot and smoke exhausted from vehicles on the visibility of obstacles on the road has not been clarified. In this study, the total revealing power of the visibility index is calculated using a model for calculating the luminance of a visual object in soot and smoke exhausted from vehicles and a model that modified the method for calculating the luminance difference threshold in a non-uniform visual environment. The required road surface luminance is shown for any given air transmittance in a tunnel, taking the total revealing power under Japan's current lighting standards as the required value. The road surface luminance can be adjusted based on the air transmittance inside the tunnel, which changes over time, it is possible to reduce energy consumption while ensuring safety.

*Keywords:* Tunnel Interior Lighting, Visibility, Air Transmittance, Total Revealing Power

## ID155
## THE TRANSMISSION OF NEAR-INFRARED ELECTROMAGNETIC RADIATION THROUGH DIFFERENT FABRIC TYPES

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Recent research has shown that Near-infrared (NIR) radiation within certain ranges is likely to have a positive effect on health and well-being, whether it is transmitted via the eyes or skin. Yet, its transmission through fabrics used in everyday clothing is frequently overlooked. This study quantifies NIR transmittance through different fabric types by measuring NIR penetration through clothing samples in a controlled laboratory setting. Our findings indicate that lighter fabrics permit greater NIR penetration.

*Keywords:* Near-infrared radiation, fabric textiles, transmittance

## ID347
## QUANTITATIVE STUDY ON SKIN WHITENESS PREFERENCE OF CHINESE YOUNG WOMEN

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In China, the preference of women for fair skin is widely recognized, but there is a lack of quantitative research on this phenomenon. The purpose of this study is to explore the quantitative effect of whiteness index on the skin colour preference. The preference of skin whiteness was studied in two application fields: cosmetics and images. The results showed that the whiteness index $ITA_M^\circ$ of liquid foundation and subjective preference evaluation have achieved a highest fitting result ($R^2$=0.97 of nonlinear fitting), and could be regarded as the best index for people to evaluate the colour preference of foundation. The whiteness preference for facial images was further explored, and the results showed the similar preferred whiteness range.

*Keywords:* skin colour preference, whiteness index

## ID212
## ASSESSING MELANOPIC ILLUMINANCE IN HOMES: FROM DESIGN TO CONSTRUCTION

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This paper presents a detailed analysis of the non-visual daylighting performance of a newly constructed, carbon-neutral, single-story home-office located in the humid subtropical climate of East Texas, USA. The house was simulated in ClimateStudio to generate climate-based annual hourly illuminance data, and in ALFA to estimate the circadian impact of light. On-site photometric and spectral measurements were conducted to compare with simulation outputs and assess compliance with recommended Melanopic Equivalent Daylight Illuminance (M-EDI) thresholds. Results indicate that M-EDI levels at office workstations and in the living-dining areas exceed the 250 lux minimum recommendation by a factor of 2 to 6 under clear sky conditions. Photopic illuminance levels also surpass the requirements specified by LEED and WELL standards for daylighting credits. The house design features small windows and minimal shading to manage glare and thermal gains.

*Keywords:* Daylighting, Melanopic EDI, EML, circadian regulation, sleep, alertness

## ID147
## THE PERFORMANCE OF COLOUR FIDELITY METRICS UNDER SPECTRAL PERTURBATIONS

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Colour fidelity metrics aim to quantify how well spectral illuminants reproduce object colours relative to a set of reference illuminants, and rank them according to the unwanted shift in the object colours. Object colours are produced indirectly through the interaction with the spectral reflectivity of their surfaces. The illuminant colour temperature directly determines the reference spectrum that putatively produces the desired colours. Applying Gaussian spectral perturbations to a library of varied realistic test illuminants, the performance of consensus colour fidelity metrics is illustrated. Potential evidence of sub-optimal metric performance is explored, suggesting the need to emphasize parsimony in colour fidelity research and application. The perturbation method also provides a means to test improvements to the design of spectral entropy as a fidelity metric, that could ultimately combine parsimony with many of the strengths of traditional metrics and those of spectral entropy itself.

*Keywords:* Colour Fidelity, Colour Rendering, Spectral Entropy, Spectral Perturbation, Metric Performance

## ID300
## COLOUR-BASED GRANULOMETRIC ANALYSIS WITH PATTERN SPECTRUM

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The granulometry of riverbed is essential for river flow simulations and sediment transport studies. Physical measurements are time-consuming and invasive, remote sensing solutions are therefore preferred, such as image-based approaches. Among them, the pattern spectrum, derived from mathematical morphology, respects metrological properties and does not require shape approximation. We illustrate here the extension of the pattern spectrum to colour images and the link between the results and granulometric distribution. Colour references are required by the ordering relation used, which allow for an order between grains and other constituents to be found. To reproducibly compare the impact of granulometric distributions, we chose to work on manufactured grain tiles. A comparative analysis of four samples is presented. The resulting pattern spectra illustrate the potential for discrimination related to granulometric distributions, as well as the problem caused by the choice of references for the ordering relation.

*Keywords:* Granulometry, Mathematical Morphology, Pattern Spectrum, Colour Image Processing, Vision

## ID131
## RETHINKING PHOTOMETER CALIBRATION STANDARDS: ALTERNATIVE SPECTRAL DISTRIBUTIONS SHAPED BY LED TECHNOLOGY

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The photometers are calibrated using a standard incandescent source (Illuminant A). However, to be up to date with light sources technology, the International Commission on Illumination (CIE) recommended to replace Illuminant A by the L41 spectral distribution (SD) which is mimicking the spectral distribution of pc-LED. But it's important to consider the fact that year 2030 is expected to be the next revolution in LED technology. The pc-LED sources will be replaced by color-mixing LED (cm-LED) as more efficient sources. In this study, a dataset of photometers calibrated with the L41 source was evaluated for its suitability in measuring cm LEDs. The research confirmed that when cm-LEDs are considered, the L41 calibration source SDs is better solution than Illuminant A, but it isn't optimal, because typical 4000 K nominal CCT ordinary cm-LED SDs performing better as calibration source. This emphasizes the necessity for the development of dedicated calibration source for cm LEDs.

*Keywords:* Photometry, spectral mismatch correction factor, Phosphor Converted LEDs, Color mixing LED

## ID148
## AUTOMATED LIGHT QUALITY MEASUREMENT IN CORRIDORS

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This paper describes an automated method to deal with standard requirements in evaluating lighting quality (illuminance levels and uniformity). We developed a system based on a calibrated illuminance meter carried by a mobile robot equipped with a 3D LiDAR. The localization of the illuminance points in space is calculated thanks to a Simultaneous Localization and Mapping (SLAM) algorithm. Finally, a processing of the illuminance data and the positions allows to build a dense illuminance map. We present two experiments made before and after relamping corridors in a workplace. The results are compared with the standard requirements.

*Keywords:* Illuminance Map, Lighting Standards, Indoor Lighting, Mobile Robotics

## ID283
## ESTIMATING GLARE IN DYNAMIC TRAFFIC SITUATIONS

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Reducing glare for nighttime drivers is important for road safety. This study estimates glare based on veiling luminance calculations using measured light distributions and 3D positioning data in two real-world scenarios: a railway near a motorway and a bicycle path illuminated with handrail lighting adjacent to an unlit motorway. For the railway case, incorporating limits on maximum allowed corneal illuminance at small angles to the glare source significantly extended road sections at risk of glare compared to only using veiling luminance as criterion for glare. However, the lack of knowledge regarding acceptable veiling luminances and which maximum distance to the source that is relevant to include, complicates the risk analysis. For the handrail lighting, while high threshold increment values were identified at specific positions, the transient nature of these potential glare occurrences suggests that their practical impact may be limited.

*Keywords:* Glare, Train, Headlamp, Driver, Nighttime, Handrail Lighting, Veiling Luminance

## ID281
## EFFECT OF METAMERIC WHITE LIGHTS ON VISUAL PERFORMANCE

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Intrinsically photosensitive retinal ganglion cells (ipRGCs) are known to be involved in non-imaging functions of the eye, through a direct stimulation of a photopigment names melanopsin. Recent studies suggested that besides playing a role in circadian rhythm and cognitive functions such as alertness and working memory, they would modulate perceptual vision. However, the underlying mechanisms involved remain unclear. Our study further investigates whether this stimulating effect of light can be extended to light detection thresholds and how it varies with aging across the visual field. To this end, a perimetry task was designed and performed under two metameric white lights, opposed in melanopsin stimulation. Findings suggest that ipRGC stimulation does not interfere with light detection thresholds but may enhance visual functions by improving reaction time. Increased performances may be the consequence of non-imaging pathways stimulation and not likely the results of brightness or contrast perception.

*Keywords:* Light, Melanopsin, ipRGC, metamerism, perimetry

## ID395
## EVALUATION OF THE VISIBILITY OF A FALLEN OBJECT IN A FULL-SCALE TUNNEL WHEN A SUBJECT IS A PASSENGER IN A MOVING VEHICLE AND VERIFICATION OF THE EFFECTIVENESS OF INDIRECT EVALUATION BY USING AN HMD

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In this study, we investigated the visibility of a fallen object in a full-scale tunnel during vehicle travel. The visibility score improved proportionally to |log ($R_L$)|, the absolute value of the natural logarithm of the luminance ratio $R_L$ between a fallen object and a background road surface. This result was consistent with that when the subjects were static. The maximum distance at which a subject recognizes a fallen object, the first recognizing distance $D$, increases in proportion to |log ($R_L$)|. The evaluation using indirect viewing with the HMD shows a high correlation with the result of the direct viewing experiment. However, the maximum distance from a subject to a fallen object when the subject recognizes it is shorter in the indirect view compared to the direct view. This difference may be attributed to the lower resolution of the HMD.

*Keywords:* Tunnel Lighting, Pro-Beam, Silhouette, Reverse Silhouette

## ID251
## SPECTROSCOPIC MEASUREMENT OF FLUORESCENT PIGMENTS FOR PENETRANT TESTING

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The purpose of this study was to rationalize the Fluorescent Penetrant Test, which is used for crack inspection of building structures, equipment, and various parts, and to establish a method for measuring fluorescent images using spectral imaging. As the fluorescent agent, five types of water-soluble fluorescent color paints with different excitation-emission wavelength ranges were used. The fluorescence properties of the fluorescent agent were performed using a spectrofluorometer comprising two spectrometers. For spectroscopic imaging, an LED lamp emitting UV light was used for illumination, and a light receiving device composed of a liquid crystal tunable filter and a monochrome CCD sensor was used. As a result of the measurement, we were able to obtain an excitation-emission matrix and a spectroscopic image, and based on this, it became possible to study how to obtain high contrast in inspection.

*Keywords:* Penetrant test, Fluorescent, Measurement, Spectral imaging

## ID152
## MODELLING SOLAR DISABILITY GLARE REFLECTED FROM MODERN BUILDING FACADES

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Buildings can be assessed during concept design to identify potential for sunlight to reflect from exterior cladding surfaces and create traffic disability glare onto surrounding roadways. Historically most assessment methodologies calculate veiling luminance hazard at roadway receiver locations assuming specular type solar reflections from glazing. A population dosage of veiling luminance is proposed in this study as a limiting measure of solar disability glare exposure to passing traffic. Modern facades are increasingly adopting metal sheet cladding products displaying both specular and highly diffuse reflective surface properties. In-house software has been developed to perform solar reflection calculations for these products. The program generates view-based luminance renderings at traffic receiver locations which are evaluated using a custom script to determine annual disability glare metrics for comparison with disability glare criteria. Threshold increment is also calculated as a measure of reduction in contrast due to disability glare. Case studies and mitigation strategies are reviewed.

*Keywords:* Solar Reflectivity, Disability Glare, Veiling Luminance, Irradiance, Contrast, Mitigation

## ID381
## REVIEW OF LIGHTING STRATEGIES TO REDUCE LIGHT POLLUTION

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This state of the art reviews the principles and technical solutions for reducing light pollution caused by Artificial Light at Night (ALAN). It is based on scientific literature, technical reports (including the CIE), international standards and regulations, as well as technical guidelines. It reviews the main proposed approaches for the management of ALAN, such as extinction, smart lighting, changes in spectral power distribution, light intensity and spatial distribution. The purpose of this overview is to give examples of useful solutions for public authorities.

*Keywords:* Light Pollution, Artificial Light At Night (ALAN), Public lighting

## ID226
## VISUAL PREFERENCE EVALUATION FOR LUMINA NIGHT WALK APPLICATION OF LIGHTING PROJECTION IN VEGETATED ENVIRONMENT: A PLEASURE-AROUSAL-DOMINANCE (PAD) MODEL PERSPECTIVE

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Emotional responses to vegetation-based nighttime lighting remain poorly understood beyond basic colour–emotion associations. This study develops a spatialized PAD framework integrating hue composition, foliage chromaticity, and center–periphery colour placement. A pre-survey and laboratory experiment examined 32 lighting projection scenarios across green and yellow foliage substrates. Regression and affective typology analyses revealed that yellow and white lighting, especially when centrally projected onto yellow foliage, consistently enhanced Pleasure, Arousal, and Dominance. In contrast, cool-toned projections (blue, purple) suppressed affective scores, particularly under green foliage. Spatial asymmetry moderated these effects, with center–dominant warm hues amplifying engagement and peripheral cold tones dampening it. The findings establish a multidimensional model of affective lighting perception and offer design-level strategies for emotionally attuned nightscape environments.

