IEA SHC Task 61 / EBC Annex 77 Integrated solutions for daylighting and electric lighting - Subtask D Field study performance tracking

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

CIE Australia Lighting Research Conference 2020

February 11, 2020
QUT Brisbane
Gardens Point Campus
Z-Block, Level 6, Room 606

Conference Programme

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PROGRAMME

09:30	**Welcome**
09:35 – 11:15	**Session 1: Colour and vision**
Alp Durmus	Ellipse fitting for IES-TM-30-18 colour vector graphic
Wenye Hu	The effect of correlated colour temperature on human thermal perception and comfort
Mariana R C Papa	The effect of luminance on the perceived saturation of near-white chromaticities
Stephen J. Dain	Contrast thresholds as a function of stimulus luminance for two commercial computerised colour vision tests
Mei Ying Boon	Mobility performance in a virtual reality maze is related to luminance and chromatic sensitivity in people with vision impairment
11:15	**Morning tea**
11:35 – 13:15	**Session 2: Lighting design and performance**
Maitreyee Bakshi	Determining the need for special lighting for ornamental plants in interior spaces
Islam A Mashaly	A multi-scenario multi-objective optimization method for complex fenestration systems (CFS) design
Francisca Rodriguez	Validation of a method for quantifying luminous changes in window views
Ayman Wagdy	Machine learning framework for developing glare predictive models
Veronica Garcia Hansen	IEA SHC Task 61 / EBC Annex 77 Integrated solutions for daylighting and electric lighting – Subtask D: field study performance tracking
13:15	**Lunch**
14:00 – 16:00	**Session 3: Photobiology and wellbeing**
Maitreyee Roy	Do blue-blocking lenses affect visual performances under different lighting conditions?
Adiba Ali	The effect of blue-blocking lenses on speed perception
Yihan(Anna) Lu	Effect of daylight on commuters' circadian rhythms
Sung-Woo Choi	The development of circadian led lighting and clinical test
Stephen J. Dain	The effects of source technology on the blue dose to the retina
Joanne Wood	Assessment of blue light hazards and correlated colour temperature for public streetlighting
16:00	**Afternoon tea**
16:20 – 17:20	**Session 4: Photometry**
So Young Lee	Smartphone lighting applications as new light measurement tools
Kieu Pham	Opportunities and challenges in capturing illuminance measurements in post-occupancy settings
Tony Bergen	Calibration of photometers – impact of the SI revision and future directions
17:20	**Concluding comments**
17:25	**Close**
19:00	**Conference Dinner**

Activity: Spot the snow leopard

ABSTRACTS

Session 1

Colour and vision

ELLIPSE FITTING FOR IES-TM-30-18 COLOUR VECTOR GRAPHIC

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ANSI/IES-TM-30-18 is an American National Standards Institute (ANSI) approved calculation framework to evaluate the colour rendition of electric light sources. TM-30 specifies several measures, such as the fidelity index (R_f), gamut index (R_g), and local chroma shift ($R_{cs,hj}$), as well as the colour vector graphic (CVG) [1]. The CVG is a visual tool that provides more detailed and comprehensible information compared to the single-number fidelity and gamut measures. Although the CVG allows quick comparisons between light sources, it has not been quantified to aid numerical specification of light sources [2].

Here, a least squares method [3] is applied by using MATLAB® to find the best fit to an ellipse for the undefined shape of a light source's CVG [4]. An ellipse can be quantified using semi-major axis (a), semi-minor axis (b), centre coordinates (X_0, Y_0), and rotation angle θ (the angle between the horizontal axis and ellipse's major axis), as shown in Fig. 1. Since Ohad's ellipse fitting calculations [5] result in floating semi-major and semi-minor axes (e.g. b values can be larger than a values), a correction was applied where if $a_{Ohad} > b_{Ohad}$, $\theta = -\theta_{Ohad}$ and if $b_{Ohad} \geq a_{Ohad}$, $\theta = |\theta_{Ohad} - 90|$. Calculations show that the ellipse fitting method can be used to quantify CVGs with close proximity. A small difference between semi-major and semi-minor axes (a-b < 0.01) indicate a round CVG. A limitation of this method is the potentially poor fitting of non-oval asymmetric CVGs to an ellipse shape, which is a rare condition.

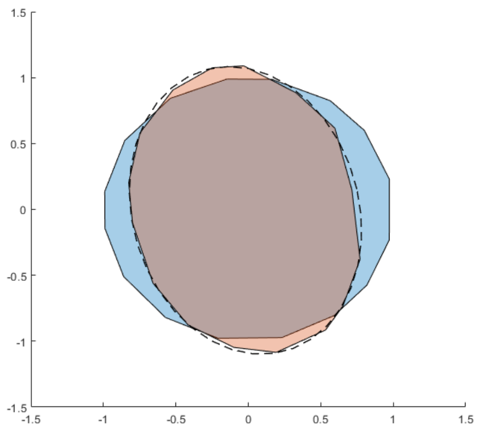

Figure 1: Colour vector graphic (CVG) of a fluorescent light source (4290 K, D_{uv} = 0.0015, R_f = 69, R_g = 86, $R_{cs,h1}$ = -26) (orange circle) can be fitted to an ellipse (black dotted line) with sub axes a = 1.1029, b = 0.7857, rotation angle θ = 102° and centre points X_0 = -0.0198 and Y_0 = -0.0076. The blue circle is the normalized CVG for the reference illuminant.

