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Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

CIE Australia Lighting Research Conference 2022

February 8, 2022
Online only, by Zoom

Conference Programme

Version 1.0
Note: The programme is still subject to change

THE CIE

The International Commission on Illumination – also known as the CIE from its French title, the Commission Internationale de l´Eclairage – is devoted to worldwide cooperation and the exchange of information on all matters relating to the science and art of light and lighting, colour and vision, photobiology and image technology. More information can be found from the CIE website: http://www.cie.co.at/.

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PROGRAMME

All times are Australian Eastern Daylight Time (AEDT, UTC/GMT +11 hours).

08:50	**Zoom meeting opens**		
09:00	Tony Bergen	Australia	**Welcome**
			Keynote address
09:05	Peter Blattner	Switzerland	Comparison of calculation methods of spectrally derived quantities
			Session 1: Interior lighting and LEDs
09:35	Wenkai Bian	Australia	Initial simulations of gaze-dependent lighting
09:55	Crispin Rock	Australia	Chromaticity preferences for dimming white LED lighting
10:15	Rugved Kore	USA	Curve fitting considerations for nonlinear LED dimming correction
10:35	David Boughey	Australia	Update on progress with Australian LED MEPS
10:55	**Break**		
			Session 2: Visibility and perception
11:15	Yuwei Wang	USA	Image quality assessment and big five personality traits
11:35	Mark Schier	Australia	The perception of traffic signal operation
11:55	Mei Ying Boon	Australia	Pilot study of relative conspicuity of cycling vests under four environmental lighting conditions
12:15	**Break, attendee screenshot #1**		
			Session 3: Clinical applications
12:55	Stephen Dain	Australia	The specification of colour limits in lenses of eye protection for use when colour-contingent clinical observations are made
13:15	Ruth Genevieve Ong	Australia	Occupant-centered approach to assessing lighting conditions in patient rooms
13:35	Stephen Dain	Australia	Clinical observation – the neglected factor in hospital and clinical examination lighting?: A review
13:55	**Break**		
			Session 4: Sky glow and road lighting
14:15	Tony Bergen	Australia	On the mesopic performance of roadway lighting sources
14:35	Adrian Cupitt	Australia	Changes in sky brightness throughout the night and seasons
14:55	Gillian Isoardi	Australia	Assessing the sensitivity of sky glow measurements for evaluating the environmental impact of new development
15:15	**Break**		
			Session 5. Photobiology and blue light hazard
15:35	Mushfiqul Anwar Siraji	Malaysia	Light exposure behaviour assessment (LEBA): A novel self-reported instrument to capture light exposure-related behaviour
15:55	Hind Saeed Alzahrani	Saudi Arabia	Evaluation of the safety of commercially available blue blocking lenses under different blue light exposures
16:15	Steve Coyne	Australia	Utilising photometric measurements to ascertain potential for blue light hazard risk
16:35	Mushfiqul Anwar Siraji	Malaysia	Influence of daytime short-wavelength dominant electric light exposure on human alertness and higher cognitive functions: A CIE S 026-based pilot study
16:55	Tony Bergen	Australia	**Concluding comments, attendee screenshot #2**
17:00	**Close**		
18:00	**Virtual afterparty**		

Keynote Address

Dr Peter Blattner
METAS, Bern-Wabern, Switzerland
President, CIE

Peter Blattner holds his Ph.D in the field of applied optics from the University of Neuchâtel, Switzerland. He joined the Federal Institute of Metrology (METAS) in 2000 where he is currently the head of the optics laboratory.

He served as Director of CIE Division 2 from 2011 to 2019. In 2015 he received the CIE Wyszecki Gold Pin award for outstanding contribution in fundamental research. In October 2017 Peter Blattner was elected CIE President for the period 2019 to 2023; he is currently just over midway through his term as President.

In 2021, CIE Division 2 established the reportership DR 2-90 *"Reference spectra and metrics for software validation"* with Peter as the reporter. The terms of reference of the reportership are *"To investigate the need, benefit and challenges for defining CIE reference spectral data for validating software, especially for calculation of derived quantities"*.

COMPARISON OF CALCULATION METHODS OF SPECTRALLY DERIVED QUANTITIES

Peter Blattner[1]

[1] METAS, Bern-Wabern, Switzerland

Correspondence: peter.blattner@metas.ch

Spectral and derived quantities play a central role in the field of light, lighting, colour and photobiology. The CIE has defined a large number of action spectra which facilitate quantification of the effect of optical radiation on humans and other organisms. Examples are the photometric quantities which are usually using the relative luminous efficiency function for the human eye, or more recently the effect functions for non-visual effects. In the field of colorimetry complex relationships exist between spectral measured quantities and the derived quantities (i.e. Correlated Colour Temperature, Colour Rendering Index, Colour Fidelity Index, etc.). The calculations are usually performed using commercial or self-developed software tools. In practice, small deviations can be observed using different tools.

CIE Division 2 has established a reportership (DR 2-90) which is investigating the usefulness of publishing spectral reference data that could be used for validating software. In the framework of the reportership, an informal comparison of calculation methods and tools took place. Participants were asked to calculate different spectrally derived quantities including chromaticity coordinates, correlated colour temperature, (photopic) illuminance and melanopic equivalent daylight illuminance of eight different spectral distributions. The spectral distributions were of different origins (measurements or artificially synthesised) representing different types of sources.

Figure 1 shows a typical result of the comparison for the quantity "illuminance". Dataset 497, de2, f68 and g06 agreed to better than 10^{-12}, whereas for dataset f68 only the 1 nm spaced has such a good agreement. It is interesting to observe that dataset 1f5 and bf2 disagree with always the same factor. It is mostly probable that a different K_m value was used in the calculation of the illuminance. In addition, possible origins of the differences are:

- Different integration methods
- Wrong 1 nm data (interpolation of 5 nm data instead of original 1 nm data)
- Rounding errors when copying reference data or the reference tables
- Finite precision of the calculations

This talk will summarize the findings of the comparison.