*Keywords:* Affective Lighting Design, PAD Emotion Model, Foliage Chromaticity, Emotional Typology

## ID244
## THRESHOLD LUMINANCE DIFFERENCE MODEL FOR PEDESTRIAN CONSPICUITY IN A COMPLEX SCENE AND DIFFERENT LIGHTING CONDITIONS

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This paper is a study aimed at determining a comprehensive model including the most important factors contributing to conspicuity, typically in night-time traffic. The authors primarily focused on the analysis of the different parts of the Adrian luminance threshold model. The influence and significance of each part of the model is shown. At the same time, a modification of this model was proposed to include the influence of the spectral power distribution of illumination, stimulus color and glare on visibility. The resulting estimates of contrast thresholds using the modified Adrian model were verified using a set of laboratory and outdoor conspicuity tests of pedestrians equipped with various visibility-enhancing contrast features. The results show benefits for the design of both high visibility workwear and sportswear for outdoor leisure activities.

*Keywords:* Contrast, Color Fidelity Index, Conspicuity, Luminance, Glare

## ID121
## EXPERIMENTAL INVESTIGATION OF IMAGE REPRODUCTION WITH PERCEPTUAL GLOSS EQUIVALENT TO REAL GLASS, METAL, AND STONE

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This study examines images that are perceptually equivalent to the gloss of real objects to see if a high-resolution colorimetrically reproduced image can reproduce the glossiness of a real object. In addition to a direct comparison of the glossiness of the real object and the colorimetrically reproduced image, a psychophysical experiment was conducted to select images that reproduce the glossiness of the real object by direct comparison between the processed image and the real object. The results, using 24 stimuli consisting of glass, metal, and stone, showed that (1) direct comparison between real objects and colorimetrically reproduced images showed that digital imaging significantly reduced the glossiness, (2) experiments to select images with equivalent gloss to real objects showed that the contrast of GLCM features contributes to the accuracy of reproducing the glossiness of real objects. Therefore, even an image may be able to reproduce glossiness through contrast modulation.

*Keywords:* Image Reproduction, Perceptual Gloss, Appearance

## ID303
## INVESTIGATION OF THE BALANCE BETWEEN WORK SURFACE ILLUMINANCE AND SPATIAL AVERAGE LUMINANCE IN DESK WORKSPACES: A COMPARISON OF YOUNGER AND OLDER ADULTS

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In 2016, the Architectural Institute of Japan published the Academic Standard for Lighting Environments (AIJES-L0002-2016), which has been in use for several years and is currently under consideration for revision. This standard specifies the lower limit of recommended average luminance values for ceilings and wall surfaces. However, it has been noted that the internal reflectance values underlying these recommendations are set too low, resulting in an excessively high contrast between work surface illuminance and average luminance. To address this issue, evaluation experiments were conducted to investigate the balance between appropriate work surface illuminance and spatial average luminance. To ensure the inclusion of a broad age range, experiments were conducted with participants in their 20s and those around 70 years of age. The results revealed that, regardless of age group, approximately half of the participants judged the contrast as inappropriate when the ratio of work surface illuminance to spatial average luminance exceeded 20:1.

*Keywords:* Luminance standard, Work surface illuminance, Spatial average luminance, Visual comfort, Spatial brightness, Age group comparison

## ID221
## RESEARCH ON IMPRESSION - SHIFT DUE TO THE INFLUENCE OF ADJACENT LIGHTING ENVIRONMENT: IMPRESSION EVALUATION EXPERIMENT CONDUCTED AT A SHOPPING MALL

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In a complex interior space, different lighting environments exist next to each other. Like colour contrast emphasizing its differences, it was hypothesized that different lighting environments adjacent to each other causes impression-shift, and differences are emphasized. Without considering the possibility of impression-shift into design, it is difficult to actualize lighting impression as originally intended. This study verified it through impression evaluation experiment and lighting measurements conducted in a shopping mall. As a result, impression-shift occurred concerning the same space when contrast in lighting environment exists compared to a single lighting environment. Through analysis, photometric quantities' differences that may have caused brightness, sharpness and warmness impression-shift were derived. This experiment was conducted in an actual shopping mall with many interfering factors, calculated numerical values are for reference only, and further experiments in a controlled condition are required to propose a specific numerical guideline.

*Keywords:* Impression Evaluation, Brightness Contrast, Sharpness Contrast, Warmness Contrast, Impression-shift

## ID237
## A SIMPLIFIED METHOD FOR CALCULATING DAYLIGHT ILLUMINANCE CONSIDERING EXTERNAL SHADING AND INTERIOR BLINDS

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We developed a simple method for calculating annual daylight illuminance, accounting for external shading and interior blinds. The key feature of this approach is that window surfaces are treated as light sources, with their light distribution determined by a combination of external shading and interior blinds. The zonal multiplier method, typically used to calculate electric lighting illumination, is applied to daylighting. This calculation method provides a faster way to determine indoor illuminance distribution compared to detailed ray tracing simulations, allowing for the energy saving calculation of electric lighting. The ability to estimate illuminance in a shorter time and in a user-friendly manner enables large-scale parametric studies and is expected to support optimal building envelope design.

*Keywords:* Daylight Illuminance, Light Distribution, Zonal Multiplier Method, Annual Calculation

## ID217
## EXAMINATION OF THE ERROR DUE TO THE POSITION OF THE BAFFLE ON THE INTEGRATING SPHERE PHOTOMETER

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The position and size of the baffle, which cause the non-uniformity of the spatial response distribution function (SRDF) in sphere photometer, were determined by optical simulation using the luminous intensity distribution of the test light sources and self-absorption coefficient in the integrating sphere as parameters to determine the measurement error. The position of the baffle was defined as the relative distance r between the baffle and the photodetector with respect to the radius of the sphere. It was found that the areas of large SRDF inhomogeneity of the integrating sphere, the area in the shadow of the baffle and the area blocked by the baffle, caused errors due to the self-absorption correction of the light source. It was also found that the position of the baffle reduces the measurement error, including the error due to self-absorption correction, in the range of r from 0,2 to 0,32.

*Keywords:* Integrating sphere, total luminous flux, reflectance, SRDF, Baffle

## ID246
## APPLICABILITY OF THE CALCULATION MODEL FOR SPACIOUSNESS IN RESIDENTIAL SPACES WITH WINDOWS

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Spaciousness is required to ensure space comfort. The quantitative evaluation of spaciousness is considered useful for space design. Studies on spaciousness prediction models using luminance and distance in windowed spaces have been limited to office spaces. Therefore, this study applies the prediction model to residential spaces with windows. Compared with office spaces, residential spaces, where the distance from the occupants to the windows is closer and expected to be more sensitive to the distance from the outdoor spaces, were shown to be inadequately represented by the calculation models of previous studies. The influence of the outdoor distance was expanded by improving the conversion method for the distance beyond the window, and an equation applicable to windowed residential spaces was constructed. Additionally, using vertical illuminance, the equation reflects the visual impact of window size on spaciousness.

*Keywords:* Spaciousness, Residential spaces, Windows, 3D luminance mapping data

## ID262
## EFFECTS OF DUV ON THE RELATIONSHIP BETWEEN PREFERREDILLUMINANCE AND CORRELATED COLOUR TEMPERATURE

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In lighting design, the amount of light and colour of light are determined according to the intended use of the space. The colour of light is generally indicated by correlated colour temperature (CCT). However, it has been pointed out that it must be shown in combination with the Duv. The purpose of this study is to identify the effect of DUV on the relationship between preferred illuminance and CCT. Subjective experiments were conducted in a concentration space and a relaxation space. The results of the psychological evaluations indicated that the differences due to Duv were observed even in the same CCT. Also, the preferred combination of illuminance, CCT, and Duv varies depending on the space and the activity. It was considered necessary to combine not only illuminance and CCT but also Duv in the evaluation.

*Keywords:* Correlated colour temperature, Duv, Illuminance, psychological evaluation

## ID344
## A MULTI-METRIC SYSTEM FOR LIMITING TEMPORAL LIGHT MODULATION

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There are three documented types of visual responses to temporal light modulation (TLM): direct flicker, the stroboscopic effect, and the phantom array effect. Depending on the waveform and viewing conditions, an observer may experience one or more of these visual phenomena, but peak sensitivity to each occurs at different frequencies. While metrics for each visual response have been developed, no single metric can be used to limit the prevalence of the unwanted visual responses. Based on experimental visibility data and a committee consensus process, a system for addressing visual responses to TLM has been developed using a categorization scheme using performance criteria for previously developed metrics ($M_P$, SVM, and PAVM). This article examines how they work together and the effectiveness of the system for limiting annoyance from TLM.

*Keywords:* Temporal light modulation, Flicker, Direct flicker, Stroboscopic effect, Phantom array effect, TLM Performance System

## ID289
## SUBJECT EXPERIMENTS CONTRIBUTING TO THE DEVELOPMENT OF DISCOMFORT GLARE EVALUATION METHOD FROM LARGE-AREA HIGHLUMINANCE SURFACE BASED ON VISUAL CHARACTERISTICS

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The authors (Takase 2021) developed a model to predict the BCD luminance, which is the basis for evaluating discomfort glare, for small-area high luminance surfaces based on human visual characteristics. It is a predictive model that can explain the results of subject experiment in which subjects were asked to report the BCD luminance when a high-luminance surface was in central or peripheral vision while fixating on a fixation point. Based on this model, the visual characteristics of the subjects were estimated (Hara 2023). In this paper, we report the outline and some of the results of a subject experiment conducted to extend the BCD luminance estimation method for small-area light sources that reflects the visual characteristics to a method for estimating the BCD luminance of large-area high-luminance surfaces. The experiment was conducted to grasp the BCD luminance of large-area high-luminance surfaces while the subjects were fixating on a gaze point.

*Keywords:* Discomfort Glare, Large-Area High Luminance Surface, Subject Experiment, BCD Luminance

## ID387
## A COLLABORATIVE APPROACH TO INTEGRATING SUBJECTIVE ASSESSMENTS AND SIMULATION DAYLIGHTING LEARNING

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We developed a shared activity for daylighting courses in various universities as part of the IEA SHC Task 70 / EBC Annex 90 "Low Carbon, High Comfort Integrated Lighting" project. This activity uses an experiential learning approach to make daylight assessments more relatable to actual daylight conditions. The approach combines theory, simulations of real spaces, and subjective assessments of daylighting conditions. Preliminary results from 46 students in Denmark indicate a gap between perceived and simulated daylight conditions, supporting the adoption of similar educational approaches in daylighting courses.

*Keywords:* Daylight provision, Subjective assessments, experiential learning

## ID363
## A CRITICAL ASSESSMENT OF ROAD LIGHTING PRACTICES IN RELATION TO OBTRUSIVE LIGHT

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Artificial light at night (ALAN) is ubiquitous due to the demands of nocturnal activity. While its use is often justified for purposes such as road safety and personal security, excessive ALAN is the primary contributor to light pollution. Improper design, installation and environmental factors increase issues such as obtrusive light and sky glow. This study investigates the influence of road lighting implementation attributes - luminaire inclination, rotation, height, and spacing - on obtrusive light parameters through simulated photometric calculations. The results are theorised to show a relation between the road lighting attributes and obtrusive light metrics, such as horizontal illuminance, uniformity and both upward light ratio and upward flux ratio. By highlighting the critical role of road lighting design and its environment, this research provides insights on light pollution mitigation while maintaining its intended functional benefits.

*Keywords:* ALAN, road lighting, obtrusive light, light pollution

## ID258
## LIGHTING COLOUR CONDITIONS THAT MAKE DISH LOOK DELICIOUS

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This study aims to examine the lighting colour conditions that make food dishes look delicious. We conducted a subjective experiment and examined the correlation between the visual deliciousness and the naturalness of colour appearance using twelve kinds of single dish. Twenty-eight illumination conditions were prepared, with four steps of correlated colour temperature from 3300 K to 6500 K and seven steps of *duv* from -0.015 to +0.015 and generated the digital images of each dish under each lighting colour condition. Twenty participants evaluated the “visual deliciousness” and “naturalness of colour appearance”. As a result, there were positive correlations between visual deliciousness and naturalness of colour appearance for all foods. Additionally, some dishes were highly evaluated in visual deliciousness when the colour appearance was natural whereas others were low evaluated when the colour appearance was not natural. Those results show that visual deliciousness depends on lighting colours and food dishes.

*Keywords:* Lighting Colour, Visual Deliciousness, Naturalness of Colour Appearance

## ID400
## BIDIMENSIONAL SPECTRAL DIFFERENCE MEASUREMENT FOR SCENE COMPLEXITY ASSESSMENT

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This study is a part of an evaluation of the impact of light quality on the perceived complexity of a scene for live entertainment. In this subpart of the study, we are wondering about the choice of the spectral difference calculation approach. The proposed experiment is first based on the comparison of an LED spotlight and its light when several filters are applied to it. Subsequently, a halogen light is compared against the same LED light under the same filters. A metrologically valid spectral difference metric (KLPD) is compared with an empirical construction based on L2 metrics and Spectral Angle Mapper differences. To establish a relationship between the physical stimuli (light spectra) to one aspect of its perceptual impact, the spectral differences were correlated with the Duv. The results show a good correlation between the KLPD and the Duv calculated using the TM30-20's method for Duv calculation (Ohno, 2013).