An ellipse fitting method can be used to quantify CVGs with a minor caveat. Future research will investigate the quantification of CVGs using $R_{cs,hj}$ values and its correlation with ellipse fitting method.

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THE EFFECT OF CORRELATED COLOUR TEMPERATURE ON HUMAN THERMAL PERCEPTION AND COMFORT

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Anecdotal evidence suggests that people are under the impression that reddish or yellowish light creates the perception of a warmer environment than bluish light. Although several studies have been conducted to test this, their findings were inconsistent [1-5]. Inside an office-like laboratory climate chamber at the University of Sydney, 45 subjects were tested when immersed in nine thermal/lighting conditions – combinations of three different room temperatures (21.5 ° C, 24 ° C and 26.5 ° C) and three correlated colour temperatures (CCTs - 2762 K, 3968 K and 6253 K). Both initial responses and adaptive responses, which were assessed after occupants were exposed to the lighting and thermal environment for 25 minutes, were evaluated with questionnaires.

The results show that, in a relatively cool environment (22 or 24 ° C), illumination CCT did not have a statistically significant impact on either subjects' initial or adapted thermal perception of environment temperature. However, in a warmer environment (26 ° C), CCT did impact subjects' thermal sensation. Subjects judged the environment to be significantly cooler under 6253 K than 3968 K light (Z=-3.371, p = 0.001 for initial responses; Z=-3. 173, p = 0.002 for adaptive responses).

Subjects' thermal comfort was also evaluated under different lighting conditions. The results showed that, after adaptation, high CCT light led to considerably improved thermal comfort at 24 ° C and 26 ° C. In a warmer environment (26 ° C), 3968 K light also positively impacted thermal comfort after adaptation (Z=-2.883, p = 0.004 for 4000 K).

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THE EFFECT OF LUMINANCE ON THE PERCEIVED SATURATION OF NEAR-WHITE CHROMATICITIES

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When designing for architectural spaces, lighting designers typically aim to provide neutral white ambient illumination. However, some lighting technologies operate more efficiently at certain chromaticities. If the visual systems of building occupants could be manipulated to reduce the perceptual effects of those chromaticities, lighting systems could be developed that to reduce the energy consumed by lighting without negatively impacting the visual environment.

Twenty observers were immersed in adaptation lighting conditions of varying luminances for five minutes. Subsequently, test lights of different chromaticities were presented for two seconds each. Using a keypad, subjects used hue scaling to report their perceptions of the colour appearance and perceived saturation of each of the 15 test light chromaticities. The adaptation time (five minutes, with 30 seconds of adaptation “top up” between trials) was constant, as was the luminance of the test lights (150 cd/m2). This was repeated for five different near-white adaptation chromaticities of four different adapting luminances.

The results show that the magnitude of perceived saturation of test lights was reduced when subjects were adapted to low luminance lighting. In these cases, the test lights of all tested chromaticities were perceived as, basically, achromatic. This finding could be used by dynamic “smart” lighting systems to reduce the energy consumed by lighting by enabling the use of high-efficacy lights with chromaticities that are typically not desirable in architectural spaces.

CONTRAST THRESHOLDS AS A FUNCTION OF STIMULUS LUMINANCE FOR TWO COMMERCIAL COMPUTERISED COLOUR VISION TESTS

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Purpose: The Cambridge Colour Test (CCT)[1] and the Colour and Diagnosis (CAD)[2] test are computerised tests that operate on different design principles. The CCT has static stimuli and luminance noise whereas the CAD has dynamic stimuli and luminance noise and a higher background luminance. Barbur et al. [2] reported the effect of luminance on the CAD, but it is not known how the CCT is affected. The purpose of this study is to compare the effect of stimulus luminance on the CAD and CCT.

Methods: Young adults (18-35 years) with at least 6/6 corrected binocular visual acuity, a pass on Ishihara's test, pupil size difference of <0.5 mm and self-reported good general health were recruited. Chromatic contrast thresholds were assessed using the CCT and CAD in pseudo random order. Luminance of the tests was reduced with neutral density filters (Density 0.3, 0.6, 0.9, 1.5 and 2.0). Pupil size was recorded for each luminance level using a Neuroptic pupillometer. The CCT result was z-scored, the CAD results already are. Repeated measures ANOVA was used for analysis.

Results: Twenty participants (median 19 range 18-32 years, 5 males, 15 female) were recruited. The effect of pupil size and ND filters on retinal luminance was calculated and the effective luminances were calculated (Figure 1).