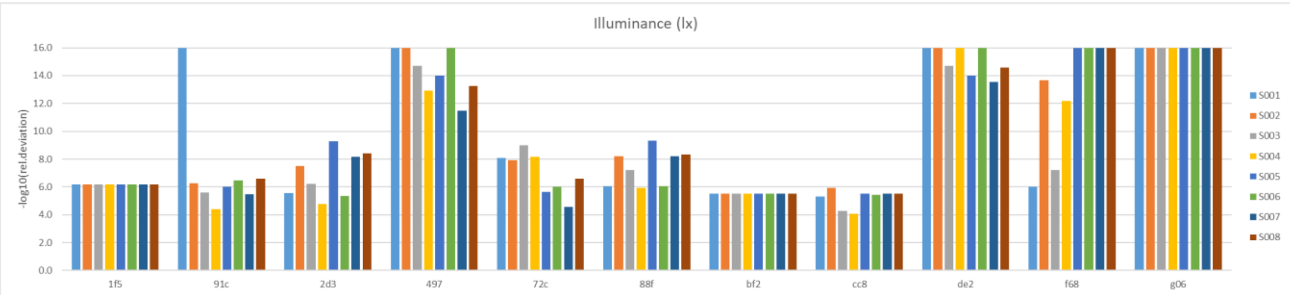

Figure 1: Deviation of calculated illuminance values of 8 spectra (S001 to S008) of 11 participants (datasets) to a reference value, where the opposite common logarithm (i.e. $-\log_{10}$) of the deviation is reported.

ABSTRACTS

Session 1

Interior lighting and LEDs

INITIAL SIMULATIONS OF GAZE-DEPENDENT LIGHTING

Wenkai Bian[1], Wenye Hu[1], Wendy Davis[1]

[1] School of Architecture, Design and Planning, The University of Sydney, Australia

Correspondence: wbia8886@uni.sydney.edu.au

Conventional lighting design strategies typically evenly illuminate entire spaces, which unnecessarily consumes energy for the illumination of areas outside occupants' visual fields. A gaze-dependent lighting strategy is proposed to illuminate spaces only partially, but provide visual environments comparable to uniform lighting. This preliminary study first determined the simulation methods that will be used in a later experiment, and then compared the energy consumed by lighting for two groups of simplified simulation spaces, representing conventional lighting design and the implementation of gaze-dependent lighting strategies.

Photometric files of 1500 products, collected from 13 light-emitting diode (LED) downlight suppliers, were categorised into 17 groups according to their beam angles. A square room, that was eight metres long, eight metres wide and three metres high, was created in the Radiance software. The reflectance values were 20% for floors, 50% for walls and 70% for ceilings. Luminaires from each group were used in simulations to achieve an average illuminance of 320 lx at 0.7 m above the floor with a uniformity (minimum/average) greater than 0.5 across the entire space, representing traditional lighting design. Simulations were then repeated to yield the same illuminance with a 0.7 uniformity only across the task area. The luminance of visible walls was comparable for all simulation conditions.

Simulation results show that gaze-dependent lighting using luminaires with beam angles greater than 60° can reduce lighting energy consumption by an average of 27.69%, compared to conventional lighting design, and create a similar visual experience. Figure 1 shows an example.

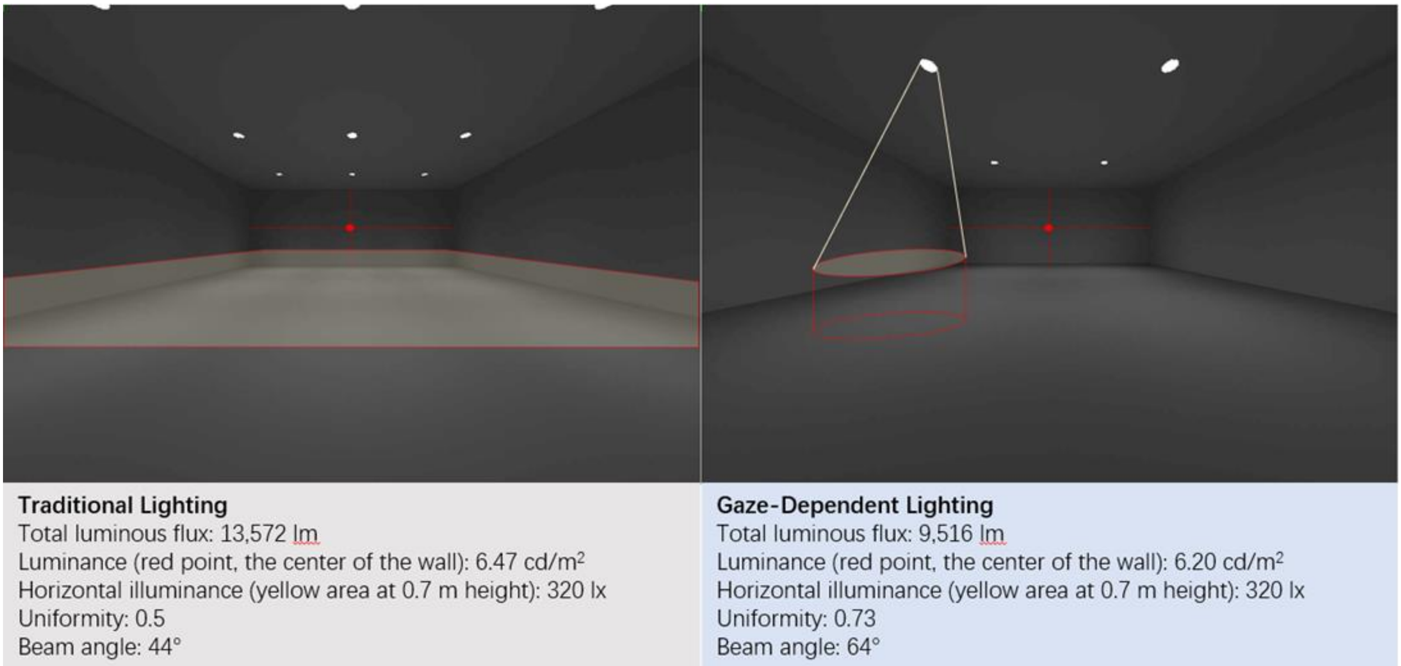

Figure 1: Simulation images for conventional illumination (left) and gaze-dependent illumination (right).

CHROMATICITY PREFERENCES FOR DIMMING WHITE LED LIGHTING

Crispin Rock[1], Wenye Hu[1], Wendy Davis[1]

[1] School of Architecture, Design and Planning, The University of Sydney, Australia

Correspondence: croc5716@uni.sydney.edu.au

When a light-emitting diode (LED) is dimmed, the light does not visibly shift in correlated colour temperature (CCT), as it does with an incandescent lamp – the LED just emits less light. To simulate the dimming behaviour of incandescent lamps that are used to create mood or atmosphere, some manufacturers have developed “warm dim” or “sunset dimming” lamps, typically using both warm white and amber LEDs. As the light is dimmed, the ratio of the output of the two types of LEDs changes to create the familiar feeling of warmth as luminous flux is decreased.