*Keywords:* spectral difference, light quality, TM30-20, hyperspectral imaging

## ID326
## PREDICTING VEILING REFLECTIONS IN THE VIEWING OF MUSEUM EXHIBITS BY OLDER ADULTS

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This study aims to understand the differences among age groups in the perception of veiling reflections on relatively diffuse painting surfaces and to construct prediction equations for veiling reflections. In this study, older adults evaluated the veiling reflections of replica paintings, and we compared the experimental results with those of young adults from a previous study. Differences in the effects of "luminance ratio" on reflected glare caused by veiling reflection and prediction equations for veiling reflections were examined. In this study, the luminance ratio is defined as the average luminance of the veiling reflection area divided by the average luminance of the surrounding area of the painting surface. As a result, prediction equations with high goodness of fit were obtained for both age groups, indicating that veiling reflections can be predicted from the luminance ratio, glossiness, and illuminance on the painting by the spotlight.

*Keywords:* Museum Lighting, Veiling Reflections, Oil Painting, Older adults, Visual Performance

## ID280
## A COMPARATIVE STUDY OF SUBJECTIVE PERCEPTIONS OF LIGHTING AND PHYSIOLOGICAL RESULTS IN REAL AND VIRTUAL ENVIRONMENTS

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Understanding the effect of psychological and physiological variables in both VR and physical environments is crucial to establishing the effect of lighting on humans. This study compares perceptions and physiological responses of artificial lighting in a physical environment versus a virtual reality (VR) setting. A total of 30 participants evaluated each lighting setup, half in the physical and half in the virtual environments. The VR environment was captured using a 360° high-dynamic-range camera and displayed on a head-mounted display. The results show that both environments have similar subjective impressions and electrodermal activity (EDA). Accurately simulating lighting is fundamental to creating immersive and compelling VR experiences. This work can help to establish knowledge that will aid in the reliable replicability of lighting environments in VR. This comparative analysis can help improve the effectiveness of VR simulations in various applications, including architectural space design, medicine and simulator development.

*Keywords:* Virtual Reality, Integrative lighting, Neuroarchitecture, physiological response

## ID178
## THE ROLE OF ROAD SURFACE IN ROAD LIGHTING QUALITY AND EFFICIENCY. A CURRENT CASE IN AN ARGENTINIAN MOTORWAY

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The road lighting installation design requires a combination of the photometric luminaire information and the road surface reflection properties. Only a thorough knowledge of both terms can guarantee a design that ensures driver visual comfort, road safety and minimal energy consumption. The replacement of discharge lamps with high-efficiency LED sources has led to a massive conversion of road lighting installations. At list in our region, designs are strongly directed by the advantages of the new technology and the commercial momentum, accentuated the lack of incentives to research the reflective properties of the new pavements. The paper describes a case observed on an Argentinian highway. The evaluation of a new installation design based on a standard CIE table resulted in inadequate quality parameters and an oversized appreciation of energy efficiency. The subsequent introduction of a new measured r-table made it possible to adjust the luminaire and correct the quality parameters.

*Keywords:* Road lighting, r-table, Energy efficiency

## ID327
## DEVELOPMENT OF A HIGH CONTRAST LUMINANCE REFERENCE SOURCE FOR CHARACTERIZATION OF HIGH-DYNAMIC-RANGE IMAGING MEASUREMENT SYSTEMS

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A high-contrast luminance reference source (HCS) was developed for characterising high-dynamic-range (HDR) Imaging Luminance Measurement Devices (ILMD) or other imaging measurement devices dedicated to the evaluation of indoor or outdoor lighting conditions. The source consists of seven independent luminance modules that cover six orders of magnitude of luminance, ranging from 0.1 cd/m$^2$ to 100 000 cd/m$^2$. The modules can be used simultaneously or separately in any geometrical arrangement. The HCS comprises a light trap for background evaluation. The diameter of the luminous emitting area of the modules is adjustable (from 25 mm and smaller). The position of the modules can be adapted to suit different imaging devices, to cover various field-of-views. Each module has a lockable articulating platform for the source-camera alignment. The HCS was fully characterised. The luminance of each module was calibrated. The development of the proposed HCS is unexpensive and simple to be reproduced by other producers.

*Keywords:* High dynamic range (HDR), Luminance measurements, ILMD, Cameras, Photometry

## ID116
## PERCEPTIONS OF LIGHTING, SAFETY, AND BIODIVERSITY: A MIXED-METHODS STUDY OF PARK USAGE IN URBAN SETTINGS

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Urban park has dual importance for recreation, socializing, and ecology; it serves as a natural retreat, enhancing physical and mental well-being among residents, while at the same time supporting biodiversity. Artificial light, though required for safety and evening access to parks, has increasingly disrupted ecosystems by altering nocturnal behaviors of wildlife and plant cycles associated with biodiversity. This research explores how lighting design influences usage of an urban park in Wroclaw, Poland, concerning users' perceptions and biodiversity for betterment of sustainable management practices. Data collection will be done using a mixed-method approach: integrating observations as qualitative and surveys as quantitative data. Detailed analysis will be done to highlight insights into public opinions concerning artificial lighting impacting biodiversity and support evidence-based recommendations for eco-friendly lighting strategies. The study aims to guide urban park management toward community engagement in biodiversity conservation based on user safety and ecological preservation for sustainable green spaces.

*Keywords:* Perception of Safety, Biodiversity, Artificial Lighting, Case Study, Urban Park

## ID306
## AN INTEGRATED ASSESSMENT METHOD FOR VIEWS, DAYLIGHTING, AND GLARE IN OFFICE BUILDINGS WITH WINDOWS

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Windows in architecture provide daylight and offer visual stimulation, which helps occupants relax and feel refreshed. Previous studies have shown that satisfaction with the view often enhances satisfaction with both daylight and the visual environment. Therefore, when designing office spaces, it is crucial to ensure good views, while achieving appropriate targets for daylighting and glare. In this study, we comprehensively evaluated the visual environments created by windows using quantitative indices related to views, daylighting, and glare. 'Volume of sight', proposed in previous studies, is a physical index for quantitatively assessing the openness of views from indoor spaces. Vertical illuminance was used to evaluate daylighting and glare. It was shown that this assessment method could ensure both views and daylighting while minimising glare by devising a window design. However, further analysis is required to determine the appropriate threshold for glare assessment.

*Keywords:* View, Daylighting, Glare, Window, Volume of sight, Office building

## ID239
## RADIANCE AND BEST INTEGRATION FOR THERMAL ENVIRONMENT EVALUATION OF SPACES WITH COMPLEX EXTERNAL SHADING

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This study examined the integration of Radiance, a light simulation tool, and BEST, a thermal load calculation program that simulates the total energy consumption of a building by accounting not only for the building itself but also for systems and equipment such as HVAC, lighting, and plumbing. The integration was used to evaluate the thermal environments of spaces with complex external shading. In the previous study (Fujita et al., 1974), calculating the solar shading performance of such systems required Radiance scripts through a command-line language, which posed challenges owing to complexity. To address this issue, we developed a user-friendly workflow using Grasshopper, which enables users to calculate the reach ratio—a value representing solar shading performance—without requiring to write Radiance scripts themselves. This approach made the assessment of the thermal environment more accessible. Using the developed tool, we also investigated the appropriate number of analysis points for accurate simulation.

*Keywords:* Radiance, BEST, External shading, Thermal environment evaluation

## ID361
## AGE-INCLUSIVE LIGHTING DESIGN

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This study introduces a room-scale, age-inclusive lighting approach that optimises the spectral power distribution (SPD) of luminaires in educational environments. The concept ensures tailored task and melanopic lighting for various age groups, supporting biological needs, fulfilling lighting requirements, and enhancing energy efficiency. The research emphasises the critical importance of balancing radiant flux to simultaneously provide task and melanopic lighting suitable for specific age groups, considering the spatial arrangement of workstations. This balance is achieved while adhering to colourimetric constraints, with luminaire intensity distributions (LIDs) and spectral reflectances (SRs) playing a significant role in determining SPDs with improved efficiency. The analysis of 20 distinct lighting situations demonstrates how these parameters guide the design of SPDs tailored to the diverse needs of users. Furthermore, the methodology introduces a precise approach to defining the nominal radiant flux of luminaires, enabling the implementation of energy-efficient and age-inclusive lighting systems in educational spaces.

*Keywords:* Age-Inclusive Lighting, Integrative Lighting, Radiant Flux Balancing

## ID287
## EFFECTS OF 24-HOUR DYNAMIC LIGHTING ON TIME PERCEPTION IN ENCLOSED SPACES

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People's perception of time is affected by environmental changes.particularly in enclosed spaces where time perception tends to be distorted. Dynamic lighting environments with light/dark cycles have been shown to serve as external temporal cues that regulate the human circadian timekeeping system. This study aims to investigate whether dynamic lighting can affect subjective time perception. A 14-day between-subjects experiment was conducted in an enclosed cabin with 20 participants, allocated to a 24-hour dynamic lighting group and a static lighting control group. The temporal bisection task was employed to evaluate the participants' capacity to judge time intervals. The results showed that the control subjects were more likely to misjudge long time-distance intervals as short time-distance intervals in the later stages of the experiment, and that the dynamic lighting group had higher accuracy in time-distance estimation. 24-hour dynamic lighting may help people maintain accurate time perception in a closed environment.

*Keywords:* Integrative lighting, Dynamic lighting, time perception, enclosed space

## ID240
## ASSESSING ATYPICAL COLOUR PERCEPTIONS IN NEURODIVERGENT INDIVIDUALS

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Challenges posed by unsuitable colour and light conditions can lead to human's visual discomfort, sensory overload, negative behaviour, and diminished mood. Such effects are often more pronounced in neurodivergent (ND) compared to neurotypical (NT) individuals due to their unique physiological and psychological processing of colour and light. However, existing research is limited and contains contradictions. Here we present a comparative study focused on a series of psychophysical visual-perceptual colour tests, to explore potential differences between ND (34) and NT (34) people regarding their Colour Preference (CP), Colour Comfort (CC), and Colour Discrimination Threshold (CD). Some results showed significant differences between ND and NT groups, such as the hue quadrants of preferred colour and their colour discrimination ability. However, colour effects on various visual perceptual and cognitive tasks are varied, and require further investigation. The findings can provide insights into the possible effect of colour on neurodivergent people.

*Keywords:* Colour, Colour Perception, Neurodivergence

## ID299
## THE EFFECTS OF THE INTERIOR SURFACE REFLECTANCE AND COLOUR ON THE RELATIONSHIP BETWEEN MEAN ROOM SURFACE EXITANCE AND SPATIAL BRIGHTNESS

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This study investigated the effect of the interior surface reflectance and wall colour on the relationship between mean room surface exitance (MRSE) and the spatial brightness, which has been excluded from published studies. Ten participants rated a total of thirteen light scenes, each delivered with seven different wall colours; four chromatic interior colours that are commonly used in offices and three achromatic interior colours with the same reflectance, and two levels of MRSE, using a scale model. The wall illuminance was controlled so that the MRSE was constant regardless of the surface reflectance. As a result of this experiment in the realistic range of MRSE and horizontal illuminance, it was shown that the relationship between MRSE and spatial brightness were influenced by both the interior surface reflectance and the interior colour.

*Keywords:* Spatial Brightness, Interior Surface Reflectance, Wall Colour, MRSE, Scale Model

## ID232
## OPTIMISING BUILDING DESIGN THROUGH WINDOW VIEW ANALYSIS: A CASE STUDY IN GDANSK

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Windows are essential for architectural design by linking residents with outdoor. The research assesses the effectiveness of window views in optimising building design. A specific part of Gdansk city was modelled in Rhino and ClimateStudio software. A thirteen-story office building near Alchemia office complex was considered. Different scenarios were analysed, including varying the floor, room orientation, building rotation, and window-to-wall ratio. The view quality according to EN 17037 and LEED standards, the elements and panorama visible through the window by a seated person, were compared. The findings indicate that by acting on window sizes and building orientation, the elements observable through the window can be altered to improve the perceived view quality, even if this does not affect the view quality as defined by standards. Finally, panoramic images can represent a great support to the design process by allowing visual comparison of design solutions and supporting participatory design.

*Keywords:* Urban Context, Visual Perception, Window View, Urban Elements, Urban Density

## ID175
## CHARACTERISING INTER-INDIVIDUAL VARIABILITY IN SIMULATED PERSONAL LIGHT EXPOSURE: IMPACT OF BODY MORPHOLOGY ON LIGHT-DOSIMETRY

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Recordings of personal light exposure, i.e. the illumination received at the eye(s) over time, are valuable for research on human health and well-being. To record these patterns, light- dosimeters (sensors) are worn on the body, acting as a proxy for measurements at the eye. Chest-worn dosimeters have become more utilised in recent years since this position strikes a balance between measurement accuracy and unobtrusiveness for the wearer. Although various studies investigated differences between chest and eye-level measurements, much remains unknown about the inter-individual variability in chest-worn dosimeter measurements. Here, we demonstrate how an individual's body shape impacts chest-worn dosimeter measurements using body scans of approximately three thousand individuals. Dosimeters placed on the upper chest show the most consistent device orientations and measurements across individuals. At this position, dosimeter measurements relative to the eyes, are within a 20% spread for half of the population, with a maximum range up to 79%.