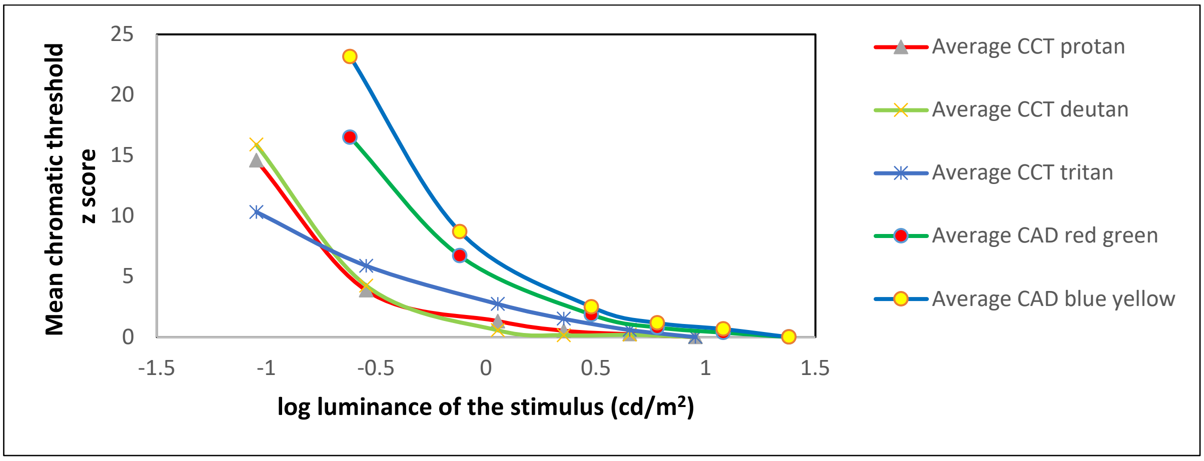

Figure 1: Thresholds (z scores) as a function of stimulus luminance

Conclusions: CAD thresholds were more affected by luminance. This may be why the CAD was designed with a higher luminance. Other characteristics of the tests may contribute to these differences since the CAD has the dynamic stimulus and luminance] noise and a more centrally located task. Results are consistent with Knoblauch et al.[3] who noted lower tritan thresholds with larger stimuli and longer duration. The CAD and luminance results are also consistent with Barbur et al.[2]

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MOBILITY PERFORMANCE IN A VIRTUAL REALITY MAZE IS RELATED TO LUMINANCE AND CHROMATIC SENSITIVITY IN PEOPLE WITH VISION IMPAIRMENT

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People with vision impairment (VI) due to pathology may present with a range of impairments. The purpose of this study was to relate measures of vision impairment with mobility performance in a virtual reality (VR) maze using a mixed methods study design.

Methods: Participants with VI were recruited from an ophthalmology clinic. Visual acuity (VA) and visual fields (VF) were obtained from clinic records. Luminance contrast, red-green and blue-yellow chromatic contrast thresholds were quantified using the UNSW Colour Vision Suite. Participants used a joystick to manoeuvre in a VR maze over four tasks (Table 1). A VR maze allows visual stimuli to be manipulated precisely and mobility to be assessed in a risk-free environment, with minimal set-up costs compared to physical mazes. Number/type of collision and travel time were indicators of mobility performance. After the tasks, participants were interviewed on their experience.

Table 1. Tasks and luminance and chromatic contrast of the obstacles against the background.

Task	Description	Luminance contrast ($\Delta L=\Delta E$)	Chromatic contrast ($\Delta C=\Delta E$)
1	Moving in a slalom manner on a grey footpath between low-lying red and white striped traffic cones and avoiding walls.	White stripe of cone: 15.34 Red stripe of cone: 13.55	White stripe of cone: 16.05 Red stripe of cone: 21.49
2	Moving along a footpath while avoiding stationary pedestrians who are wearing yellow shirts and black trousers	Yellow jacket: 1.32 Black trousers: 17.17	Yellow jacket: 62.64 Black trousers: 16.87
3	Following a yellow line on grey concrete between parked cars and walls in a car park	Yellow line: 29.93	Yellow line: 67.87
4	Moving along a footpath while avoiding moving pedestrians who are wearing red shirts and black trousers, walls and railings	Red jacket: 1.51 Black trousers: 17.17	Red jacket: 130.63 Black trousers: 16.87

Results and discussion: Seventeen people with VI (having retinitis pigmentosa, achromatopsia, corneal dystrophy, optic neuropathy, Stargardt's disease, cone-rod dystrophy and choroideraemia) and three controls volunteered. Significant predictors for collision included poor VA, central and peripheral VF loss, poor red-green chromatic and luminance contrast sensitivity. Significant predictors for travel time included VA, central VF loss, blue-yellow chromatic contrast sensitivity. Yellow lines in Task 3 were reported as very faint by participants who had poor luminance and blue-yellow chromatic contrast sensitivity, which ties in with quantitative findings.

Conclusions: Difficulties experienced moving around a VR world are related to vision measures such as VF, VA, luminance and chromatic contrast sensitivity.