There has been little research on users’ subjective responses to this phenomenon, except for analysis of the Kruithof curve, which posited that, at lower illuminances, lower CCTs are more pleasant than higher CCTs. A review of the many experiments that have tested the Kruithof curve indicates that changes in CCT have little or no effect on lighting preferences, whereas illuminance has a strong effect [1].

A lab-based psycho-physical experiment has been developed to identify CCT preferences and evaluate perceptions of naturalness when white light is dimmed, in both work/office and home/relaxing contexts. The experiment will not evaluate the Kruithof curve but aims to identify any preferred shifts in CCT as white light is dimmed. Using multi-channel LED luminaires and a combination of fixed and participant-controlled dimming, this experiment is expected to shed some light on the apparent disconnect between lighting design practice and lighting research. Because of the COVID-19 lockdown in New South Wales, data collection has been delayed.

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CURVE FITTING CONSIDERATIONS FOR NONLINEAR LED DIMMING CORRECTION

Rugved Kore[1], Dorukalp Durmus[1]

[1] Pennsylvania State University, University Park, USA

Correspondence: rsk97@psu.edu

Multi-colour LEDs can be optimized for energy efficiency, colour rendition, art conservation, circadian entrainment, and cyanosis detection [1-5]. Computational optimization of LED spectral power distribution (SPD) is based on the assumption that spectral outputs are linear (e.g. 50% dimming level should provide 50% of the full output). However, LEDs may exhibit a nonlinear response when dimmed, as shown in Figure 1. LEDs nonlinear response can be corrected using a fitting curve of the measurement data to either dimming levels or estimated SPDs.

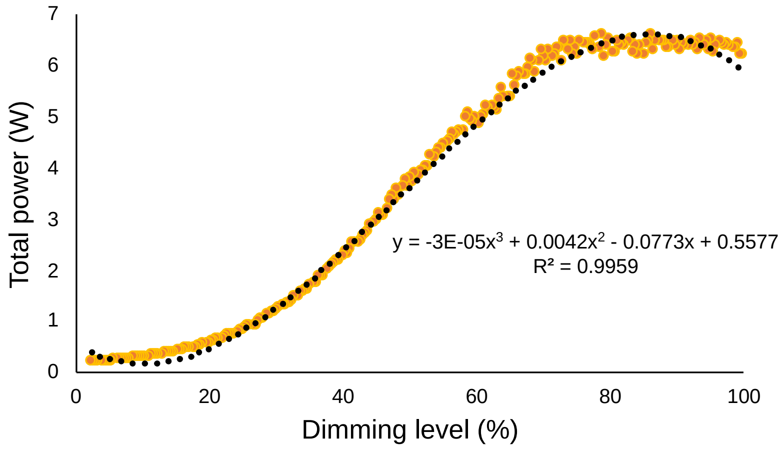

Figure 1: The cubic fitting (black dotted line) of the total measured power of a blue LED (y-axis) to dimming levels (x-axis)

Here, two curve fitting parameters were investigated: scaling reference (50% or 100% dimming level of the measured SPD) and method for reducing SPD to a single value (maximum, total, or average). Results indicate that using maximum, average, or total power to reduce SPD to a single value, or the choice of reference (100% vs. 50% of the measured SPD) do not affect the cubic dimming curve functions, as shown in Table 1. Future work will look into the effect of curve fitting parameters on LEDs with peak wavelength shifts.

Table 1. Curve fitting formulae and correlation coefficients

Reference	Comparison	Maximum power	Total power	Average power
100%	Estimated vs measured SPDs	$y = 37.41x^3 - 13.108x^2 + 1.8273x + 0.011$ $R^2 = 0.9675$	$y = 0.0509x^3 - 0.5062x^2 + 1.9665x + 0.1425$ $R^2 = 0.9669$	$y = 11286x^3 - 238.42x^2 + 1.9665x + 0.0003$ $R^2 = 0.9669$
	Dimming level vs measured SPDs	$y = -6E\text{-}08x^3 + 2E\text{-}05x^2 - 0.0011x + 0.0165$ $R^2 = 0.9959$	$y = -2E\text{-}06x^3 + 0.0007x^2 - 0.0303x + 0.5577$ $R^2 = 0.9959$	$y = -4E\text{-}09x^3 + 1E\text{-}06x^2 - 6E\text{-}05x + 0.0012$ $R^2 = 0.9959$
50%	Estimated vs measured SPDs	$y = 43.068x^3 - 15.091x^2 + 2.1037x + 0.0126$ $R^2 = 0.9675$	$y = 0.0593x^3 - 0.5899x^2 + 2.2916x + 0.1661$ $R^2 = 0.9669$	$y = 13235x^3 - 279.61x^2 + 2.3063x + 0.0004$ $R^2 = 0.9669$
	Dimming level vs measured SPDs	$y = -6E\text{-}08x^3 + 2E\text{-}05x^2 - 0.0011x + 0.0165$ $R^2 = 0.9959$	$y = -2E\text{-}06x^3 + 0.0007x^2 - 0.0303x + 0.5577$ $R^2 = 0.9959$	$y = -4E\text{-}09x^3 + 1E\text{-}06x^2 - 6E\text{-}05x + 0.0012$ $R^2 = 0.9959$

References

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UPDATE ON PROGRESS WITH AUSTRALIAN LED MEPS

David Boughey[1], Steve Coyne[2], Gillian Isoardi[2]

[1] Department of Industry, Science, Energy and Resources, Canberra, Australia

[2] Light Naturally, Brisbane, Australia

Correspondence: David.Boughey@industry.gov.au

In April 2018, Energy Ministers agreed to further improve lighting energy efficiency regulation by phasing out inefficient halogen light bulbs in Australia and introducing minimum standards for LED light bulbs in Australia and New Zealand in line with the revised European Union (EU) standards.

This presentation outlines work underway on the development of minimum energy performance standards (MEPS) for LED light bulbs in Australia and New Zealand (in line with the single lighting regulation implemented Sept 1, 2021, in the European Union (EU)). This will include information on the features of AS/NZS 5341 LED lamps—Test methods—Energy and functional performance, which brings together and references the range of international (e.g. IEC and CIE) and regional standards for use in testing LED performance parameters. The presentation will also discuss some of the key technical challenges encountered in developing the MEPS within the Australian context.