*Keywords:* Light-Dosimetry, Personal Light Exposure, Chest, Dosimeter, Light Sensor, Measurement Accuracy

## ID234
## IMPACT OF SHORT DARK ADAPTATION PERIODS ON POST-ILLUMINATION PUPIL RESPONSE

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The pupil response serves as a proxy for the biological potency of light. A reproducible measurement of the pupil response requires controlled dark adaptation, but it is currently unclear whether shorter dark adaptation periods can be used to reliably determine the biological potency of light through measuring the pupil response. Therefore, we conduct a within-participant experiment, continuously measuring the pupil response for dark adaptation periods between 40 and 120 seconds. Results show a trend in the effect of mEDI on the 6s-PIPR increasing with longer adaptation periods. The dark adaptation period of 120 seconds does not fit this trend, and more research is needed here. Overall, our study shows that a dark adaptation period of 60 to 100 seconds is suitable for repeated measurements of the 6s-PIPR, with the aim of using the pupil response as a proxy for the biological potency of light.

*Keywords:* pupillometry, post-illumination pupil response, biological potency, dark adaptation

## ID371
## DIAGNOSING HUMAN-LIGHT INTERACTIONS WITH THE AID OF 360º HDR IMAGING

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This study presents a 360° field of view high dynamic range (HDR) lighting measurement method using a panoramic camera to assess human-light interactions in both field and computer-simulated environments. A technical workflow was developed to measure lighting at eye level, enabling multi-metric analysis for diagnosing visual exposure. Validation in an office setting showed high consistency between measured and simulated data (r = 0.976, mean bias error = 0.33%, RMSE = 7.69%), with only a 0.69% difference in total light exposure dose. Outdoor scenarios further illustrated the method's ability to assess lighting quality. This technique provides a practical tool for monitoring light exposure to human eyes.

*Keywords:* Light exposure dose, Binocular luminous flux, High dynamic range imaging, Indoor positioning system, Gaze-dependent visual field

## ID372
## A PROPOSAL OF STANDARD DEVIATE OBSERVERS BASED ON 100 OBSERVERS

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Our team utilized the LEDMax visual trichromator to measure the color matching functions (CMFs) of 100 Chinese observers with normal vision. From the 100 resulting LMS cone response curves, we calculated the standard deviations (SD) of each of the LMS curves and shifted the portion of the curve after the trough to the negative domain. Consequently, we derived eight unique triplets of cone curves (L±SD * M±SD * S±SD). We then used the CIE 2015 standard transformation matrix to transform them from LMS to XYZ CMFs and thus generated "standard deviation observers (SDOs)" By adding the SDOs to the CIE standard CMFs, the curves can usefully represent the distribution of CMFs within the population. This approach provides a straightforward method for modelling visual differences across individuals and facilitates the study of observer metamerism.

*Keywords:* Color Matching function, Standard Deviate Observer, Observer Metamerism

## ID396
## COMPARING PSYCHOPHYSICAL RESEARCH METHODS FOR DISCOMFORT FROM GLARE

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This study explores discomfort from glare in indoor lighting environments, focusing on psychophysical research methods to evaluate the phenomenon and their experimental biases. Seven psychophysical procedures were compared, including absolute (rating, method of constant stimuli, method of limits, and adjustment) and relative judgment methods (paired comparison, matching, and magnitude estimation). Experimental setups featured spectral stimuli variations (LowMel and HighMel) at multiple luminance levels. Results highlight the influence of procedural choices on discomfort from glare thresholds and the reliability of results. Statistical analyses emphasize the necessity of standardized approaches to mitigate biases and ensure repeatability. This work contributes to advancing the understanding of discomfort from glare and offers guidelines for methodological selection.

*Keywords:* discomfort from glare, psychophysics, indoor lighting, experimental methods, glare thresholds

## ID134
## THE RELIABILITY OF LED DRIVERS - ESTIMATING FAILURE RATES AND TRENDS

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The reliability of LED drivers is usually expressed in product datasheets as the number of failures after a given time of operation. The unit must be operated within the specification limits of case temperature and humidity to achieve the stated lifetime. Typical values would be lifetime 50 000 h, with failures of 10%, case temperature not to exceed 75°C, relative humidity 10% to 90%. These values do not give the user a feel for the expected number of failures with time. The exponential and binomial distributions are used to illustrate failure rates and upper confidence bounds for LED drivers in installations of 100, 300 and 1 000 units. The Laplace Test is used to indicate if failure rates are stable, increasing or decreasing.

*Keywords:* Failure rates, Laplace Test, LED drivers, Monte Carlo simulation, Rate constant, Reliability

## ID298
## LARGE RESIDENTIAL AREA LIGHT POLLUTION MODELLING

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The article explains approaches to modelling classic outdoor lighting systems, such as road lighting, but also new approaches to implementing the radiating characteristics of vertical light sources such as windows and advertisements. All these lighting systems are subsequently implemented in the residential area model with the specification of individual obstacles and their reflective surfaces. A light-technical model is calculated on the points located on the sphere surface named “virtual” software goniophotometer. The output is a lighting calculating model made from available sources simulating the most faithful copy of the residential area with regarding radiation into the upper hemisphere. All lighting systems that radiate at night into the outdoor space are included in the model (public lighting, windows, advertisements and cars). The performed calculations determine both the direct and total radiation of individual lighting systems into the upper hemisphere and thus enable a comparison of their influence on light pollution.

*Keywords:* Light Pollution; Residential Area; Software Goniophotometer; Luminous Intensity Distribution Curve (LIDC); Lighting Model

## ID163
## EXPLORING THE LIGHTING ENVIRONMENT OF RESEARCH AND DEVELOPMENT LABORATORIES FOR DRIVING AND RIDING EXPERIENCE IN THE SMART TRANSPORTATION ERA

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With the rapid development of smart transportation and autonomous driving technologies, creating realistic and immersive lighting conditions in vehicular research and development laboratories has become crucial for understanding the effects of in-vehicle lighting on visual and non-visual perceptions, comfort, health and overall experience. However, current experimental setups either lack immersion or fail to reproduce high-intensity dynamic light sources such as sunlight and headlights. To address this, field measurements of luminance distributions in urban driving scenarios were conducted, and key characteristics of in-vehicle lighting were identified, including variations influenced by natural and artificial light, vehicle directions, times of day, and obstructions such as buildings. Based on these findings, the paper proposes a novel laboratory design to better reproduce real-world lighting while ensuring essential immersion. The laboratory setup will support more precise investigations into in-vehicle lighting, providing technical support for optimising future smart transportation systems and improving driving and riding experience.
ID163

*Keywords:* In-vehicle lighting, Luminance distribution, Field measurements, Virtual driving and riding environment, Smart transportation

## ID284
## INTRA-LENS-SPECTROMETER FOR A NEAR-EYE DISPLAY MEASUREMENT APPLICATION

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A spectroscopic measurement should reference color measurement parameters for high-precision color measurements using an imaging color measuring device (ICMD). Within an augmented and virtual reality (AR/VR, in general, called near-eye displays - NED) measurement application, the spectral distribution of the device under test (DUT) should be measured within a 2° field of view according to the standard observer. The measuring spot should be on the optical axis of the imaging device. Integrating the spectrometer coupling in an AR/VR measuring lens can guarantee those fundamental criteria by optical design and adjustment. We present a lens design that meets these requirements and thus combines other various advantages of the elemental lens design.

*Keywords:* Photometry, Colorimetry, Spectrometer, Near Eye Display NED, ILMD, ICMD

## ID122
## THE HELMHOLTZ–KOHLRAUSCH EFFECT ON VIRTUAL REALITY HEAD MOUNTED DISPLAYS

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The Helmholtz–Kohlrausch effect is a well-known phenomenon where a colour with constant luminance in the photopic vision range is perceived as having a different brightness if its purity is increased. An increase in colourfulness is often accompanied by an increase in perceived brightness. Some hues display the effect more than others, such as red and magenta as compared to yellow. Many studies on the Helmholtz–Kohlrausch effect have been performed on conventional displays, but the advent of Virtual Reality provides new opportunities to explore the effect in head mounted displays. In this paper, the Helmholtz–Kohlrausch effect is analysed for a commercially available head mounted display, the Meta Quest 2. To this end, a dataset was collected from an experiment with 20 observers and the development of a lightness function for head mounted displays is discussed, based on established models in the literature.

*Keywords:* Helmholtz–Kohlrausch effect, Virtual Reality, Head Mounted Displays, Colour Science, Psychophysics

## ID337
## PEDESTRIAN LIGHTING IN URBAN FORESTS – A MULTIDISCIPLINARY PERSPECTIVE

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When planning for pedestrian lighting in (sub)urban green areas, various considerations need to be addressed. Lighting guidelines generally aim to provide sufficient illumination to support pedestrian visual performance and comfort. However, the objective of this project was to address concerns not only related to human needs but also wildlife ecology by better understanding options, processes, and outcomes when adjusting illumination in two urban forest areas. Over the course of four years, researchers from six different disciplines worked together on the conditions in those areas to develop and collect information relevant for planning, design, and application. Specifically, we set out to explore and evaluate several lighting scenarios with differences in illumination qualities to relate them to responses from human and wildlife perspectives and current local guidance documentation. Preliminary results suggest that lighting guidance and conditions in these green zones could be adjusted to reduce impact on ecology without compromising human usability.

*Keywords:* Pedestrian Illumination, Outdoor Lighting, Lighting Guidelines, More-than-human

## ID282
## PHYSIOLOGICALLY-RELEVANT COLORIMETRIC SYSTEM $(LMS)_{PHYS}$ AND COLOUR DIFFERENCE

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The mathematical model for threshold colour vision (MMTCV) enabled the calculation of l(λ), m(λ), and s(λ) values for individuals with normal colour vision, and the creation of physiologically-relevant colorimetric system $(LMS)_{phys}$, a fully integrated system with CIE 1931 standard colorimetric system. The research also demonstrated that the functions l(λ), m(λ), and s(λ) differ between individuals with dichromatic and trichromatic vision. The authors concluded that threshold colour differences in any colorimetric system tend to resemble ellipses, with the orientation and size of these ellipses being influenced not only by the chromaticity coordinates but also by the spectrum of the light source. To address this issue, the authors developed a colour difference space, $M_{\Lambda}$, using MMTCV.

*Keywords:* Colour-matching functions, Dichromats, Trichromats, Mathematical model for threshold colour vision, Colorimetric system, MacAdam ellipse, Colour difference, Spectral sensitivity curves of L, M, and S receptors

## ID219
## PRELIMINARY ANALYSIS: UTILIZATION OF LIGHT QUANTIFICATION METRICS IN CLASSIFYING SLEEP-WAKE TIMINGS

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In light dosimetry research, various quantification metrics were utilized to investigate how light affects the human circadian rhythm or sleep-wake cycle. With the discovery of melanopsins in intrinsically photosensitive retinal ganglion cells (ipRGCs) and their importance in entraining human circadian rhythms, this investigative process was further complicated by the need to measure light as photopic and α-opic illuminances. Hence, in this research, we aim to analyse the relationships between light, measured as photopic and α-opic illuminances, and sleep-wake timings. Additionally, we utilize different combinations of light quantification metrics described in past research to generate data-driven models of sleep-wake cycles to determine which metrics are possibly relevant in relating light and human sleep-wake timings. Our preliminary analysis shows that classification of the human sleep-wake cycle is best (out-of-bag error: 52.94%) when melanopic MLiT150, photopic M1m, melanopic M3mid, M3off and M3on, photopic M6m, L-cone-opic $T_B$, M-cone-opic $CE_{Midpoint}$ and L-cone-opic $LE_{Centroid}$ are used.

*Keywords:* Dosimetry, sleep-wake cycle, α-opic illuminance, circadian rhythm

## ID345
## CAR BODY LIGHTING: MASTERING THE BALANCE BETWEEN RECOGNITION AND DISTRACTION

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Car body lighting (CBL) is created by lamps located in the external vehicle area without any functional purpose. In the context of nighttime driving, this study employs a human factors research approach to investigate the balance between distraction and vehicle identification potentially induced by CBL. This study investigates CBL parameters in terms of position, colour, and brightness. These CBL variations were evaluated from drivers' perspectives by subjective assessment, response time, and visual attention distribution. The results show that the parameters of CBL have a significant effect on drivers' attention and task performance. The findings of the virtual reality experiment indicated that excessively increasing the amount of CBL did not necessarily improve vehicle identification but increased distraction levels. The real-vehicle experiment further revealed that side contour lamps with specific luminance ($10^{2.5}$cd/m$^2$ amber, $10^3$cd/m$^2$ white) were effective in improving vehicle recognition at night. This study establishes a foundation for developing relevant standards.

*Keywords:* Car body lighting, Traffic safety, Distraction, Recognition

## ID294
## AN EXPERIMENTAL INVESTIGATION ON DEVELOPING A VISIBILITY MEASURE FOR THE PHANTOM ARRAY EFFECT FOR GENERAL LIGHTING APPLICATIONS

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The phantom array effect (PAE) has been extensively studied, but data on its visibility in well-illuminated environments, such as offices, remain insufficient for designing an appropriate visibility measure. According to CIE 249:2022, two essential sets of parameters are needed to develop such a measure: the temporal contrast threshold function and the Minkowski norm (i.e., the frequency summation exponent). Therefore, we designed an experiment to measure the visibility threshold of the PAE under the circumstances of a vertical illuminance of ~75 lx at eye level. In the experiment, we used sinusoidal waveforms at different frequencies, as well as complex waveforms, consisting of combinations of two or three sinusoids.