ABSTRACTS

Session 2

Lighting design and performance

CIE Australia

DETERMINING THE NEED FOR SPECIAL LIGHTING FOR ORNAMENTAL PLANTS IN INTERIOR SPACES

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In recent years, the lighting industry has directed significant research and development efforts to supporting both human and plant health. Human health is not only affected by lighting – research has shown that plants in indoor spaces enhance well-being [1]. A separate line of research has facilitated the development of LED lighting technology for commercial horticulture and floriculture. This work is primarily focused on agricultural production [2] and it remains unclear whether special lighting is required for the health of ornamental plants in architectural spaces. In this study, common full-grown ornamental plants were illuminated by various architectural lighting conditions – representing lighting appropriate for a conference room, corporate workspace, retail showroom, classroom and residence. The effects on the plants were recorded in terms of their physical characteristics and visual assessments of plant health. Over a period of seven weeks, it was observed that plant health depended on the pattern of change in lighting correlated colour temperature (CCT) throughout the day. Constant CCT and frequent changes in CCT led to deterioration of plant health. Plants were healthiest under lighting that gradually changed in CCT over the day. Frequent changes in illuminance and long hours of low illuminance also appeared to impact the rate of photosynthesis, and hence the overall health of the plant. The study is a preliminary step toward developing architectural lighting strategies that support indoor plant health without requiring additional hardware or energy consumption.

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A MULTI-SCENARIO MULTI-OBJECTIVE OPTIMIZATION METHOD FOR COMPLEX FENESTRATION SYSTEMS (CFS) DESIGN

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The presentation will report the work-in-progress and results of research regarding a new complex fenestration system (CFS) design method. The new method aims to optimize CFS designs while considering both the architectural and the environmental context. This will include the new daylight metrics developed specifically for assessing the CFS performance in a living space. The new method can be easily generalised to include multiple types of complex fenestration systems without the need to generate the designs beforehand, thus giving flexibility in adjusting the parameters and decreasing their discretization. The method is applied through an original tool, called CFStrace [1], created by the authors, that is easy to use and access by architects and building practitioners. The method requires less technical optical modelling knowledge and accessible tools for design.

We applied a virtual case study to demonstrate the methodology, where a light redirecting device is designed as part of the CFS to enhance the daylight performance of a simple room. A genetic algorithm method is used to optimize a bi-objective cost function with several constraints. A trade-off between the objective functions is demonstrated by weighing the objective functions and plotting the Pareto solutions. The results demonstrate the importance of optimizing CFS designs and the importance of the user's input and preferences in the design problem.

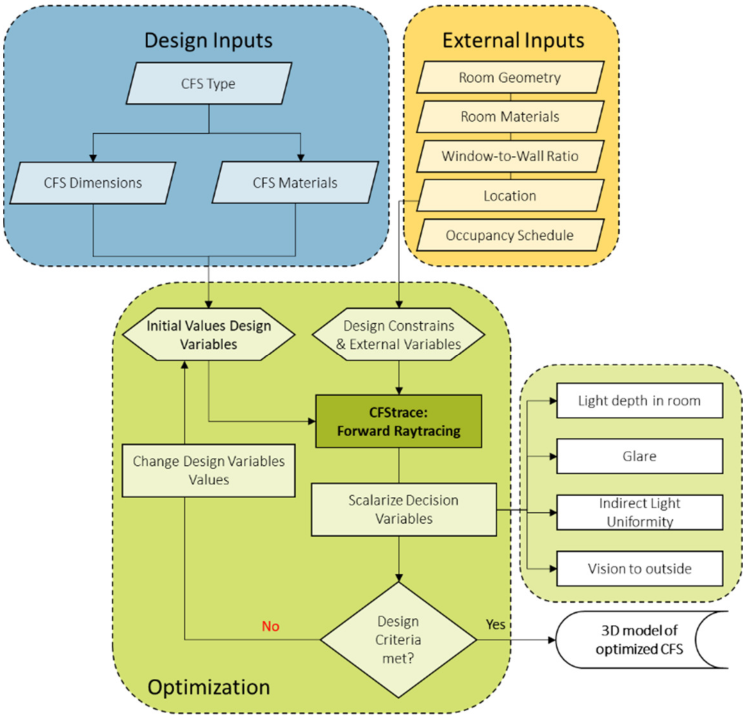

Figure 2: The Optimization methodology for designing CFS

References

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VALIDATION OF A METHOD FOR QUANTIFYING LUMINOUS CHANGES IN WINDOW VIEWS

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As we spend over 90% of the time indoors, continuous exposure to environmental changes is crucial to stimulate positive psychological and health responses. A good way to promote such effects is to design windows with visual access to restorative features outdoors. Recent studies highlighted the importance of investigating temporal aspects of the recovery process [1]; as such, developing procedures for documenting views over time is an essential step towards understanding the variables that contribute to recovery via experiencing outdoor views. In a previous study, we introduced a proof-of-concept methodology to categorize and collect luminous changes in views, based on the systematic labeling of view scenes through computer vision methods, and combined use of time-lapse panoramas and in situ environmental measures [2]. Yet, an in-depth analysis conducted over a larger data sample was needed to verify the validity of this approach.

In this study, we present the results of implementing the proposed methodology over a 5-month period, using a representative sample of urban and suburban view scenes (n = 18) from Brisbane, Australia. Panorama time-lapse images (n = 414) were collected using a Canon Mark III camera fixed with a Canon 1.4 50 mm lens and later processed in Matlab software. Concurrently, continuous solar irradiance, vertical illuminance, and spectral measures were collected to correlate sky conditions to luminous changes in views using inferential statistical analysis. This presentation validates a systematic framework aimed at understanding the effects of luminous variability in window views.