ABSTRACTS

Session 2

Visibility and perception

IMAGE QUALITY ASSESSMENT AND BIG FIVE PERSONALITY TRAITS

Yuwei Wang[1], Alp Durmus[1]

[1] Pennsylvania State University, State College, USA

Correspondence: ykw5337@psu.edu

Subjective assessments of the visual environment, such as visual complexity, visual clarity, visual preference, and colourfulness, can be quantified using image quality metrics [1-3]. However, little is known about the influence of personality on visual perception. For example, a participant who has a high “agreeableness” personality trait can make positive judgments about the visual environment, such as visual preference, compared to participants who has low agreeableness. An exploratory study was conducted to investigate whether personality influences subjective evaluations.

Fifty images with varying spatial and chromatic characteristics were collected from online databases in ten categories: offices, residential spaces, educational spaces, gyms, retail spaces, industrial spaces, restaurants, health centres, museums, and houses of worship. The images were scaled to the same height (709 pixels) and displayed on a calibrated display in random order. Forty participants completed the ten-item personality inventory (TIPI) [4], which includes five personality traits: extraversion, agreeableness, conscientiousness, emotional stability, and openness to experience. In the experiment, participants judged the quality of each image in terms of preference, visual clarity, visual complexity, and colourfulness using a nine-point Likert-type scale with no neutral point. Participants’ reaction time was also recorded.

Table 1. Spearman correlation coefficient (ρ) shows the correlation between personality types and subjective evaluations.

	Extraversion	Agreeableness	Conscientiousness	Emotional stability	Openness to experience
Preference	0.111	-0.181	-0.093	-0.043	0.167
Complexity	0.084	-0.065	0.112	-0.120	0.188
Clarity	-0.004	-0.184	-0.082	-0.255	0.146
Colorfulness	0.031	-0.134	-0.041	-0.092	0.122

The results indicated that none of the personality types were significantly correlated ($p > 0.05$) with their subjective evaluations. However, there was a weak, negative correlation between the agreeableness and emotional stability. Future research can investigate the effect of personality types on subjective evaluations of colour samples and immersive architectural environments and contextual objects.

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THE PERCEPTION OF TRAFFIC SIGNAL OPERATION

Mark Schier[1,2], Tony Bergen[2]

[1] School of Health Science, Swinburne University of Technology, Melbourne, Australia

[2] Steve Jenkins and Associates, Melbourne, Australia

Correspondence: mschier@swin.edu.au

Incandescent traffic signals have been replaced by LED traffic signals in recent times largely because of their capital and running costs. Although LEDs can effectively switch on or off instantaneously, the LED drivers can sometimes take several power line cycles to activate before the LEDs emit light. This is illustrated in Figure 1.

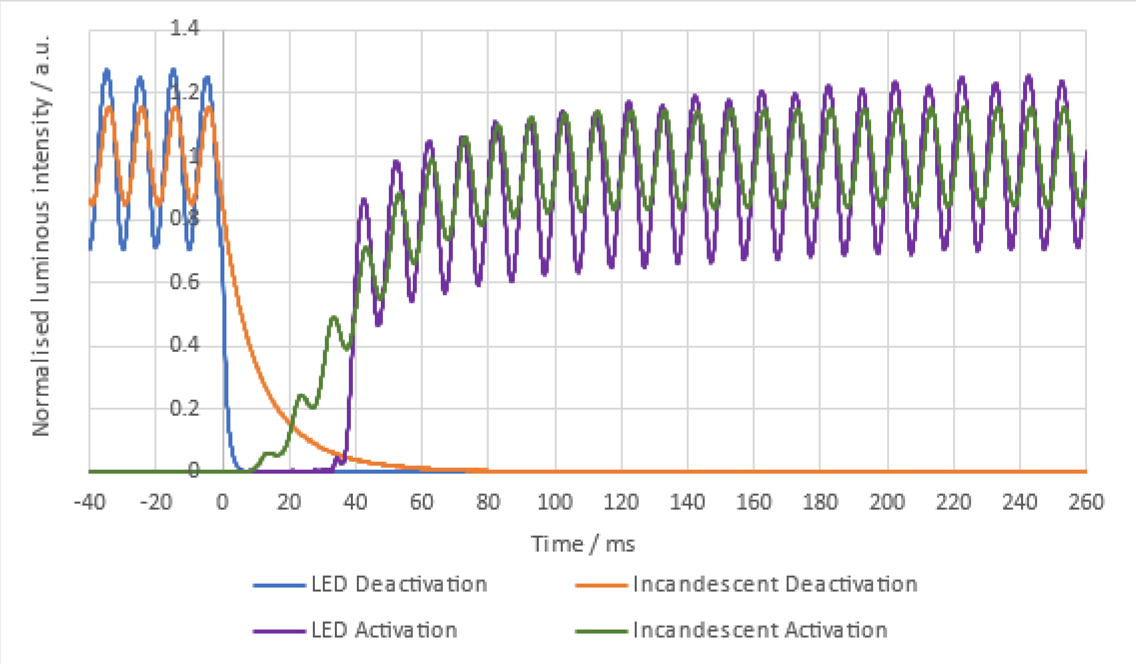

Figure 1: Example activation and deactivation profiles of LED vs incandescent traffic signals, showing that there can be a time for the LED signal colour transition where no signal is visible.

The Australian standard for traffic signal lanterns, AS 2144, was most recently revised in 2014, which was before all of the properties of LED devices were well known. One aspect of the existing standard is the affordance of a gradual activation time for the lamps. This was largely due to the inertia of the incandescent lamp filament warming up and is potentially largely redundant with the LEDs. The changeover time inherent in the standard could create some perceived gaps in the change from red-green or from green-yellow-red.

We designed a psychophysical experiment to determine optimum gap times between the colour changeover so that gap was not noticeable or less noticeable and thereby not creating a discomfort for a driver approaching an intersection. The experiment was implemented using PsychoPy software (a specialist Python environment for perceptual work https://www.psychopy.org) and we are ready to begin pilot recordings with the authors. Once the pilot is complete, we will finalise application for human experimentation ethics approval ahead of a larger pool of participants.

The results will help inform revisions of the Australian standard.

PILOT STUDY OF RELATIVE CONSPICUITY OF CYCLING VESTS UNDER FOUR ENVIRONMENTAL LIGHTING CONDITIONS

Mei Ying Boon[1,2], Emily Langley[2], Nina Kolhatkar [2], Byoung Sun Chu[2,3], Stephen Dain[2], Soufiane Boufos[2], Maitreyee Roy[2]

[1] University of Canberra, Bruce, Australia

[2] University of New South Wales, Sydney, Australia

[3] Catholic University of Daegu, Daegu, Korea

Correspondence: MeiYing.Boon@Canberra.edu.au

Aim: Cycling vests may be useful visibility aids to increase conspicuity of cyclists. Cyclists may use standard high visibility vests made of high visibility fluorescent materials with reflective material that meet relevant standards. Alternatively, other cycling vests are on the market that have LED lights incorporated in lieu of fluorescent and reflective materials. The purpose of this study was to determine whether cycling vests might offer similar conspicuity to high visibility vests under different environmental lighting conditions.