*Keywords:* Temporal Light Modulation, Temporal Light Artefact, The Phantom Array Effect, Visual Perception, General Lighting Applications

## ID233
## IMPACT OF ANTARCTIC OVERWINTERING ON RHYTHMS, SLEEP, AND MOOD OF CHINESE EXPEDITION MEMBERS AT ZHONGSHAN STATION

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During the Antarctic overwintering mission, the expedition encounters various challenges, such as environmental adaptation and seasonal changes, leading to fluctuations in their psychological and physiological states. The expedition at Zhongshan Station underwent continuous health monitoring across five phases: initial arrival (January to March), pre-polar night (March to May), polar night (May to July), post-polar night (July to September), and pre-task completion (September to November). A comparative analysis was performed on sleep, mood and life quality indicators during these phases. The results demonstrated that sleep quality decreased upon initial arrival at Antarctica, during the polar night, and before the end of the mission. Emotional well-being significantly declined upon first arriving and following the polar night. Quality of life initially deteriorated upon arrival but subsequently improved and stabilized over time. This continuous monitoring underscores the critical importance of developing personalized support strategies in extreme environments to ensure optimal health and performance.

*Keywords:* Antarctic, Overwintering, Sleep-Wake Rhythm, Mood State, Life Quality

## ID274
## WEARABLE DEVICE FOR PERSONAL LIGHT MONITORING: ASSESSING VISUAL AND NON-VISUAL RESPONSES WITH SPECTRALLY-RESOLVED SENSOR

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Light has not only visual effects, but also physiological and psychological effects on people. To understand individuals' light exposure pattern and its health impacts, accurate measurement of light spectra is essential. Here we have designed a wearable device measuring less than 2.5 cm and integrating spectrally-resolved sensor to accurately and comprehensively evaluate personal light exposure. In this study, we introduced its design and functions, and calibrated the light sensor under various light sources. For the reconstruction of LED and daylight spectra, most RMSE values are near or below 0.1, indicating high accuracy. Under daylight, 90% of the equivalent daylight illuminance (EDI) calculation errors are reliably within 10%, but for multi-peak light sources, the spectral reconstruction and EDI calculation still need improvements. In actual tests, the device demonstrates high practicality, which could support light environment assessment in scientific research, daily life and more potential application scenarios.

*Keywords:* Wearable Device, Spectrally Resolved Sensor, Illuminance, Personal Light Exposure

## ID184
## A WORKFLOW FOR CONVERTING 2D IMAGES TO REALISTIC NAKED-EYE 3D VISUALIZATIONS USING COMFYUI

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Based on the training of large-scale artificial intelligence models, the transformation of 2D planar images into 3D styles has become possible. However, the current production of naked-eye 3D content often relies on costly 3D modeling and animation, posing a significant challenge for clients with urgent design needs. This study establishes a ComfyUI workflow to directly generate naked-eye 3D images with perspective depth and subject control from 2D planar images, which can be applied to outdoor architectural corner screen displays. The goal is to provide efficient and customizable solutions for each stage of architectural media facade design and creation, generating realistic renderings for reference and visualization. The workflow retains the main subject and background content of the 2D image, emphasizing strong perspective effects. It also enhances the efficiency of presenting naked-eye 3D visual effects on media facades, improving their adaptability to real-world spatial contexts.

*Keywords:* Naked-eye 3D Effect, Three-dimensional Displays, Media Facade, Artificial Intelligence, AI-Assisted Creation, ComfyUI, LoRa, Stable Diffusion

## ID110
## SHARING POWER BANK—NEW NETWORK FOR BUILDING EVACUATION LIGHTING IN THE MOBILE ERA

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It is difficult for emergency lighting to provide timely power supply in large-scale power outages caused by extreme events. In the era of mobile electronic devices and sharing economy, per capita handheld lighting terminals and widely distributed energy storage networks provide new possibilities for this. Taking smartphones and sharing power banks as examples, this paper simulates the evacuation scenario under sudden power outages in the sample area, adopts the strategy of mobile phone lighting and temporary rental of sharing power banks, and calculates the ratio of the number of power banks to the number of mobile phones that need to be charged under different evacuation durations. The results show that: under the sharing power bank network in the core area of the city, mobile device lighting can meet the evacuation lighting duration of a certain stage, which is conducive to emergency evacuation in the early stage of emergencies.

*Keywords:* Sharing power banks, Emergency lighting, Evacuation lighting, Smartphone, Flash light, Electric storage

## ID399
## LUMINANCE CONTRAST DISCRIMINATION THRESHOLDS FOR OBJECT AND BACKGROUND SURFACES IN SILHOUETTE AND REVERSE SILHOUETTE VIEWS

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This study investigates the relationship between object size and luminance contrast discrimination threshold under tunnel lighting conditions using a head-mounted display (HMD). The results demonstrate that the required contrast threshold to recognize an object differs between silhouette and reverse silhouette views, with the latter allowing for easier recognition. Moreover, higher background luminance leads to lower discrimination thresholds. These findings suggest that reverse silhouette conditions and increased background luminance improve object visibility. As a practical implication, concrete surfaces are recommended over asphalt in tunnel environments to enhance safety through better visual detection.

*Keywords:* Silhouette view, Reverse silhouette view, Luminance contrast discrimination threshold

## ID265
## TOWARDS RESILIENT LIGHTING DESIGN FOR DISASTER REFUGES PART 1: SUBJECTIVE EXPERIMENTS IN A JAPANESE CLASSROOM

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The objective of this study was to identify the most suitable lighting environments in refuges and shelters for individuals across different age groups and living hours to ensure their safety and security. To this end, we conducted an experiment in a classroom to analyse the lighting environment that would suit the needs of young and older adults based on the results of a psychological evaluation and analysis of luminance data. We concluded that each group's acceptance level of the light environment in each activity could be explained by the appropriateness of spatial brightness. Moreover, the adequacy of brightness for each activity differed between the two groups.

*Keywords:* Resilient Lighting, Age, Activities in Shelters, Classroom, Psychological Evaluation, Luminance

# ID271
# LINEARITY CALIBRATION OF ARRAY SPECTRORADIOMETER FOR MEASURING SPECTRAL RADIANCE

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We have designed a linearity calibration facility, which can realize spectral radiance over six orders of magnitude with nearly unchanged spectrum. The facility uses a spectral radiance light source with variable aperture to irradiate a white diffuser. White diffuser such as pressed PTFE has a nearly flat reflectance and can reflect light in a 2 π space. It has a good attenuation property in nature. By changing the aperture area and the distance between the aperture and the white diffuser, the reflected spectral radiance of the white diffuser can be decreased further. It's easy to realize a spectral radiance 6 orders of magnitude lower compared to the light source. The facility links the aperture area, the distance, and reflection characteristics of the white diffuser together, and can achieve an uncertainty better than 0.5%.

*Keywords:* Linearity, Spectral Radiance, White Diffuser

## Wednesday, July 9, 08:30 - 09:30: Keynote lecture 3

## LIGHT AND HUMAN HEALTH

**Prof. George C. Brainard**
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Light profoundly impacts consciousness through the stimulation of the visual system, and powerfully regulates circadian rhythms, hormones, and behaviour in humans. These physiological effects of light have broad regulatory impact on virtually all tissues in the body. This presentation will address topics ranging from how light spectrum regulates the human pineal gland, how NASA has used that fundamental information to change the lighting onboard the International Space Station, and how advances are being made towards changing the lighting in places where we live, work, learn, and play. The door is open to understanding the impact of light on all levels of human health.

## Wednesday, July 9, 10:00 - 11:40: Oral Session 10 (OS10): D3 - Integrative lighting 1

### ID109
### PERFORMANCE OF MELANOPSIN-BASED SPATIAL BRIGHTNESS METRICS

**Dr. Dorukalp DURMUS[1], Dr. Anders THORSETH[2], Dr. Wenye HU[3], Dr. Wangyang SONG[1]**
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Traditional photometric measures fail to accurately estimate perceived brightness, leading to the development of spatial brightness as a concept to quantify overall scene brightness. Recent research has revealed that melanopsin-containing intrinsically photosensitive retinal ganglion cells (ipRGCs), in addition to cone cells, contributes to brightness perception, and new metrics have been developed to predict cone and melanopsin-driven brightness perception. This study evaluates the performance of three melanopsin-based spatial brightness metrics through a two-alternative forced choice (2AFC) simultaneous brightness experiment involving 15 pairs of lighting conditions. Results indicate that the melanopsin-based spatial brightness metrics perform poorly, with a maximum accuracy of 50%, which is on par with chance. Future research should explore a wider range of illuminance, melanopic illuminance, and correlated colour temperatures (CCT) levels.

*Keywords:* Melanopsin, Visual Scene Brightness, Indoor Lighting, Circadian Entrainment, Visual Perception, Indoor Environmental Quality

### ID186
### A DEMENTIA PERSPECTIVE: INTERACTIVE WORKSHOPS HIGHLIGHTING INTEGRATIVE LIGHTING PREFERENCES FROM A DEMENTIA COHORT

**Kate TURLEY[1,2], Dr. Joseph RAFFERTY[2], Prof. Raymond BOND[2], Prof. Assumpta RYAN[2], Prof. Maurice MULVENNA[2], Lloyd CRAWFORD[1]**
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The CIE's 2024 Position Statement centres around the ipRGC's requirements for lighting. It also states how these requirements are tailored towards healthy middle-aged adults but does not consider ageing populations with diverse needs. People living with dementia experience cognitive decline, difficulty with everyday tasks, mood changes and disruptive sleep which negatively impact their wellbeing. Their lighting requirements must therefore be considered carefully, but often they are excluded from these conversations. This paper presents findings from 8 workshops on integrative lighting preferences for this cohort. A total of 46 persons participated in interviews about their interactions with light. A luminaire with tuneable white, dimmable LEDs allowed for participants to choose their preferred illuminance and CCT at a specific time of day in order to produce inter-individual comparisons. Group comparisons with integrative lighting for healthy middle-aged adults are also conducted to assess how well current guidelines can be extrapolated for this cohort.

*Keywords:* Integrative Lighting, Dementia, Inclusive Environments, Daylight-simulating, Wellbeing

## ID187
## INCREASING PERFORMANCE IN THE OFFICE WHEN WORKING WITH MONITORS: A PILOT STUDY

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Light can impact our sleep, well-being, cognition, and attention. Several studies have investigated how bright light can influence observers' alertness and attention. In an office context nowadays monitors are ubiquitous. These monitors emit slightly blue-tinted light and can thus meaningfully contribute to the necessary light dose of the office worker. In this study, the impact of two lighting scenes on alertness, attention, and memory is investigated in an office-like environment. In addition, the lighting scenes (including monitor luminance) are chosen to be equally comfortable. The current results show no significant impact of the lighting scene on the measures and no impact on the time of day. This is likely due to the short exposure time and relatively small sample size. Based on the current results, a new experiment will be developed and conducted.

*Keywords:* alertness, attention, memory, melanopic EDI

## ID349
## INTEGRATED LIGHTING FOR ENCLOSED SPACES FOCUSING ON VISUAL AND NON-VISUAL EFFECTS TO IMPROVE WORKERS' WELL-BEING

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Artificially integrated lighting for confined spaces is essential for compensating for the absence of natural light and ensuring proper visual and non-visual functioning. This series of studies delve into the effects on workers' emotions, performance, sleep, circadian rhythms, and interplay within confined environments. We constructed a simulated enclosed space with adjustable lighting and conducted controlled experiments using subjective questionnaires and physiological measurements. Experiment 1 uncovered the significant effects of CCT and illuminance on mood and perception in confined spaces. Experiment 2 demonstrated that lighting schemes within confined spaces differentially impact work performance and sleep across different shift schedules. Experiment 3 clarified the role of lighting in regulating rhythm disorders and performance declines in enclosed spaces, emphasizing the cumulative effect over time. Collectively, these studies underscore the significance of integrated lighting in confined spaces for worker's well-being and offer insights into the feasibility and potential pathways for light intervention.

*Keywords:* Enclosed Spaces, Integrated Lighting, Non-visual Effects, Human Well-being

# ID181
# INTEGRATIVE LIGHTING IN EDUCATIONAL ENVIRONMENTS: A CRITICAL ANALYSIS OF CURRENT LITERATURE AND FOOD FOR THOUGHT FOR FUTURE RESEARCH ACTIVITIES AND DESIGN PRACTICE

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Lighting in educational environments deserves proper attention since students spend a long time indoors and cannot personally control the light they receive which, in turn, affects their physiological and psychological state as well as learning performance. Hence, guaranteeing integrative lighting supporting visual and non-visual needs is crucial. Despite this consciousness, the topic is not fully explored yet. This study aims to provide an overview of the current state of knowledge about this theme and to highlight outstanding issues for lighting design solutions aimed at achieving integrative lighting in educational environments. The findings reveal that most studies opted for simulation-based analysis due to the difficulties connected to field study and measurements. While visual effects of light were assessed using both static and dynamic metrics, non-visual effects ones were commonly evaluated through static circadian metrics. It is concluded that there is still no shared evaluation approach for integrative lighting design.