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MACHINE LEARNING FRAMEWORK FOR DEVELOPING GLARE PREDICTIVE MODELS

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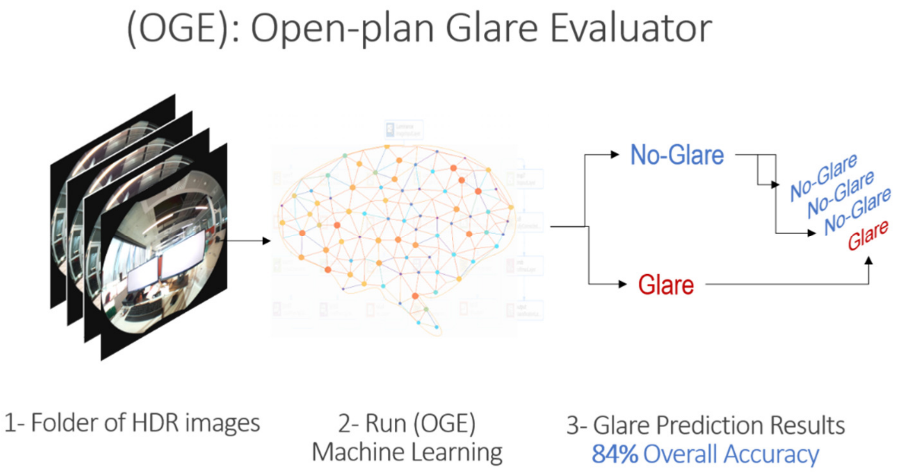

Figure 3: Glare evaluation using machine learning

Although in the last decade many indices and metrics have been developed to predict glare in the built environment, there is a lack of consensus-based glare metrics that could measure the level of visual discomfort indicated by people in their actual working environment.

We present a new approach which integrates the use of Machine Learning algorithms for developing more accurate glare predictive model for open-plan offices. Field data were collected in four open-plan offices in Brisbane, Australia to obtain glare responses from 80 office workers and HDR images of their field of view using a calibrated smartphone [1]. We computed 24 glare metrics for each image and compared them with glare responses of the office workers. Using ROC analysis, we calculated the best thresholds for each glare metric based on the data collected which are only valid for an open-plan office building typology.

We tested 825 Machine Learning models with various methods of training features to identify the best predicative ML model. We found that ML algorithms were better in finding the non-linear relationship between the input predictors (i.e. various multi-region luminance values, luminance, illuminance and glare indices) and the discomfort glare using the MRL method [2]. By comparing ML with ROC analysis, it was found that ML outperformed the conventional statistical methods with an overall accuracy of 83.8% (0.8 TPR, and 0.86 TNR) based on our dataset. Finally, we will provide the machine learning framework in the form of stand-alone software as shown in Figure1 which not only allows the users (architects, engineers, lighting designers) to use the trained model to predict glare, but also to train and develop new models using new HDR images [3].

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IEA SHC TASK 61/EBC ANNEX 77 INTEGRATED SOLUTIONS FOR DAYLIGHTING AND ELECTRIC LIGHTING – SUBTASK D: FIELD STUDY PERFORMANCE TRACKING

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Abstract

Smart technology has made a significant impact in modern commercial buildings and is considered a key solution for efficient lighting and visual comfort [1]. Lack of proper processes to effectively couple smart lighting systems with daylighting can be just as inefficient as traditional lighting. Hence, in 2018 the International Energy Agency (IEA) launched an international project between the Solar Heating and Cooling (SHC) and the Energy in Buildings and Communities (EBC) called the IEA SHC Task 61/EBC Annex 77 "Integrated Solutions for Daylighting and Electric Lighting: From component to user-centered system efficiency" with an objective to foster the integration of daylighting and smart electric lighting solutions for the benefit of higher user satisfaction and energy savings [2]. In particular, the IEA SHC Task 61 Subtask D was initiated to investigate existing knowledge in integrated solutions to form a monitoring protocol to evaluate integrated projects. This presentation describes the initiatives, structure and current status of the IEA SHC Task 61 Subtask D by presenting exemplary case studies. First, an overview of the aims and objective for lab and field study performance tracking is described, including an overview of the framework for monitoring protocol. Second, an outline of exemplary projects around the world are highlighted. Finally, two exemplary buildings in Brisbane Australia are presented in detail regarding the circadian potential, electrical energy performance, and, description of smart integrative lighting solutions and photometric assessments.

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ABSTRACTS

Session 3

Photobiology and wellbeing

DO BLUE-BLOCKING LENSES AFFECT VISUAL PERFORMANCES UNDER DIFFERENT LIGHTING CONDITIONS?

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Background: The need for blue-blocking lenses (BBLs) is driven by the fact that nascent screen and lighting technologies utilise light-emitting diodes, which emit a considerably higher proportion of short-wavelength light. While, BBLs have been designed to beneficially reduce exposure to blue hazard light, their secondary and unintended effect on vision has not been fully characterised [1, 2]. This study aimed to quantify the effect of BBLs on (i) the photo-stress recovery times due to exposure to a bright light source for different types of BBLs, and stimuli that differed in contrast, and colour (ii) the contrast perception of targets defined by colour (chromatic) using a visual search design detection task.

