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

CIE Australia Lighting Research Conference 2024

Conference Programme

Tuesday, 30th January 2024
Melbourne Eyecare Clinic, The University of Melbourne
Building 260, 200 Berkeley Street, Carlton, Vic, 3053
Also online via Zoom

Version 2.0
Note: The programme is subject to change

CIE Australia

The Australian National Committee of
the International Commission on Illumination
www.cie.org.au

Registered as CIE Australia Inc.
Associations Registration No: A0022976Z
ABN: 32 301 390 692

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. For more information see: http://www.cie.co.at/.

The CIE is comprised of six scientific Divisions which carry out its technical work:

Division 1: Vision and Colour
Australian Division Member: Wenye Hu

Division 2: Physical Measurement of Light and Radiation
Australian Division Member: Tony Bergen

Division 3: Interior Environment and Lighting Design
Australian Division Member: Veronica Garcia Hansen

Division 4: Transportation and Exterior Applications
Australian Division Member: Adrian Cupitt
Alternate Division Member: Gillian Isoardi

Division 6: Photobiology and Photochemistry
Australian Division Member: Urbain du Plessis

Division 8: Image Technology
Australian Division Member: *<vacant>*

Founded in 1948, originally as the Australian National Commission on Illumination (ANCI), CIE Australia is the Australian National Committee of the CIE, which represents the interests of the CIE in Australia and represents the interests of Australia in the CIE. For more information see: http://www.cie.org.au/.

CIE Australia National Committee Executive:

- President: Tony Bergen
- Vice President: Steve Coyne
- Treasurer: Eric Southgate
- Secretary: Gillian Isoardi
- IT Officer: Adrian Cupitt
- Executive officers without portfolio: Wenye Hu, Maitreyee Roy

CIE Australia Lighting Research Conference 2024 Scientific Committee:

- Tony Bergen (Chair)
- Steve Jenkins
- Andrew Metha

CIE Australia Lighting Research Conference 2024 Local Organising Committee:

- Luisa Interdonato
- Andrew Metha
- Tony Bergen

Any mention of organisations or products in this programme or by the speakers does not imply endorsement by the CIE or by CIE Australia.

PROGRAMME

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

08:30	**Registration**		
08:50	**Zoom meeting opens**		
09:00	**Welcome, housekeeping, introduction**		
09:10	**Keynote address 1**		
	Emma Woolliams	UK	Satellite observations of a changing climate: How radiometric measurements from space help society respond
09:40	**Session 1: Measurement**		
	Guillaume Dotreppe	Belgium	Modelling near-field illuminance: The influence of the LID fit
	Tony Bergen	Australia	Application of cone fundamentals to everyday photometry
	Vineetha Kalavally	Malaysia	Accurate daylight prediction for an integrative light simulator (ILIS)
	Question and answer session		
10:40	**Morning tea**		
11:10	**Session 2: Perception and Preferences**		
	Georgios Triantafyllidis	Denmark	EEG-based comparison of lighting perception in real and virtual environments
	Dario Maccheroni	Italy	Visual experience of artworks: Results of a study campaign on a 2D and a 3D masterpiece at the National Museum of San Matteo in Pisa, Italy
	Crispin Rock	Australia	Chromaticity preferences for dimming white LED lighting – variations in CCT
	Jumanah Alawadhi	USA	Perceptual and cognitive responses to chromatic light and background music
	Mark Schier	Australia	Detection threshold of traffic signal changes
	Question and answer session		
12:50	**Lunch**		
13:50	**Keynote address 2**		
	Andrew Metha	Australia	The power of seeing: New waves in watching the structure and function of individual cells in living human eyes
14:20	**Session 3: Hazards and Risks**		
	Naser Shehab	USA	The effect of colored ambient and display lighting on risk taking
	Matt Glanville	Australia	Modelling solar reflections off modern building facades
	Hind Saeed Alzahrani	Saudi Arabia	Blue light exposure from dental examination lamps across age groups: Risk assessment
	Question and answer session		
15:20	**Afternoon tea**		
	Workshop		
15:50	Steve Coyne, Gillian Isoardi	Australia	Understanding LED performance: Evidence-based approaches to supporting stakeholders of energy efficient lighting programs
16:20	**Session 4: Germicidal UV Applications**		
	Simon A Joosten	Australia	Comparing the effectiveness of germicidal ultraviolet radiation to high efficiency particulate air filtration using a bacteriophage bioaerosol model
	Robert Gangi	Australia	Multispectral photocatalyctic disinfection system design
	Urbain du Plessis	Australia	Standardised photocatalyctic disinfection efficacy measurement
	Question and answer session		
17:20	**Voting on "Best Presentation", concluding comments** **Close**		
17:30	**Laboratory tour**		
18:30	**Conference dinner**		

Note: The programme is subject to change.

Keynote Address 1

Dr Emma Woolliams

National Physical Laboratory, London, UK

Dr Emma Woolliams graduated from Imperial College London in 1998 and has worked at the National Physical Laboratory since then. Her PhD was on the establishment of the UK's primary spectral irradiance scale.

In her early career, she worked as a laboratory metrologist specialising in radiometry and thermometry, and conducting international comparisons to ensure SI consistency. This naturally led to work on radiometric satellite sensors – first for pre-flight calibrations, then for ways of calibrating satellites in orbit. She was the lead metrologist on several projects that, for the first time, established rigorous methods for determining and validating uncertainties in satellite sensors post-launch.

Having established a successful team of scientists who focus on applying metrology approaches to a wide range of radiometric sensors, Emma has now switched her focus to radar satellites. She is also chair of the European Metrology Network for Climate and Ocean Observation.