*Keywords:* Integrative lighting, Educational environments, Lighting in classroom, Literature review

## Wednesday, July 9, 10:00 - 11:40: Oral Session 11 (OS11): D2 - Photometry & radiometry 2

### ID124
### RECIPE FOR TYPICAL MINIMUM AND MAXIMUM SPECTRAL MISMATCH CORRECTION FACTOR USING BROADBAND PHOTOMETER MEASUREMENTS AND CATALOG PARAMETERS FOR TESTED WHITE LED SOURCES

**Prof. Irena FRYC[1], Maciej LISTOWSKI[1], Robert SUPRONOWICZ[1], Prof. Dorota MOZYRSKA[1], Dr. Eric ROSAS[2], Dr. George EPPELDAUER[3], Dr. Peter CSUTI[4], Dr. Alejandro FERRERO[5]**

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Using a look-up chart developed in this work, we show that accurate photometric measurements of characteristics like illuminance or luminous intensity of test LED sources can be measured in one step. This is a simple broadband measurement that may substitute for complicated and costly spectral measurements currently in place. To develop the look-up chart, the typical minimum and maximum of the Spectral Mismatch Correction Factor (SMCF) for a given photometers was estimated in relation to catalog parameters of the LEDs such as correlated color temperature (CCT) and melanopic daylight efficacy ratio. This research was based on the unique and large dataset of real photometers spectral response collected and measured at accredited laboratories located at America, Asia and Europe and LED's spectral distribution (SD) data. Independent look-up tables were developed for color-mixed LEDs (cm-LEDs) and white phosphor-converted LEDs (pc-LEDs), two common LED types.

*Keywords:* Photometry, Spectral Mismatch Correction Factor, LEDs

### ID189
### CHANGE IN SPECTRORADIOMETER CHARACTERISTICS ON CHROMATICITY FOR TRICOLOUR LASER LIGHT SOURCES

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The errors in the output of the CIE 1976 chromaticity coordinates (*u*', *v*') due to nonlinearity of spectroradiometers was investigated for light sources reproduce by tricolour laser light sources. Two white light sources and one red light source were selected to be simulated by the tricolour laser light source. Due to the nonlinearity of 24% that occurs in the spectroradiometer, a change in the chromaticity coordinate of up to 0.0091 was found in the reproduced light source. Evaluating chromaticity errors due to these spectroradiometer characteristics can help us to obtain accurate colour measurements for imaging and display devices based on tricolour laser light sources.

*Keywords:* spectroradiometer, Colorimetry, tricolour laser, laser display

## ID241
## ASSESSMENT OF THE VALIDITY OF THE CURRENT MINIMAL TEST DISTANCES OF (O)LED LUMINAIRES

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Standardisation bodies including the CIE and IESNA propose several test distances for far-field photometry based on the applicability of the inverse square law. Depending on the beam width, luminaire size and configuration, various guidelines regarding the minimal test distance are proposed. Recent literature suggests some norms are overoptimistic and larger far-field distances are required. Furthermore, the proposed test distances are only based on observations along the optical axis, whereas a strong angular variation of the limiting photometric distance was recently demonstrated. Therefore, this work presents a comparison between the regulations and the observations made in recent literature, assessing the application region of the standardised test distances as a function of the luminaire characteristics and the location of the measurement equipment.

*Keywords:* Photometry, Far-Field, Near-Field, LED, OLED, Photometric Distance

## ID316
## CHARACTERIZATION AND CALIBRATION OF TRANSFER-STANDARD SPECTRORADIOMETERS USING A TUNABLE LASER

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Several spectroradiometers to be used as transfer standards for spectral irradiance scale are characterized and calibrated using a tuneable laser. The calibration is based on transfer-standard trap detectors that have expanded uncertainties of less than 0.10 % (k = 2) for irradiance responsivity in the visible region. The expanded uncertainty of the spectral irradiance responsivity of the spectroradiometer is expected to be 0.25 % (k = 2) in the visible region, significantly smaller than those of conventional spectral irradiance transfer-standard FEL lamps, which are typically greater than 0.50 % (k = 2) in the visible region. The scale realization chain of the transfer-standard spectroradiometer is much shorter than that of the conventional transfer-standard FEL lamp. The calibrated spectroradiometer is a new detector-based spectral irradiance standard in addition to the conventional source-based spectral irradiance standard FEL lamp for dissemination of the spectral irradiance scale.

*Keywords:* Spectroradiometer, Transfer-standard, Calibration, Detector-based, Tuneable laser

# ID331
# BROADBAND LIGHT SOURCE BASED ON LIGHT-EMITTING DIODES FOR RADIOMETRIC CALIBRATIONS IN THE ULTRAVIOLET REGION

**Oskari Joonatan KUITTINEN[1], Afsaneh EGHBALI[1], Dr. Petri KÄRHÄ[1], Dr. Ralf ZUBER[2], Christoph RINGLER[2], Prof. Erkki IKONEN[1]**

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Phaseout of incandescent standard light sources is ongoing, creating a need for new solutions to replace the FEL lamps in radiometric calibrations. In the ultraviolet (UV) range, this challenge is especially demanding to meet. For the new light source, we have studied two light-emitting diodes (LEDs), one with a peak wavelength of 266 nm and the other with a peak wavelength of 277 nm. We combine the LED with a phosphor component with two broad emission peaks at wavelengths of 318 nm and 338 nm. A significant factor in ultraviolet wavelengths is the ageing of the components, which must be studied thoroughly. The light-emitting components can be complemented with optics to ensure enough signal for radiometric calibration purposes. One optical solution increases the intensity by a factor of 12 compared to the source without optics. Stable LED-based standard sources are expected to serve as the basis for radiometric calibrations shortly.

*Keywords:* Calibration, Light-emitting Diode, Radiometry, Ultraviolet

## Wednesday, July 9, 10:00 - 11:40: Oral Session 12 (OS12): D1/D8 - Vision & colour 2

### ID200
### DEVELOPMENT OF A DATABASE FOR FABRIC VISUAL APPEARANCE

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Fabric products are the must-buy commodities that humans are exposed to. Current fabric image databases were developed mainly for pattern recognition and classification. Despite the large number of fabric images available in other databases, the inaccessible of the real fabrics make them less suitable for studying the differences in tactile perception between images and real fabrics. Our Leeds Fabric Tactile Database includes two parts: (1) 15 real fabrics. Images were captured when fabrics in flat and draped conditions, and then rendered by 16 evenly distributed colours. (2) 118 real fabrics. Images were captured in flat conditions, and videos were captured in rotating conditions where three frames were extracted to represent the draped condition. The visual appearance of fabrics was well captured using a digital image system and reproduced in the database. We demonstrated one of the applications of this database: predicting visual tactile perception through extracting image features.

*Keywords:* Fabric Appearance, Tactile Perception, Fabric Images, image feature extraction

### ID201
### SKIN COLOUR PERCEPTION IN HUMAN FACES AND TEXTURED PATCHES

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This study investigates skin colour perception among Japanese observers. We test the hypothesis that the average colour represents the perceived skin appearance while examining the influences of viewing contexts and face ethnicity. Using fifty facial images - 25 Western European and 25 East Asian - colour matching experiments were conducted to assess the skin colour appearance of both faces and corresponding skin patches over two sessions. The results reveal that the matched colour appearance is lighter and less chromatic, significantly deviating from the average skin colour, particularly for facial stimuli. Skin colour perception is influenced by the viewing context, with significant differences between isolated skin patches and entire faces. Additionally, lightness perception is affected by the stimulus ethnicity, with Western European faces more easily perceived as lighter than their average colour. These findings highlight the complex mechanisms by which our visual system integrates skin colour with facial information.

*Keywords:* Face, Skin, Colour Appearance, Western European, East Asian

## ID285
## COMPARATIVE EVALUATION OF CIE SPECTRAL LUMINOUS EFFICIENCY FUNCTIONS USING LED-BASED BRIGHTNESS AND COLOUR MATCHES

**Prof. Jiaye LI[1], Dr. Yoshi OHNO[2]**
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Four CIE spectral luminous efficiency functions for photopic vision—CIE 1924 2° $V(\lambda)$, 1964 10° $V_{10}(\lambda)$, and the 2015 cone-fundamental-based 2° $V_{F2}(\lambda)$ and 10° $V_{F10}(\lambda)$—were assessed using data from a side-by-side colour and brightness matching experiment. The study involved 22 observers who completed achromatic matching tasks with six RGB primary sets, each consisting of one red, one green, and one blue primary selected from eight LED primaries with distinct peak wavelengths. The stimuli were viewed on non-fluorescent white sheets in a double booth setup. Results showed that the 10° $V(\lambda)$ functions outperformed the 2° $V(\lambda)$ functions, particularly the 1924 2° $V(\lambda)$, with accuracy in brightness prediction improvements of up to 13 %, especially around 500 nm. Older observers exhibited brightness prediction trends similar to younger observers but had a higher (~5.6%) brightness discrimination threshold. These findings align with our prior results from a different experiment, supporting the robustness of the conclusions.

*Keywords:* Luminous Efficiency Function, V(λ) Function, Cone Fundamentals, Brightness Matching, Colour Matching

## ID373
## INVESTIGATION OF DIFFERENT HELMHOLTZ–KOHLRAUSCH (H-K) FORMULAE

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The Helmholtz–Kohlrausch phenomenon is well known in the field of colour science. It considers the change in lightness of a perceived colour stimulus, produced by increasing the chroma of that stimulus while keeping its luminance constant, within the range of photopic vision. The phenomenon has been found to be marked for the wide colour gamut and high dynamic range displays, as a sudden increase of the lightness for the highly colourful colours. An experiment was carried out to study the effect in such display. The visual results were compared with the other three independent datasets. Finally, a model based on CAM16-UCS was obtained. It fits better than that of CIECAM16.

*Keywords:* Helmholtz–Kohlrausch effect, H-K effect, CIELAB, CIECAM16, CAM16-UCS

# ID397
# VALIDITY OF CIE COLOR MATCHING FUNCTIONS FOR OLED-LCD MIXED TECHNOLOGY MATCHES

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The presence of mixed display setups like OLEDs with LCDs in the same scene has become very common nowadays. Mixed technology setups can be found in the living room between televisions, laptops, monitors, smartwatches and smartphones or outside in automotive cockpits. The requirement to have color matches between OLED and LCD displays has thus become very important. Based on a color matching experiment conducted between an OLED and LCD, this study evaluates the performance of various CIE color matching functions in successfully predicting color matches between these two display technologies and observers' variability. The results show that CIE 1964 10-degree and CIE 2006 10-degree observers minimizes observer variability towards color matches between OLED-LCD and were also found to be the best in predicting color matches between them. The CIE 1932 2-degree observer performed the worst in terms of inter-observer variability and in predicting color matches between the two display technologies.

*Keywords:* CIE color matching functions, mixed displays, OLED, LCD, ambient illumination

## Wednesday, July 9, 12:40 - 14:20: Oral Session 13 (OS13): D3 - Integrative lighting 2

### ID182
### STUDENTS' "LUMINOUS DIET": ARE EDUCATIONAL BUILDINGS DESIGNED TO PROVIDE THE PROPER DAILY LIGHT DOSAGE?

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This paper aims to evaluate the daily light dosage received by students in a university building. To evaluate their weekly "luminous diet", their study plan is analysed to select a week for each period of classes. Electric light eye-level spectral irradiance and work-plane illuminances were measured in spaces where students attend lectures and study without teachers, while daylight illuminance was simulated with DIALux. The measured and simulated values were summed to define melanopic equivalent daylight illuminance patterns representative of the light dosage received by students. The results show that in some of the analysed spaces the lighting system does not guarantee the minimum illuminance level on work-planes, whereas quite always lighting is ineffective for the regulation of circadian rhythms.
ID182

*Keywords:* Circadian rhythms, Educational buildings, Melanopic equivalent daylight illuminance

### ID205
### DAYLIGHT – VISUAL AND NON-VISUAL EFFECTS IN THE CONTEXT OF NEARLY ZERO ENERGY BUILDING: THE LABZERO CASE

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Daylighting architecture enhances user well-being and contributes to energy efficiency in buildings. The LabZero (207.00m²), a demonstrative building at the University of Brasília, is designed to achieve a nearly Zero Energy Balance (nZEB). This article presents the results of daylight simulations (visual and non-visual effects), to evaluate its performance in a nZEB design (LabZero). The methodology included theoretical research and simulations daylighting regarding visual effects (ClimateStudio), and non-visual effects (ALFA), simulated energy demand (DesignBuilder), estimated photovoltaic generation (SAM). The results show that daylighting strategies meets Brazilian standards for visual effects and fulfills non-visual effects requirements, with Melanopic Equivalent Daylight Illuminance (mel-EDI) above 250. The energy demand and photovoltaic generation results confirm the building meets nZEB criteria through its lighting solutions. The elongated form, North-South orientation, solar protection, and 35% wall-window ratio, besides the efficient electric lighting system contributed to this outcome. Future studies will explore day and artificial lighting integration.

*Keywords:* Daylight, Visual Effects., Non-visual Effects, nZEB

## ID183
## CLOSED-LOOP PROPORTIONAL DAYLIGHT-LINKED CONTROL SYSTEMS: HOW TO CALIBRATE THEM FOR INTEGRATIVE LIGHTING PURPOSES?

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Effective integration between daylight and electric light is of paramount importance for high-quality lighting. Currently, daylight-linked control systems are calibrated to guarantee required work-plane illuminance while saving energy, but how can they be calibrated if integrative lighting purposes must be fulfilled? Based on on-field measurements, the functioning of a closed-loop proportional system is simulated considering 3 electric light CCTs and by adopting 4 different calibration strategies: 1 to achieve work-plane illuminance equal to 500 lx and 3 to guarantee melanopic equivalent daylight illuminance (melEDI) equal to 250 lx. Results show that if the system is calibrated to provide adequate work-plane illuminance, sufficient melEDI values are achieved with 6500 K only; if the system is calibrated to achieve melEDI=250 lx, very high work-plane illuminance levels occur in some cases depending on the adopted strategy. Overall, the choice of CCT is crucial to guarantee the simultaneous fulfilment of visual and circadian needs.