Methods*:* Four types of commercially available BBLs and a clear control lens were used for the study. (i) Twelve participants recruited in the photo-stress recovery time study. The participants were asked to view chromatic and achromatic stimuli, through BBLs and a clear lens, under low and high contrast luminance conditions. (ii) Five participants were recruited for the colour contrast sensitivity study. The contrast detection threshold was measured using the visual search colour detection task and staircase procedure.

Results: (i) The recovery times required to detect high contrast chromatic and achromatic stimuli were unaffected by BBLs when compared to a clear control lens. However, recovery times were significantly affected by BBLs and were longer when chromatic and achromatic stimuli were of low contrast. (ii) Colour contrast was impaired only for blue colours, and this was most evident at low contrast. Additionally, the BBLs with lower transmittance profiles led to greater reductions in colour contrast sensitivity and shown to affect colour contrast thresholds.

Conclusion: While reducing blue light through BBLs may potentially minimise the harmful effect of blue hazard light, a reduction in recovery time and colour contrast sensitivity may unintentionally reduce the effectiveness and visual sensitivity particularly under low-lighting conditions in real-world conditions such as driving at night, and other night-time activities in which the overall light level is low.

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THE EFFECT OF BLUE-BLOCKING LENSES ON SPEED PERCEPTION

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Background: Blue-light filtering lenses (BFLs) are commercially available to protect the eyes from hazardous blue light. However, there is limited knowledge about the consequences of BFL on visual functions such as speed perception [1, 2]. Because BFLs selectively attenuate light from the environment, it is expected that scene and object contrast is reduced which previous studies have shown may also reduce its perceived speed [3]. This study aims to establish whether wearing BFLs lenses affects speed perception and if so, quantify this effect.

Methods: The effect of three BFLs on speed perception was assessed in 20 participants while wearing each of BFLs and clear control lenses. Participants were presented with randomised pairs of chromatic and achromatic stimuli to decide which was faster; the test stimuli (viewed through BFL) or the reference stimuli (viewed through clear control lens), using a computer-based psychophysical study.

Results: The results demonstrated that BFLs significantly reduced speed perception by approximately 7 to 13 % compared to the clear control lens across chromatic and achromatic stimuli as shown in Table 1. The extent of the effect was dependant on the lens' spectral transmittance characteristics, with lenses that attenuated the most light producing the largest reduction in perceived speed.

Conclusion: All blue-light filtering lenses significantly decrease speed perception, but BFLs with lower spectral transmittance profiles have shown the highest effect. This may lead to substantial real-life consequences, such as during driving and visual search.

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EFFECT OF DAYLIGHT ON COMMUTERS' CIRCADIAN RHYTHMS

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The research evaluates the effects of daylight on commuters' circadian systems. Light, especially short-wavelength light, entrains humans' circadian systems [1]. Daylight, which is rich in the short-wavelength light, has been widely regarded as an ideal light source for regulating humans' biological clock. Commuters spend significant time travelling from home to work on a daily base by driving, taking public transport, and/or walking, during which they are involuntarily exposed to daylight. Average commuting times of employed Australians can be up to one hour [2]. Although some studies have suggested that excessive electric light in indoor spaces can disrupt users' circadian rhythms [3], the circadian effect of daylight on workers while they are commuting is still unclear. In this study, the spectral irradiance distribution (SID) of daylight was measured repeated in a variety of commuting modes and conditions, including different traffic conditions, times of day, weather, and locations on roads. The α-opic irradiance will be calculated for each condition using the method recommended in CIE DIS 026/E:2018 [4]. The circadian stimulus (*CS*) will also be calculated and compared with the working threshold of 0.3 [5] to estimate possible melatonin suppression. The equivalent melanopic lux (EML) will also be calculated and compared with the working threshold of 200 melanopic lux [6]. The analysis will elucidate the relative importance of people's commutes on circadian rhythms.

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THE DEVELOPMENT OF CIRCADIAN LED LIGHTING AND CLINICAL TEST

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With a built-in sleep and wake cycle regulated by natural sunlight, the human body has evolved over centuries to stay active during the day and rest at night. However, keeping an optimal 24-hour body cycle is increasingly difficult in modern society as more and more people spend the majority of their days indoors. Many bio-, medical- and lighting related research groups have reported that artificial lighting interferes with melatonin production and disrupts the circadian rhythm.[1-4] In this research, we have considered not only visual functions but also biological functions of LEDs as the next generation illumination. We performed package and spectrum design suitable in daytime and nighttime for the human-centric lighting. It is known that the melanopic sensitivity located at 480nm can mainly controls the suppression and secretion of the melatonin hormone as shown in figure 1. In order to confirm the biological effect, we conducted the clinical test through the certified organization with conventional LEDs and circadian LEDs designed by spectrum engineering. As a result, we obtained the spectrum that could improve both the performance by suppression of melatonin during the daytime and the sleep quality by secretion of melatonin during the nighttime. We confirmed that the specific wavelength and spectrum shape of LEDs has an influence in the melatonin hormone and circadian rhythm of human.