Methods: A repeated measures study design was conducted to compare reaction time to observe the on-road location of cycling vests (left or right side of a driving lane) by 2 observers seated in a stationary car in a real traffic environment of an open air rooftop concrete car park under 4 lighting conditions of daylight, twilight and night with low beam and high beam head lights. Each cycling vest configuration was presented 5 times and the average of the 5 presentations was the estimate of the reaction time for that vest. The cycling vest configurations were front and back of a high visibility vest, front and back of commercially produced cycling vests incorporating LED lights (none, static and flashing white on the front and red on the back) on the vests.

Results: The pilot study suggested that the yellow commercial vest had shorter reaction times than the red commercial vest, and had equal reaction times to an Australian Standard Vest during the daytime. Colour did not have an effect under any other environmental lighting conditions. Static and flashing LED lights marginally improved reaction time under low-beam headlights at night. Lighting condition did not significantly affect reaction time to the cycling vest configurations assessed.

Conclusions: Pilot results indicated that the research should continue with a larger sample size and include an option of plain black clothing and plain black clothing without any vest.

ABSTRACTS

Session 3

Clinical applications

THE SPECIFICATION OF COLOUR LIMITS IN LENSES OF EYE PROTECTION FOR USE WHEN COLOUR-CONTINGENT CLINICAL OBSERVATION ARE MADE

Stephen J. Dain[1], Jeffery K. Hovis[2], Annette K. Hoskin[3,4]

[1] School of Optometry and Vision Science, University of New South Wales, Sydney, New South Wales, Australia.

[2] School of Optometry and Vision Science, University of Waterloo, Waterloo, Ontario, Canada.

[3] Save Sight Institute, Discipline of Ophthalmology, Sydney Medical School, The University of Sydney, Sydney, New South Wales, Australia.

[4] Lions Eye Institute, The University of Western Australia, Perth. Australia.

Correspondence: s.dain@unsw.edu.au

Objective: To investigate if colour limitations, using traffic signal detection criteria, in eye and face protection standards are sufficient to avoid significant restrictions in colour-contingent clinical decisions. If not, to propose a requirement that will ensure appropriate products.

Methods: Examples of yellow-tinted eye protectors complying with the lightest category of sunglare eye protector [1-3], blue-blocking lenses and lightly tinted filters were assessed by considering effects on colour rendering, in effect placing the lens over the light source rather than the eyes. The CIE [4] and Crawford [5-7] methods were used since both have been used in studies of lighting for clinical observation. The more recent CIE method [8] has yet to be used in any study of lighting for clinical observation study, recommendation or standard.

Results: Yellow-tinted eye protectors and many tinted filters cause significant noncompliance with hospital lighting recommendations and standards; however general eye protection standards do not exclude these lenses. The standard for eye protection against intense light sources, in cosmetic and medical applications [9], does exclude lenses identified as affecting lighting colour significantly.

Conclusions: Any recommendation or standard for eye and face protection for persons making colour- contingent clinical decisions must include the requirement of ISO 12609-1 [9]. Persons making colour-contingent clinical decisions should be advised to use only untinted or neutral-coloured lenses

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OCCUPANT-CENTERED APPROACH TO ASSESSING LIGHTING CONDITIONS IN HOSPITAL PATIENT ROOMS

Ruth Genevieve Ong[1], Francisca Rodriguez[1], Veronica Garcia-Hansen[1], Oystein Tronstad[2], Sean Cain[3]

[1] Queensland University of Technology, Brisbane, Australia

[2] The Prince Charles Hospital Critical Care Research Group, Brisbane, Australia

[3] Monash University, Melbourne, Australia

Correspondence: ruthgenevieve.ong@hdr.qut.edu.au

Understanding how different people experience lighting is crucial to designing dynamic environments that meet user requirements for performance and well-being. Most studies performed in hospitals about occupant-centred responses to light have been conducted in workspaces and offices, with little attention given to patient rooms. Hospital lighting conditions are typically assessed using illuminance levels measured at floor or desk level [1-3]; this metric only focuses on enabling occupants to move safely and perform desk-based tasks. Nurses (excluding ICU nurses) are often on the move [4] and about 47% of their tasks are conducted in patient rooms [5]. Patients, meanwhile, spend much of their recovery period lying on the bed, subjecting them to visual discomfort and circadian disruption (due to ceiling-mounted electric lighting and limited access to natural light). Patient rooms require more comprehensive lighting assessment procedures to ensure the lighting can accommodate the varying needs of users (patients, family members and staff).

This exploratory study presents preliminary findings about various techniques and instruments [6-7] for collecting environmental lighting data from the user's perspective. The ICU simulation bay of a Brisbane tertiary hospital was the setting for this pilot study, with four lighting conditions measured from the perspectives of a 1) patient lying on a bed, and 2) a nurse standing next to the bed. Lighting metrics collected included melanopic and photopic illuminances, luminance distribution, and spectral data. Design interaction techniques (i.e., movement map) were also used to refine the instrument's positions [8]. The study outcomes are alternative procedures to capture naturalistic field data, which will inform the development of lighting strategies that respond to user requirements.

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CLINICAL OBSERVATION – THE NEGLECTED FACTOR IN HOSPITAL AND CLINICAL EXAMINATION LIGHTING?: A REVIEW

Stephen J. Dain[1]

[1] School of Optometry and Vision Science, University of New South Wales, Sydney, New South Wales, Australia.

Correspondence: s.dain@unsw.edu.au

Objective: To review the current priorities in the specification of hospital lighting

Methods: The standards and recommendations for hospital lighting were assembled, tabulated and examined for any reference to clinical examination as a criterion for the documents. The literature was searched on Medline and Web of Science using “hospital lighting” as a keyword. The topics used as a basis for recommendations were tabulated.