*Keywords:* Daylight-linked control system, Circadian rhythm, Integrative lighting

## ID169
## A NOVEL ANNUAL SPECTRAL MATRIX SIMULATION METHOD AND THE EFFECT OF SPECTRAL DISCRETIZATION ON ANNUAL LIGHTING ENERGY DEMAND WITH SWITCHABLE GLAZING

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In recent years, a growing body of research has shown that different parts of the visible spectrum produce visual and non-visual effects in humans, highlighting that full spectral information is necessary for accurate quantification. Therefore, new simulation tools that allow for fast and efficient annual spectral simulations are necessary to support decision-making processes in planning. The described annual spectral matrix simulation method, which focuses on spectral resolution, was used to evaluate the impact of luminaires and switchable glazing on visual and non-visual metrics, as well as lighting energy demand. The study that looked at a typical office room with switchable glazing found that increasing the number of channels improved prediction accuracy, especially for luminaires with discontinuous spectra. For fluorescent luminaires, accuracy improved by up to 32.6%, while for LED luminaires, the improvement reached 9.3%. Daylight simulations also showed improved prediction accuracy, particularly for melanopic equivalent daylight illuminance.

*Keywords:* Annual Spectral Metrix Simulation, Melanopic Equivalent Daylight Illuminance

## ID194
# ELECTROCHROMIC GLAZING: NON-VISUAL EFFECTS IN HIGHLY GLAZED NON-RESIDENTIAL BUILDINGS IN BRAZIL

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Technologies of electrochromic glazing have been developed as solutions for issues concerning luminous comfort caused by glazed facades, predominant type in non-residential buildings. The aim of this research is to examine electrochromic glazing for daylighting conditions, including non-visual effects, in a representative non-residential room within Brazilian latitudes. Computer simulations were carried out in ALFA combining 34,560 cases. The variables were: six cities/latitudes (from 3° to 29° south), four window orientations and four glazing materials, including electrochromic glazing, clear, green, and reflective silver glass. Based on the detected cases with a lack of circadian lighting and the distortions detected in the spectral analyses in the darker tint states, recommendations were made to improve the performance of electrochromic glazing regarding the minimum supply of non-visual effects of light in Brazil, by increasing from dark tint state to medium tint state according to the city/latitude, window orientation and time of the year (season).

*Keywords:* Electrochromic glazing, Non-residential Buildings - Brazil, ALFA, Non-visual effects

## Wednesday, July 9, 12:40 - 14:20: Oral Session 14 (OS14): D3/D8 - Virtual reality application in lighting

### ID132
### MACHINE LEARNING AIDED APPROACH TO ESTIMATE IMPRESSION FOR RESIDENTIAL LIGHTING IMAGES

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In Japan, lighting for single rooms with one luminaire has been common, but lighting designs incorporating multiple luminaires are getting popular marginally. While those lighting designs can shape the impression of a space flexibly, it is difficult to select the optimum lighting design from the infinite number of lighting designs. To overcome this, accumulating impressions of various lighting designs is important. However, impression evaluations with many participants and real spaces consume massive time and cost. To avoid this, we developed a deep learning-based model to estimate impressions for Virtual Reality lit spaces. The model was trained with impression evaluation data for the spaces. A model test with validation data shows accuracy of 84% to 98%. Consequently, we constructed a database of 1,000 lighting designs with images and impression scores.

*Keywords:* Deep Learning, Virtual Reality, Impression

### ID248
### INTEGRATING VIRTUAL REALITY AND EYE-TRACKING TO ASSESS THE RESTORATIVE POTENTIAL OF DYNAMIC VISUAL CONDITIONS

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As interest in the physiological impacts of indoor environments grows, increasing attention is oriented toward how lighting conditions shape gaze and internal states. While broader and more flexible gaze patterns have been linked to improved physiological regulation, particularly in clinical contexts, the specific influence of dynamic lighting conditions on gaze behaviour in everyday interior environments remains underexplored. As a result, design strategies often rely on static assumptions about visual engagement, overlooking the potential of dynamic stimuli to support well-being. This study presents a narrative review synthesising recent findings on how dynamic environmental stimuli, including lighting variation and visual saliency, mediate gaze behaviour and influence cognitive and emotional outcomes. The review integrates evidence from vision science, environmental psychology, and lighting research to highlight emerging relationships between dynamic conditions, attention, mood, and recovery. The findings aim to inform adaptive lighting strategies that enhance occupant well-being and attentional engagement in interior environments.

*Keywords:* Dynamic Visual Conditions, Gaze Behaviour, Lighting Environments, Cognitive Load, Emotional States

## ID180
## COLOUR OF THE SKY - A PILOT STUDY TO EXPLORE GEOGRAPHICAL DIFFERENCES IN THE SPECTRAL PROPERTIES OF TWILIGHT

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In a pilot study, the colorimetric properties of daylight in Berlin, Brisbane and Chiba, focusing on the dynamic changes of sky light during civil twilight and after sunrise, for solar altitudes from -6° to 6°, were recorded. A spectroradiometer and a fisheye camera were used to collect data. The preliminary findings indicate that both spectral power distributions as well as dynamics vary geographically, likely due to variations in atmospheric conditions such as ozone concentration and aerosol scattering. Further analysis, including additional measurements and considering factors like relative azimuth angle and seasonal variations, is necessary to assess the geographical differences in more detail. The results and future research will support the development of advanced light-based therapies in Virtual Reality using daylight simulation that incorporates localised daylight characteristics to treat depressive behaviours in urban environments.

*Keywords:* Daylight, Dawn Simulation, Dawn, Twilight, Geographical Variations

## ID165
## DESIGN CRITERIA FOR USER-CENTRED SHADING SYSTEMS: A VR-BASED STUDY ON USER PREFERENCES

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Solar shading systems are essential for creating comfortable indoor climates, reducing glare, and enhancing overall building energy performance. In addition, they influence how building users connect with their environment and shape architectural spatial experiences. However, conventional systems often fail to effectively address variable environmental conditions and individual user preferences. Advancements such as dynamically switchable glass and films, integrated with sensor technology, theoretically offer new possibilities for user-centred façade systems as these technologies enable real-time optimization of glare reduction and outward visibility by detecting user positions and viewing directions. Due to the novelty of these systems, their design requirements remain underdeveloped. A laboratory study using virtual reality technologies investigated user preferences for pixelated façade systems. The results indicate the importance of carefully balancing the expressive and functional behaviour of the system. Insights were gained for both static and dynamic façade configurations, providing a first foundation for future system design.

*Keywords:* Daylight, Façade Systems, Virtual Reality, User-centricity, User Preferences

# ID170
# INFLUENCE OF LEVEL OF DETAILS OF 3D OBJECTS ON REALISM IN VR ENVIRONMENTS

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Rendering high levels of detail (LOD) in virtual reality (VR) requires extensive 3D modelling, which is computationally intensive and often requires high-end hardware. These demands frequently lead to compromises in performance, resulting in lower frame rates, inconsistent graphics, and system lag, which reduce immersion and increase the risk of motion sickness. To address these challenges, this study explores perceived realism rather than solely pursuing photorealistic rendering. The goal is to identify the most important visual features for maintaining realism in VR environments without significantly increasing the computational load. An experiment was conducted to examine the impact of the LOD on the perception of realism. Participants evaluated VR spaces in which virtual human models with different LODs were placed. The results indicated that the LOD of objects is the dominant factor in perceived realism. But other visual cues such as shadows would affect perceived realism when the LOD is low.

*Keywords:* Virtual Reality, Level of Detail, Realism, Display, Style transfer

## Wednesday, July 9, 12:40 - 14:20: Oral Session 15 (OS15): D4 - Walking and cycling

### ID379
### LIGHTING PUBLIC SPACES FOR PEOPLE WELL-BEING: RESULTS FROM AN IN-FIELD MEASUREMENT CAMPAIGN

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The European research project EnlightneME is intended to collect evidence about indoor and outdoor lighting impacts on human health and wellbeing, particularly for people over the age of 65 and other vulnerable groups. Within the project, outdoor lighting and its impact on people's well-being was studied through a participatory process and social research, considering 3 case studies in Europe. The research was supported by a measurement campaign conducted before and after the implementation of the new LED lighting installation. The measurement campaign was conceived to assess the impact of lighting for both visual and non-visual effects. Photopic and melanopic quantities were measured, as well as luminance distributions. Results from the experimental campaign showed a general improvement in lighting conditions, both in terms of quantity and quality. Considering the circadian impact, an increase in mel-EDI and CS values was observed, although the measured values remained below the recommended nighttime limits.

*Keywords:* outdoor lighting, integrative lighting, lighting measurement, human well-being, social research

### ID261
### THE PRESENCE OF ROAD LIGHTING LEADS TO MORE CYCLING

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Encouraging people to cycle more has a range of individual and societal benefits. Previous studies using cycle count data have shown that darkness reduces the number of people cycling. This study extends previous work by establishing a model for the impact of road lighting on cycling after dark. Analysis of data from 117 cycle counters in five cities using a pooled odds ratio, incorporating all possible combinations of case and control hours to improve accuracy, confirmed that darkness reduces cycling numbers. This deterrent effect of darkness was reduced by the presence of road lighting. Specifically, a linear regression model suggests the presence of lighting reduces the odds ratio from 2.51 to 1.31, showing that road lighting is of critical value to support cycling after dark. This research contributes to the development of evidence-informed lighting design guidance, aiming to encourage active travel and improve cyclist safety.

*Keywords:* Road lighting, Cycling, Darkness, Odds Ratio, Active Travel

## ID120
## BIOMOTION LIGHTING ENHANCES CYCLIST CONSPICUITY

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This article discusses cyclists' conspicuity to other road users after dark. A conspicuous cyclist is more likely to be correctly recognised, and to be recognised in a shorter time, reducing the risk and severity of road traffic collision. An experiment was conducted to measure the ability to correctly identify cyclists when using cycle-mounted lighting which marks biomotion versus standard steady or flashing lamps. When using pedal mounted lamps a target was correctly identified as a cyclist in near 100% of trials, better than the near one-third of trials when using frame mounted lighting, regardless of whether the lamp was steady or flashing. The reaction time was also faster, being reduced by about 50%. Revising regulations for cycle-mounted lighting to include lighting marking biomotion would improve cyclist safety and would thus support moves to reduce the provision of road lighting.

*Keywords:* Cycle lighting, conspicuity, biomotion

## ID322
## NEW CONCEPT FOR ROAD LIGHTING TO IMPROVE THE VISIBILITY OF CYCLISTS IN SHARED ROAD SPACE

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Since the number of accidents involving cyclists is significant, partly due to poor visibility, our research aimed to develop and test a new lighting concept for urban road lighting systems to improve the visibility of cyclists. The previous requirements of CIE 115 and subsequently EN 13201 aim to ensure a negative contrast with the help of certain illumination levels. The approach we subsequently investigated was to create a positive contrast in conflict situations with a low lighting level. For this purpose, the parameter vertical illuminance was selected, quantified and implemented by optimised light distributions. The effectiveness of the parameter was then validated by practical measurements in which the effect on the visibility of cyclists was assessed. On the basis of the investigations, recommendations were developed, along with a proposal for revising EN 13201, the application of which would lead to a lighting concept that enables a higher visibility of cyclist.

*Keywords:* Cyclists, Visibility, Road lighting, Contrast

# ID392
# LIGHTING LEVELS ON A TRAM PLATFORM: AN EXPLORATORY STUDY

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The recent increase in night-time switching off of public lighting has an impact on the lighting of tram platforms. The aim of this study is to define minimum lighting thresholds for tram platforms to ensure visibility suitable for tram drivers. The study is based on a survey of tram drivers, who were asked to comment on several lighting levels proposed for several sections of the tramway network in Grenoble, France. The proposed lighting levels were defined following a campaign of in situ illuminance and luminance measurements at the selected inter-stations. Two minimum luminance thresholds to be guaranteed on the tram platforms were obtained following the survey, depending on the complexity of driving.

*Keywords:* road lighting, tram platforms, visibility

## Wednesday, July 9, 14:50 - 16:30: Oral Session 16 (OS16): D3/D6: Lighting and circadian rhythm

### ID111
### CIRCADIAN RHYTHMS OF THE RETINA AND THE SKIN

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Following the discovery of the non-visual effects of light and the existence of circadian cycles, understanding the daily rhythms of our internal organs is one of the great challenges facing the scientific community. The retina is made up of multiple layers made up of interconnected cells and neurons that contain circadian gene proteins. The layers of the skin have cyclical mechanisms to adapt to daily variations in light and temperature. The study of the circadian cycles of the skin may be key to protection against ultraviolet light and the treatment of chronic diseases such as psoriasis and atopic dermatitis. The cyclical processes of retina are regulated by melatonin at night and dopamine during the day. Knowledge of their influence on ocular development could be very useful in understanding the causes of the myopia pandemic and being able to alleviate it.

*Keywords:* dopamine, chronotherapy, skin circadian rhythms, chronodisruption, melatonin, myopia, atopic dermatitis, psoriasis

### ID368
### STUDY ON SPATIAL IMPRESSION AND OBJECT VISIBILITY BY AGE OF MELANOPIC EQUIVALENT DAYLIGHT ILLUMINANCE CONTROL LIGHTING

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In recent years, the introduction of individual booths in offices has increased in Japan, primarily for improving the acoustic environment rather than the lighting conditions. Confined spaces present challenges related to decreased comfort and reduced task efficiency. Moreover, individual booths are often windowless, making it difficult to receive sufficient daylighting during the day. To maintain the circadian rhythm, it is essential to regulate the melanopic EDI (mel-EDI) in accordance with the time of day. Furthermore, it is crucial to consider that visual characteristics vary with age. This study examined the effects of different combinations of correlated colour temperature (CCT) and mel-EDI on spatial impressions and object (sentence and colour) visibility in youth and elderly. The two-factor model human lens were used for the evaluation of the elderly. In this study, age-related differences were observed in spatial impressions, sentence visibility, and colour evaluation.