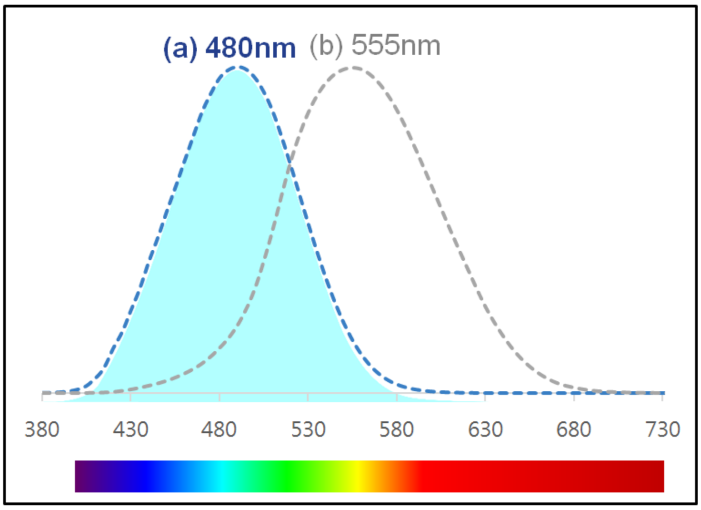

Figure 4: Biological sensitivity of 480nm in melanopsin cell and photopic sensitivity of 555nm in R,G,B cone and rod.

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THE EFFECTS OF SOURCE TECHNOLOGY ON THE BLUE DOSE TO THE RETINA

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Background : White LEDs have a blue or violet LED stimulating phosphors to produce white light. The visual impression of a similarity in the LED spectral emission to the retinal blue light hazard has led to an alleged hazard and promotion of eye protection products.

Methods: A Topcon SR-3 telespectroradiometer was used to measure spectral radiance 380-780 nm. The sources were incandescent, fluorescent and LED lamps. Computer screens with cathode ray tubes, cold cathode and LED backlit liquid crystal displays, plasma and organic LEDs were measured. Where applicable, all the correlated colour temperatures (CCT) settings were tested. The spectral radiances of the sky, grass and man-made objects in the outside environment were also measured.

Results: All sources of the same CCT, had the same relative blue content (±15%). However, changing from warm white (CCT≈2900 K) to daylight (CCT≈7500 K) resulted in an increase of around 3x the blue dose, regardless of the technology. Computer screens varied from 5000 K to 11000 K and the relative blue dose rose 1.8x, regardless of the screen technology. In absolute terms, the theoretical time taken in the outdoor environment to reach the blue dose limit ranges from around 10 to 200 days of continuous noon viewing. The viewing time, calculated the same way, for a computer or tablet screen (set on maximum brightness) is between 250 and 5000 days.

Conclusions: Given the same CCT, all technologies provide the same dose to the retina. The only way to increase relative dose is not by changing the technology but by raising the CCT. If concerned, people should choose warm white lighting or a low CCT setting on the computer screen. They can also reduce the screen brightness. The outdoor environment is still, by far, the more hazardous.

ASSESSMENT OF BLUE LIGHT HAZARDS AND CORRELATED COLOUR TEMPERATURE FOR PUBLIC STREETLIGHTING

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Background: The increasing application of LED sources for public lighting has raised concerns about the

impact these sources have on human health and the environment. This study investigated the level of blue light associated health risks from LED streetlighting with different Correlated Colour Temperatures (CCT) compared with commonly encountered interior and personal light sources.

Methods: This field-based analysis measured the amount of Blue Light Hazard (BLH) present for road users (driver, cyclist and pedestrian) and at property boundaries at a range of LED streetlight installations (with CCTs of 3200K, 4000K and 5900K) compared with other traditional streetlights (high pressure sodium, mercury vapour and fluorescent) and commonly encountered light sources at night (TV, computer and smartphone). Blue light was analysed in terms of its potential effect on eye health and circadian health.

Results: In the assessed road user scenarios, all streetlights produced blue-weighted irradiance readings that were well below the recommended exposure limits for BLH (100 times less), both directly under the light sources and at the property boundaries, and were lower than many common interior activities and personal light sources. All maximum exterior circadian stimulus (CS) values measured directly under the luminaires and at property boundaries were well below the threshold (8 times less) considered to induce melatonin suppression or circadian disruption and were lower than interior activities and personal light sources.

Conclusion: The findings suggest that the BLH and CS values for LED streetlighting are well below the levels required to negatively impact on eye and circadian human health.

ABSTRACTS

Session 4

Photometry

SMARTPHONE LIGHTING APPLICATIONS AS NEW LIGHT MEASUREMENT TOOLS

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When intense blue light enters our eyes, photoreceptors and retinal pigment epithelium (RPE) cells in the retina can be damaged by photochemical processes, potentially contributing to age-related maculopathy [1]. The damage is cumulative and permanent, and its severity depends on intensity and duration of exposure to blue light sources [1,2]. Workers who are routinely exposed to blue light such as welders, healthcare professionals or stage performers, are more at risk of retinal damage.

Using a spectroradiometer, blue-weighted spectral radiance (L_B) can be measured, with the occupational limit being 100 W/m^2sr when the exposure duration is within 10,000 sec [3]. However, exposure assessment for a complex task requires more detailed time/activity assessment relative to direct/reflected blue light and assessment of the risk of exposure needs consideration of the occupational visual field (OVF) [4]. For this, two new smartphone applications were developed by University of Rome Tor Vergata to assess the personal OVF, luminance and L_B (Figure 1, left).