Results: Recommendations and standards are varied (Table 1)

Table 1 Summary of requirements and recommendations for lighting for clinical observation

	Year	Authority CCT limits	Color Rendering limits	
Medical Research Council [1]	1965	≈ 4000 K	Originally Crawford’s Category B. Redefined as CIE Ra ≥ 85 [2]	
AS 1765 [3]	1975	3200 –5500 K	CIE R_a and R_{13} ≥ 85 in the range 3200-3500 K rising to CIE R_a and R_{13} ≥ 95 at 5500 K	
Lovett et al [2, 4, 5]	1991	≈ 4000 K	CIE R_a ≥ 80	
ISO [6] (EN and BS EN are the same)	2013	3300 – 6700 K	CIE R_a ≥ 85	
AS/NZS1680.2.5 [7]	2018	3300 – 5300 K	General CIE R_a ≥ 80	Observation of Cyanosis COI ≤ 3.3
Light and Lighting Society of UK [8]	2019	≈ 4000 K	General CIE R_a ≥ 80	Surgical CIE R_a ≥ 90
ANSI/IES [9]	2020	4000 – 5000 K	Examination CIE R_a ≥ 80	Surgical CIE R_a ≥ 90

Only one [7] contains any basis for the requirements/requirements. It is some decades since any studies of lighting for clinical observation, particularly in the recognition of the colour-contingent factors in jaundice, cyanosis and erythema, have been carried out. The more modern papers on hospital lighting are based on the effects of lighting on circadian rhythms,(e.g. [10] sleep, feelings of well-being (e.g. [11] and visual amenity (e.g. [12], to the complete exclusion of consideration clinical examination. The most extensive study[1] precedes the adoption of the CIE method[13].

Conclusions: In recent years, clinical observation appears to have been neglected as a priority in hospital lighting. While the other factors that are taken into account are important, they are not life-threatening in the way that a misdiagnosis of patient colour has the potential to be. The old studies of lighting and clinical examination are worth revisiting and re-interpreting into modern lighting specification methods.

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ABSTRACTS

Session 4

Sky glow and road lighting

CIE Australia

ON THE MESOPIC PERFORMANCE OF ROADWAY LIGHTING SOURCES

Tony Bergen[1]

[1] Photometric Solutions International, Melbourne, Australia

Correspondence: tonyb@photometricsolutions.com

Historically, the Australian and New Zealand roadway lighting standard series AS/NZS 1158 have required the derating of high pressure sodium (HPS) lamps and low pressure sodium (LPS) lamps in order to account for their relatively poor visual performance at low lighting levels encountered in some low-level pedestrian lighting areas [1]. Derating involves reducing the luminous flux of the source by a given factor (25 % for HPS and 50 % for LPS) in these circumstances. Bergen [2] evaluated the performance of LED sources compared with the traditional white sources using the "mesopic enhancement factor" defined by the CIE [3].

In this presentation, the author will present the continuation of this research, which includes the evaluation of the mesopic performance of a variety of "traditional" sources and comparing them with the mesopic performance of amber and white LED sources ranging in correlated colour temperature from 1400 K to 7500 K (total 52 LED sources and 56 traditional sources evaluated).

Some results are shown graphically in Figure 1. The first conclusion is that the S/P ratio is the better predictor of mesopic performance than correlated colour temperature (R^2 = 0.9953 for a linear fit), and the second conclusion is that this correlation holds regardless of the technology type (i.e. across significantly different spectral compositions).

The third conclusion is that, for the low-level pedestrian lighting areas, amber LED sources should be derated the same as LPS sources, i.e. by 50 %, and amber white sources around 2200 K should be derated by 15 %.

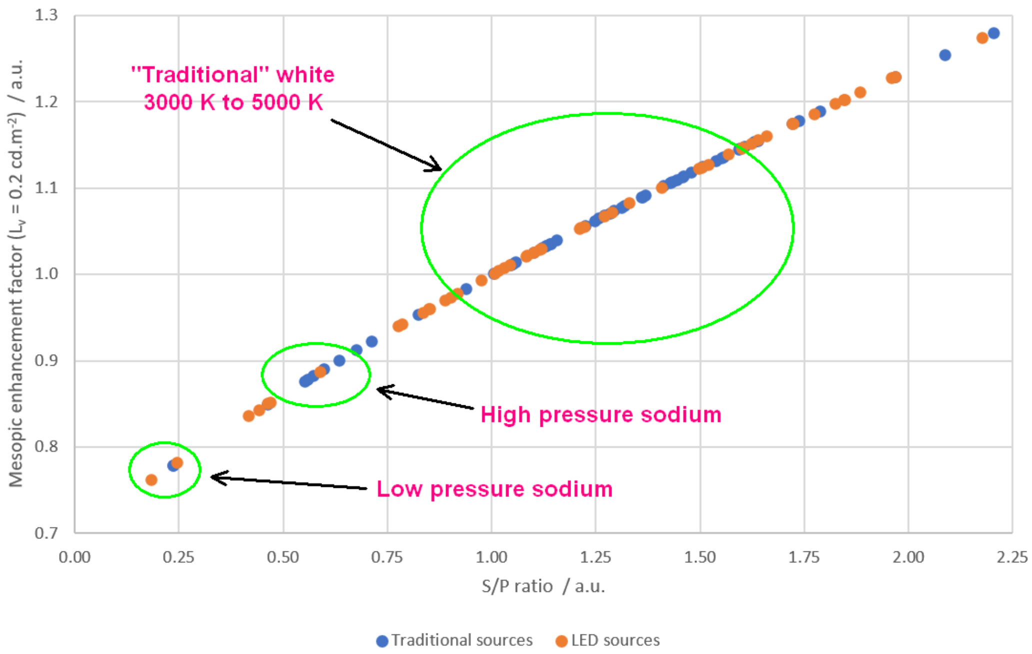

Figure 1: Graph showing the correlation between the S/P ratio of a source and its mesopic enhancement factor; highlighting the typical ranges of traditional light sources used in roadway lighting

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CHANGES IN SKY BRIGHTNESS THROUGHOUT THE NIGHT AND SEASONS

Adrian Cupitt[1]

[1] WAVES Testing, Research and Consulting, Brisbane, Australia

Correspondence: adrian@wavestrac.com.au

A Digital Single-Lens Reflex camera and fisheye lens were used to investigate the natural and human-influenced changes in sky brightness over the night and seasons. The visual magnitude of the zenith zone (0-30° altitude) was calculated for locations selected around Moreton Bay, Queensland.

The sky brightness at 'base' locations were chosen as they were separated from nearby artificial light. The results of the artificial light at night (ALAN) surveys demonstrated a change in sky brightness throughout the night of approximately 0.2 mag/arcsec^2 (between 20:00 and 02:30), with the darkest skies around midnight.

In developed areas, the natural sky brightness cycle is impacted by human activity. The contributions of temporary lighting and maintained lighting were isolated during the analysis process. Temporary lighting includes vehicles, residential and commercial lighting, and maintained lighting includes streetlights, shop façades, unit block stairwells/common areas, and other sources which remain on throughout the night.