*Keywords:* Office booth, Melanopic EDI, Correlated Colour Temperature, Visual Characteristics

## ID277
## EFFECTS OF NIGHTTIME DISPLAY COLOR TEMPERATURE AND CIRCADIAN STIMULUS ON CIRCADIAN RHYTHMS AND VISUAL FATIGUE

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As displays become ubiquitous and increasingly integrated into daily life, their impact on human health has become a significant concern for both academia and industry. This study aimed to investigate the effects of display backgrounds with varying Correlated Color Temperature (CCT) and Circadian Stimulus (CS) settings on human circadian rhythms and visual fatigue at night. Twelve participants underwent 4-hour display lighting interventions over a 20-day period: LL (CCT = 5000K, CS = 0.05), LH (CCT = 5000K, CS = 0.3), HL (CCT = 7300K, CS = 0.05), and HH (CCT = 7300K, CS = 0.3). Participants' melatonin levels, cortisol levels, visual fatigue, sleep quality, and 24-hour core body temperature were monitored. The results indicated that the LL condition was the most circadian-friendly, associated with the least visual fatigue and the best sleep quality. Additionally, the CS parameter exerted a greater effect on circadian rhythms than CCT.

*Keywords:* Circadian Rhythm, Display, Eye Fatigue

## ID380
## CIRCADIAN RHYTHMS AND LIGHT EXPOSURE: INSIGHTS FROM WEARABLE SENSORS

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This study investigates how LED lighting conditions affect circadian health using wearable sensors to monitor office workers' light exposure, salivary melatonin, and skin temperature over five days. As LED lighting offers spectrally tunable options, understanding its non-image-forming (NIF) effects is critical for health optimization. Results show cool white light exposure over consecutive days reduced morning melatonin levels, while warm white light stabilized or increased them, emphasizing spectral sensitivity. Most participants failed to meet recommended light exposure thresholds, with declining morning melatonin suggesting insufficient circadian-effective office lighting. Nocturnal skin temperature remained unaffected by lighting changes, indicating it is less responsive to short-term spectral variation. These findings highlight the need for dynamic, circadian-supportive workplace lighting strategies to mitigate circadian disruption risks. By integrating wearable sensor data with melatonin biomarkers, this work advances evidence-based lighting design to harmonize spectral composition, visual comfort, and physiological health in real-world settings.

*Keywords:* Non-Image Forming Effects, Melatonin, Wearable Sensors, Circadian Rhythms, Lighting Conditions, Health and Well-Being

# ID164
# QUANTIFYING THE IMPACT OF DYNAMIC NIGHT-SHIFT DISPLAY LIGHT ON MELATONIN SECRETION

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To mitigate the undesirable circadian disruption caused by self-emitting displays in the evening, various night-shift display modes have been developed. However, the specific lighting factors that accurately quantify the impact of dynamic display modes remain unclear. In this study, participants were instructed to use displays with different night-shift modes before bedtime. Among these modes, three had equivalent cumulative m-EDI but varied in the use of either constant or dynamically reduced m-EDI levels. It was found that the static mode with a medium m-EDI resulted in higher melatonin concentrations compared to the dynamic modes. Additionally, despite the dynamic modes achieving a low m-EDI before bedtime, they still caused significantly greater melatonin suppression compared to the mode with constant low m-EDI level. These findings suggest that the peak m-EDI plays an important role in quantifying the melatonin responses to dynamic light, even when the cumulative m-EDI is held constant.

*Keywords:* Melanopic Equivalent Daylight Illuminance, Melatonin Secretion, Night-shift Display Mode

## Wednesday, July 9, 14:50 - 16:30: Oral Session 17 (OS17): D2/D4: Road surface reflectance

### ID220
### EFFECT OF R-TABLE MEASUREMENT DISPERSION ON ROAD LIGHTING QUALITY CRITERIA

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Knowing the reflective properties of road surfaces is an important lever for optimizing the performance of lighting installations. Nevertheless, measuring these properties is still a confidential exercise, and the uncertainties associated with r-table measurements are rarely evaluated. Based on a cross-test campaign between 3 laboratory gonioreflectometers, we investigated the effect of the dispersion of r-table measurements on the quality criteria of a lighting installation. We were able to show that these dispersions were still acceptable, and that characterizing the optical properties of a pavement is an advantage over the traditional use of CIE standard r-tables. By carrying out these measurements in different observation geometries, we also showed that reconsidering the standard 1° geometry would offer the possibility of reducing measurement uncertainties. This contributes to current research aimed at better integrating different types of night-time mobility into urban lighting practices.

*Keywords:* Gonioreflectometer, R-tables, Measurement Dispersion, Road Lighting Calculation

### ID135
### MEASURING THE REFLECTION PROPERTIES OF WET ROAD SURFACES

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For road lighting design, reflection properties of dry surfaces are considered. Yet, wet roads impair lighting performance, emphasizing the critical need of measured data for wet road surfaces. However, these measurements are challenging, as one has to characterize different wetting states, and ensure that time-consuming measurements are done in a given state, notwithstanding the evaporation and drain process. We propose to address these challenges. Different wetting states, from “dry” to “flooded”, have been characterized qualitatively and linked to an objective feature, the specularity of the surface. Then, a protocol is proposed, to regulate the wetness of a road sample in order to keep it in a given wetting state throughout its measurement. In this regard, a device was designed and included on a gonioreflectometer to pour water on the sample when needed. Examples of measurements of three samples in several wetting states are presented, highlighting significant photometric differences across wetting states.

*Keywords:* BRDF, r-table, road surface, gonioreflectometer, rain, soaked, wet, humid, road lighting

## ID136
## A ROAD REFLECTANCE ANALYTICAL FUNCTION BUILT FROM BRDF MODELS

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Optimising road lighting, and particularly quality criteria related to luminance, requires detailed knowledge of the optical properties of road surfaces. Known as *r*-tables for road lighting applications, these properties need to be described by analytical models to represent their evolution as a function of the observation angle, ageing or to solve inverse problems to be retrieved from indirect measurements. To address this issue, a database of 60 *r*-tables is compiled, as varied as possible. Then 9 known reflectance models were tested: 8 from the world of computer graphics and one dedicated to *r*-tables. The performance of all models to represent our data was not satisfactory. Finally, several models' modified components were combined to create our model, which considerably improved the database estimation. The main advantage of this model is allowing an *r*-table to be represented not by 580 elements but by just 10 parameters associated with a formal analytical expression.

*Keywords:* Road Optical Properties, r-table, Reflectance Models, BRDF

## ID185
## MODELLING CHANGES OVER TIME IN THE REFLECTIVE PROPERTIES OF DIFFERENT TYPES OF ROAD SURFACES

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The reflection properties of road surfaces depend on both the type of pavement and its age, but this dependence is not well known. This paper proposes a deterministic nonlinear model to predict the evolution of reflection properties of road surfaces up to 36 months, focusing on the macroscopic CIE descriptors Q0 and S1. Based on French experimental data, the model takes the age, the aggregate size and the colour of the road surface into account. Internal and external validations show that the model quite satisfactorily captures the overall trends in the evolution of Q0 and S1. These results provide a solid basis for improving the prediction of reflection properties of road surfaces, guiding future applications.

*Keywords:* Photometry, Road surface, Modelling, Ageing, Reflection properties

# ID195
# INVESTIGATING THE ACCURACY OF ROAD SURFACE REFLECTION CHARACTERISATION BASED ON ROUND-ROBIN MEASUREMENTS

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Knowing the reflection properties of road surfaces is necessary for road lighting design. Road surface reflection is commonly specified by a set of luminance coefficients *q*. However, measured data *q* are limited and a fortiori, little is systematically known about the accuracy of measurements. To address this, a comparison based on the recommendations of standard ISO 5725 was organized among three laboratories. Seven samples were measured (six different road surfaces and one near diffuse reflective material). The calculations include trueness and precision. While trueness was checked for a suitable geometry (as we lack reference road surface reflection data) and was found to be quite good, the precision proved to be quite variable, e.g. for characteristic values versus those of single q-values. Precision was not closely related to the values of *q*, but rather to the geometrical conditions of the measurement.

*Keywords:* Road surface, r-table, Light reflection, Gonioreflectometer, BRDF, Measurement dispersion, Interlaboratory comparison, ISO 5725

## Wednesday, July 9, 14:50 - 16:30: Oral Session 18 (OS18): D1/D2/D3/D4: TLM and energy efficiency

### ID249
### COHERENCE OF FLICKER VISIBILITY AND PERCEPTIBILITY THRESHOLD DEFINITIONS BY CIE AND IEC

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Flicker is a subjective perception of instability of artificial light sources, which can be, under certain conditions, induced in a human observer by temporal light modulation (TLM). As such, it is addressed by the CIE as a phenomenon related to lighting, but also by the International Electrotechnical Commission (IEC) as a phenomenon related to light sources that are supplied by electricity and whose properties are eventually governed by electronic circuits. However, each organisation uses not only slightly different definitions of what flicker is, but also of the visibility/perceptibility threshold of flicker in terms of TLM properties. This paper aims to compare these definitions. To this end, a data set of threshold measurements with human observers performed via QUEST procedure is evaluated according to each definition. Resulting thresholds are then compared in order to determine whether both definitions of threshold are equivalent (i.e., yield the same threshold).

*Keywords:* Flicker, Flicker Visibility Threshold, Flicker Perceptibility Threshold

### ID295
### INTERPRETATION OF THE FLICKER SEVERITY METRICS PRODUCED BY THE LIGHT FLICKERMETER

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The paper focuses on the Light Flickermeter, a standardised algorithm which is widely used to estimate the severity of flicker of artificial light sources for human observers. The development of the algorithm is briefly covered with special focus on clarification of many ambiguities about meaning of the results that the algorithm produces. Laboratory measurements performed with human observers are used as an empirical basis for the claims presented in the paper. Some of the limitations of the algorithm, being a necessary consequence of how the algorithm was developed, are exposed and discussed. A modified algorithm is presented which removes some of these limitations and thus allows for an easier interpretation of the results.

*Keywords:* Flicker, Flickermeter, Flicker Perceptibility, Flicker Irritability, Flicker Visibility

## ID377
## RESULTS OF IEA 4E SSL ANNEX INTERLABORATORY COMPARISON ON TEMPORAL LIGHT MODULATION MEASUREMENT

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The International Energy Agency (IEA) 4E SSL Annex has conducted an Interlaboratory Comparison (IC 2023) of the measurement of temporal light modulation (TLM) of solid-state lighting (SSL) products. Designed to meet proficiency test requirements, IC 2023 compared measured TLM quantities including short-term flicker indicator ($P_{st}^{LM}$) and stroboscopic effect visibility measure (SVM, $M_{VS}$), as well as three other TLM quantities, on four LED lamp artefacts and on five waveforms produced by a TLM generator source as a technical study. IC 2023 was prepared by five Nucleus and Link Laboratories and had 19 participating laboratories worldwide. The results showed larger variations than expected, especially in $P_{st}^{LM}$ measurements. The causes of these variations were investigated and are discussed. The analytical results of IC2023 identified the need for more robust test methods, an improvement in performance specifications for TLM instruments, and clearer guidance on determining measurement uncertainties.

*Keywords:* flicker, interlaboratory comparison, short term flicker indicator, stroboscopic effect visibility measure, SVM, temporal light modulation, TLM

## ID245
## WILL INCREASING EFFICACY IN LIGHTING TECHNOLOGY DELIVER LOWER ELECTRICITY CONSUMPTION?

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Advancements in LED technology and smart controls have increased lighting efficiency significantly. However, the International Energy Agency reports that global electricity consumption for lighting has remained stable over the past decade. Despite efforts to reduce energy use to combat global warming, expectations are not met. Governments, companies, and individuals must understand the principles behind their investments in modern lighting installations. The reviewed and suggested indicators may help identify possible causes of these shortcomings.

*Keywords:* Efficacy, Energy Savings, Lighting Usage Patterns, Global Warming, Energy Performance Indicators

# ID157
# THE IMPACT OF SEASONAL OCCUPANCY PATTERNS ON ENERGY-RELATED LIGHTING OBJECTIVES

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A greater reduction in artificial lighting energy demand in buildings is necessary to achieve climate targets. The control of artificial lighting depending on presence plays a central role in this. To optimise the energy consumption of switch-off times coupled with passive infrared sensor technology without affecting disruptive false-off rates, there are probabilistic approaches that adapt the switch-off times to real occupancy patterns. The identification of individual attendance patterns and their consideration in the control system is essential for the optimisation process. Work processes and sociological structures have a significant influence on occupancy behaviour and can prove to be time-variant. It is therefore necessary to examine whether one-off or cyclical applications of the optimisation algorithm are required. This study uses a high-resolution data set from an open-plan office to investigate the effect of temporal variability on switch-off time optimisation. The results show that there are no significant seasonal effects.

*Keywords:* Energy efficiency, Switch-off time, Occupancy behaviour, Optimisation algorithms