The *OVF3 DR* app provides visual field information related to the actual centre vision and the *BlueEval* app can measure luminance and L_B. Using attachable filters (luminance filter and blue filter), a light source targeted by a smartphone camera can be used to measure these parameters (Figure 1, right). These can be available relatively simply at low cost compared to the spectroradiometer.

The outcomes of the Blue Eval app were compared with the Minolta luminance meter and the Specbos 1211UV spectroradiometer. The values of luminance between the BlueEval app and the luminance meter differed, but both the app and the spectroradiometer showed similar values for the L_B.

These mobile apps are still at a developmental stage, but hopefully will be able to be used effectively in the occupational setting soon.

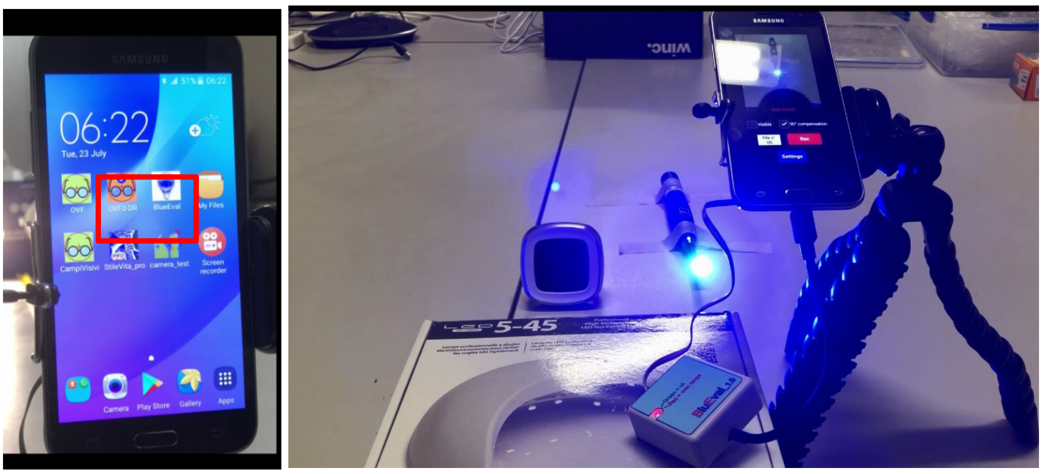

Figure 5: Smartphone applications in a red box (left) and measurement experiment using a dental curing lamp (right)

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OPPORTUNITIES AND CHALLENGES IN CAPTURING ILLUMINANCE MEASUREMENTS IN POST-OCCUPANCY SETTINGS

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Abstract

Field illuminance measurements in post-occupancy settings are valued data for determining the effectiveness of integrative lighting solutions under real-world conditions. Traditionally, practical measurements are obtained using an illuminance meter to take spot measurements horizontally (on the work plane) or vertically at the eye [1,2]. The measurement protocol would require the researcher to remove the building occupant from the scene to take repeated measurements. Normally, this would be manageable if only a few spot measurements are needed under smaller settings (i.e. single or shared office with only one or two occupants). However, for studies that aim to couple illuminance measurements with human behaviour in much larger settings, the measurement protocol and devices would need to be much more adaptable, flexible and practical for diverse settings. This presentation reports on the opportunities, challenges and limitations when capturing large quantities of field illuminance measurements outside of the standard measurement protocol in settings where building occupants are present and when multiple wireless dataloggers with low-cost illuminance sensors are used. A commercial large open plan office containing 150 building occupants is used as an exemplar to discuss: the practical challenges when determining the placement and location of sensors; the impact of data quality when occupants are present; and the issues of data matching (i.e. different time resolutions) between illuminance measurements and observational data.

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CALIBRATION OF PHOTOMETERS – IMPACT OF THE SI REVISION AND FUTURE DIRECTIONS

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The recent redefinition of the SI has largely unaffected the field of photometry and radiometry, where measurement uncertainties are typically of the order of a few tenths of a percent up to a few percent. However, a quirk in rounding errors has led to a small redefinition in the properties of the light sources used to calibrate photometers.

The International Commission on Illumination (CIE) has defined standard illuminants, which are standardised tables of spectral data that are representative of common light sources [1]. CIE standard illuminant A is intended to represent typical tungsten filament lighting, and is calculated by the normalized Planck's Law based originally in 1931 on a Planckian radiator at a temperature of approximately 2848 K. The small changes in fundamental constants over the years has resulted in the temperature of the Planckian radiator changing, and the recent redefinition of the SI has resulted in a further "tweak" of this temperature from 2856 K to 2855.5 K.

According to ISO/CIE 19476 [2], photometers (illuminance meters and luminance meters) are calibrated using CIE Source A, a gas-filled tungsten filament lamp which is a practical realisation of CIE standard illuminant A. This has been used since it was first adopted (by convention) in the early 20th century. Errors can occur when the spectral content of a light source being measured differs from that of the source used in the calibration. These errors, known as spectral mismatch errors, have become more prominent since the recent large-scale adoption of LED lighting. In order to minimise these errors, the CIE is currently working on a LED reference spectrum to compliment standard illuminant A for photometer calibrations [3].

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