Figure 1 illustrates data recorded at Woorim, Bribie Island, which has a large retiree population. As restaurants and bars close and residents start going to bed, the impact of the temporary lighting can be seen to drop off from about 9:30 p.m.

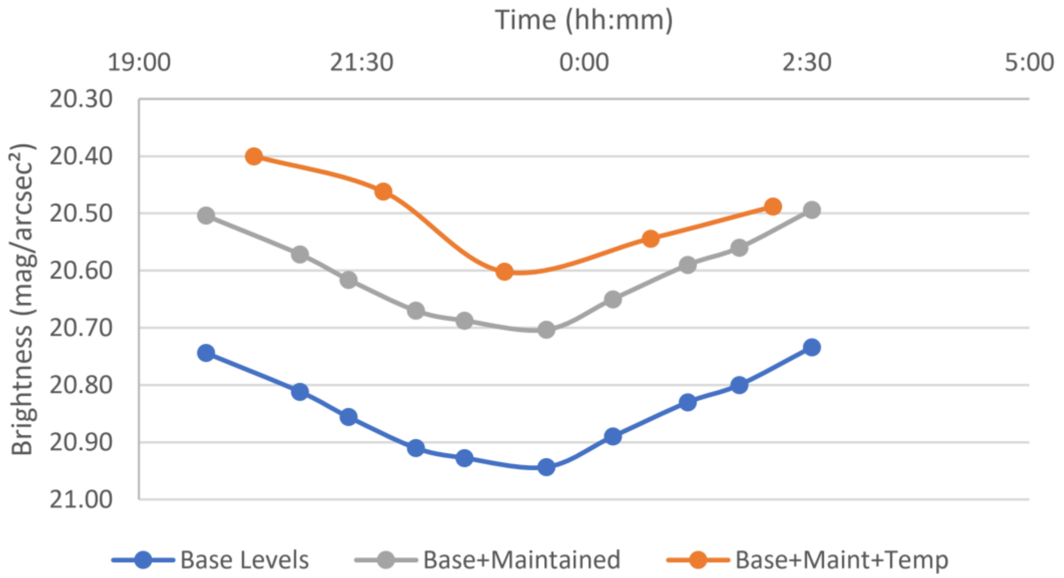

Figure 1: Change in sky brightness over the night, showing natural, maintained and temporary light levels.

The sky brightness at a reference location demonstrated a change in sky brightness throughout the year of approximately 0.4 mag/arcsec^2, with darkest skies in winter.

ASSESSING THE SENSITIVITY OF SKY GLOW MEASUREMENTS FOR EVALUATING THE ENVIRONMENTAL IMPACT OF NEW DEVELOPMENT

Gillian Isoardi[1], Steve Coyne[1]

[1] Light Naturally, Brisbane, Australia

Correspondence: gillian@lightnaturally.com.au

Whole-of-sky or large regional field-of-view measures of sky glow, including zenithal luminance, average all-sky luminance and luminance of the 360° banded region above the horizon; are being used to assess the impact of lighting from new developments on sensitive receptors in nearby environments. In such cases, sky luminance may be reported with a single regional value, using the (logarithmic-scaled) measurement quantity of Visual Magnitude, V_{mag}, with the unit, magnitudes per square arcsecond.

This paper presents an analysis of the application of these large, regional sky measures to the environmental impact assessment of artificial light at night arising from new development. The analysis uses real measurements of the night sky, with calculation-based projections of different development scenarios to evaluate the sensitivity of regional sky luminance and the visual magnitude scale for assessment of critical impacts of light on the natural environment. Also evaluated and presented are alternative assessment approaches that offer greater sensitivity in determining the impacts of light from new development.

ABSTRACTS

Session 5

Photobiology and blue light hazard

cie Australia

LIGHT EXPOSURE BEHAVIOUR ASSESSMENT (LEBA): **A NOVEL SELF-REPORTED INSTRUMENT TO CAPTURE LIGHT EXPOSURE-RELATED BEHAVIOUR**

Mushfiqul Anwar Siraji[1]**, Rafael Robert Lazar**[2, 3], Juliëtte van Duijnhoven[4, 5], Luc Schlangen[5, 6], Shamsul Haque[1], Vineetha Kalavally[7], Céline Vetter[8, 9], Gena Glickman[10], Karin Smolders[5, 6], & Manuel Spitschan[11, 12, 13, *]

[1] Monash University, Department of Psychology, Jeffrey Cheah School of Medicine and Health Sciences, Selangor, Malaysia

[2] Psychiatric Hospital of the University of Basel (UPK), Centre for Chronobiology, Basel, Switzerland

[3] University of Basel, Transfaculty Research Platform Molecular and Cognitive Neurosciences, Basel, Switzerland

[4] Eindhoven University of Technology, Department of the Built Environment, Building Lighting, Eindhoven, Netherlands

[5] Eindhoven University of Technology, Intelligent Lighting Institute, Eindhoven, Netherlands

[6] Eindhoven University of Technology, Department of Industrial Engineering and Innovation Sciences, Human-Technology Interaction, Eindhoven, Netherlands

[7] Monash University, Department of Electrical and Computer Systems Engineering, Selangor, Malaysia

[8] University of Colorado Boulder, Department of Integrative Physiology, Boulder, USA

[9] XIMES GmbH, Vienna, Austria

[10] Uniformed Services University of the Health Sciences, Department of Psychiatry, Bethesda, USA

[11] Max Planck Institute for Biological Cybernetics, Tübingen, Germany

[12] Technical University of Munich, Department of Sport and Health Sciences (TUM SG), Munich, Germany

[13] University of Oxford, Department of Experimental Psychology, Oxford, United Kingdom

Correspondence: manuel.spitschan@tuebingen.mpg.de, manuel.spitschan@tum.de

Light exposure is an important driver of health and well-being. Many aspects of light exposure are modulated by our behaviour. How these light-related behaviours can be shaped to optimise personal light exposure is currently unknown. Here, we present a novel, self-reported and psychometrically validated instrument to capture light exposure-related behaviour, the Light Exposure Behavior Assessment (LEBA).

An expert panel prepared the initial 48 item pool. Responses to these items were then collected in an online survey producing responses from an international sample (690 completed responses, 74 countries, 28 time zones). Exploratory factor analysis (EFA) on an initial subset of our sample (n=428) rendered a five-factor solution with 25 items (*Wearing blue light filters, spending time outdoors, using phone and smart-watch in bed, using light before bedtime, using light in the morning and during daytime*). In a confirmatory factor analysis (CFA) performed on an independent subset of participants (n=262), we removed two further items to attain the best fit for the five-factor solution (CFI=0.97, TLI=0.96, RMSEA=0.05, SRMR=0.09). The internal consistency reliability coefficient for the total instrument was McDonald's ω_t=0.73. Measurement model invariance analysis between native and non-native English speakers showed our model attained the highest level of invariance (residual invariance; CFI=0.95, TLI =0.95, RMSEA=0.05). Lastly, a short form of LEBA (n=18) was developed using Item Response Theory on the complete sample (n=690).

The psychometric properties of the LEBA instrument indicate the usability to measure the light exposure-related behaviours across a variety of settings and may offer a scalable solution to characterise light exposure-related behaviours in remote samples. The LEBA instrument will be available under the open-access CC-BY-NC-ND license.

Keywords: light exposure, light-related behaviour, non-visual effects of light, psychometrics

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EVALUATION OF THE SAFETY OF COMMERCIALLY AVAILABLE BLUE BLOCKING LENSES UNDER DIFFERENT BLUE LIGHT EXPOSURES

Hind Saeed Alzahrani[1,2], Sieu K. Khuu[1], Maitreyee Roy[1]

[1] School of Optometry and Vision Science, The University of New South Wales, Kensington, Sydney, NSW 2052, Australia

[2] Department of Physics, Taif University, Ta'if, Saudi Arabia

Correspondence: maitreyee.roy@unsw.edu.au

Background: A new generation of blue-blocking lenses (BBLs) are now commercially available and marketed under different brand names. However, their benefits in terms of protecting and regulating the circadian rhythm and cycle remains to be definitively established[1-3]. In this study to evaluate the potential benefits of BBLs, we measured the melanopic ratio and the protective effect of BBLs against retinal damage by natural and artificial light sources.

Methods: Seven different types of BBLs and untinted control lenses were evaluated. Blue-light irradiance and limited exposure duration for viewing different light sources were calculated based on ICNIRP guidelines. The melanopic irradiance effect of each BBL type was evaluated based on the CIE 026/E:2018 guidelines. Finally, a correlation test was conducted to determine if there is an association between the protective effect of BBLs and the natural circadian cycle.

Results: All BBL types significantly reduced the photochemical retinal damage if their use did not exceed the limited exposure duration. A significant positive correlation was found between the melanopic ratio and hazard ratio for all BBL types (r = 0.876 (+2.00D); r = 0.827 (plano); r = 0.918 (- 2.00D).

Conclusion: All BBL types significantly reduce the potential photochemical retinal damage. The natural circadian cycle can potentially be altered by the evening exposure to the artificial blue light of digital devices, but the same lens allows the natural rhythm of the circadian cycle in the case of natural, solar light exposure.

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UTILISING PHOTOMETRIC MEASUREMENTS TO ASCERTAIN POTENTIAL FOR BLUE LIGHT HAZARD RISK

Steve Coyne[1], Gillian Isoardi[1], Tony Bergen[2], David Boughey[3]

[1] Light Naturally, Brisbane, Australia

[2] Photometric Solutions International, Melbourne, Australia

[3] Department of Industry, Science, Energy and Resources, Canberra, Australia

Correspondence: steve@lightnaturally.com.au

The method for assessing the risk of blue light hazard from light sources is described in the international standard, CIE S 009 / IEC 62471 and involves measurements that are not straightforward to be undertaken with typical photometric laboratory equipment. Having analysed a database of 1,500 spectra of white light LED light sources, the concept of specifying maximum luminance limits based on CCT provides the opportunity to assess whether the blue light hazard weighted radiance low risk limit of ≤ 10,000 $W.m^{-2}.sr^{-1}$ is met based on photometric measurement quantities.

This presentation will describe the approach to setting the limits and propose test method alternatives with a discussion on the potential measurement accuracy and likely required tolerances for each. Such an approach has the potential to reduce the test burden for many white-light LED products where a full test to CIE S 009 / IEC 62471 is unnecessary, while still providing complete protection from blue light hazard by maintaining an assessment regime for all LED lighting products.

INFLUENCE OF DAYTIME SHORT-WAVELENGTH DOMINANT ELECTRIC LIGHT EXPOSURE ON HUMAN ALERTNESS AND HIGHER COGNITIVE FUNCTIONS: A CIE S026-BASED PILOT STUDY

Mushfiqul Anwar Siraji[1], Yi Jiau Saw[2], Alexandre Schaefer[3], Shamsul Haque[1], Vineetha Kalavally[2],

[1] Monash University, Department of Psychology, Jeffrey Cheah School of Medicine and Health Sciences, Selangor, Malaysia

[2] Monash University, Department of Electrical and Computer Systems Engineering, Selangor, Malaysia

[3] Sunway University, Malaysia, School of Medical and Life Sciences, Selangor, Malaysia

Correspondence: mushfiqul.anwarsiraji@monash.edu

We tested the effect of daytime short-wavelength dominant light exposure on alertness and higher cognitive functions among university students using spectrally tunable lights. Participants (n = 24; mean age ± SD = 23.96 ± 2.42 years; 8 Female) were randomized to a two-hour daytime exposure to one of three light conditions with photopic illuminance maintained at 285 ± 2 lx; measured at horizontal plane at 80 cm and 170 ± 10 lx measured at eye level vertical plane at 122 cm with three different melanopic daylight efficacy ratio (MDER) (High: 0.91 MDER, 164 lx MEDI, 6793 K CCT; Neutral: 0.63 MDER, 108 lx MEDI, 4248K CCT, Low: 0.45 MDER, 72 MEDI, 2592 K CCT).

Along with subjective measures of alertness, a robust cognitive battery including auditory psychomotor vigilance task (aPVT), N-back task, digit-span, and Tower of London were administered to measure attention and higher cognitive functions. A significant main effect of light exposure ($F(2,21) = 558$, $p = .01$, $\eta^2 = .35$.) on subjective alertness was observed where participants reported higher subjective alertness under high MDER light settings in comparison to neutral ($p = .02$) and low ($p = .04$) MEDI light settings. No main effect of light exposure was observed in the performance of aPVT, N-back task (accuracy, reaction time), Tower of London (efficiency, planning time, execution time), and digit span task (forward, backward and sequential).

These results demonstrate that exposure to high-MDER (short wavelength-enriched) light improves subjective alertness. However, further investigation is required to understand the possible influence of short-wavelength dominant light on higher cognitive functions.

Keywords: light exposure, non-visual effects of light, alertness, cognition