SATELLITE OBSERVATIONS OF A CHANGING CLIMATE: HOW RADIOMETRIC MEASUREMENTS FROM SPACE HELP SOCIETY RESPOND

Emma Woolliams[1]

[1] National Physical Laboratory, London, UK

Correspondence: emma.woolliams@npl.co.uk

This presentation will provide an overview of how satellite measurements are providing society with the essential information needed to mitigate and adapt to a changing climate and the role that metrology, the science of measurement, has in ensuring that society can have confidence in that data. It will show how observations are used to understand the Earth system through the carbon and water cycles and measures of the Earth energy balance, as well as through detailed measurements of individual processes.

The presentation will cover a wide range of missions and techniques, but focus predominantly on optical radiometric missions and will also introduce TRUTHS, a climate-focused satellite mission led by the UK Space Agency with international partners and delivered by the European Space Agency. This mission will make a ten-fold improvement in how we can observe and quantify climate change through its own direct measurements of the sun’s energy and how that is scattered, reflected and absorbed by the Earth. TRUTHS will also provide a ‘gold standard’ reference data set that can be used to calibrate and improve the performance of other satellites.

Keynote Address 2

Dr Andrew Metha

Department of Optometry and Vision Sciences
University of Melbourne

Associate Professor Andrew Metha is currently Head of the Department of Optometry and Vision Sciences at the University of Melbourne, where he teaches with a research-focus into all levels of its Doctor of Optometry course. Andrew holds therapeutically-endorsed optometry registration but is mostly active as a collaborative and eclectic vision scientist.

After gaining expertise in psychophysical methods to understand visual processes during his PhD, he branched into single-cell electrophysiological recordings in primate and other mammalian primary visual cortex to investigate the neurological bases of adaptation phenomena and brain plasticity. Most recently his laboratories use Adaptive Optics (AO) to image cellular-level structure and function in living human and animal eyes, including unique ways of visualising and quantifying the flow of single red and white blood cells through living capillary networks.

He joined the University of Melbourne in 2000 after serving postdoctoral positions in Canada (McGill Vision Research, Montreal), the University of Rochester’s Centre for Visual Science (NY, USA) and the Psychobiology Laboratory in Canberra's ANU.

With this diverse range of exposure and experience, Andrew brings a multi-disciplinary approach to bear on the questions: ‘How do we see?’; and ‘How can we improve vision when it goes awry’.

THE POWER OF SEEING: NEW WAVES IN WATCHING THE STRUCTURE AND FUNCTION OF INDIVIDUAL CELLS IN LIVING HUMAN EYES

Andrew Metha[1]

[1] University of Melbourne, Melbourne, Australia

Correspondence: ametha@unimelb.edu.au

Herman Von Helmholtz built the first device to look inside the eye, the ophthalmoscope, in 1851. The ability to peer inside the eye has bought about enormous benefits in understanding basic physiology as well as what goes awry in disease states. The succeeding century has bought about technological developments that have enabled us to go beyond merely seeing the structure of retinal elements to recording both the minute structure and function of different cell types within the eye.

This talk will outline those developments going from using various light sources including lasers and super luminescent diodes, harnessing their various coherence properties, measuring and shaping optical wave fronts to enable visualisation of single cell detail at temporal resolutions – all in an effort to continue making discoveries of how we see.

ABSTRACTS

Session 1

Measurement

MODELLING NEAR-FIELD ILLUMINANCE: THE INFLUENCE OF THE LID FIT

GM Dotreppe[1,2], P Van Den Bossche[1,2,3], VA Jacobs[1,3]

[1] MERLIN at Mobility, Logistics and Automotive Technology Research Centre, Department of Electrical Engineering and Energy Technology, Vrije Universiteit Brussel, Brussels, Belgium

[2] Department of Engineering Sciences and Technology, Vrije Universiteit Brussel, Brussels, Belgium

[3] Flander's Make, Heverlee, Belgium

Correspondence: guillaume.mario.dotreppe@vub.be

A recent study has demonstrated that the illuminance generated by an extended light source can be effectively characterised through the discretisation of the luminous surface of the source. This approach assumes a uniformly distributed $cos^n(\alpha_s)$ luminance over a flat luminous surface, resulting in a $cos^{n+1}(\alpha_s)$ luminous intensity distribution (LID), where $n+1$ relates to the full width at half maximum (FWHM) and α_s represents the emission angle from the photometric centre of the source. The model's accuracy was validated through ray tracing simulations and direct illuminance measurements across a diverse range of angles and distances.

The discretisation model is employed for the assessment of the Limiting Photometric Distance (LPD) and its angular variation. Different models can be used to represent the LID of a narrow-beam source. Four of those are derived through a non-linear least square fitting to measured data, as detailed in Table 1. While each model presents small differences for the illuminance computed in the far-field, substantial disparities are observed in the near-field. These disparities result in the different LPD profiles, sometimes difficult to interpret and explain (see Figure 1). This presentation will show the larger differences arising in the near-field for small changes in the far-field LID models.

The origin of the large discrepancies and the resulting LPD profiles is still unknown, but under investigation. Nevertheless, we believe that for a broad comprehension and compatibility with existing research, the utilisation of the simpler cos^{n+1} model is advised.

Table 1. Different LID models used. The goodness of fit is assessed using Bergen's fitting index f_{fit} [1] and the R^2 is used to assess the degree of congruence between numerical model outcomes and reference data.

Model	Equation	f_{fit}	R^2
Cosine	$I = I_0 \cos^{n+1} \alpha_s$	96.9815	0.9853
Sum of 2 cosines	$I = I_{01} \cos^{n_1+1}(\alpha_s) + I_{02} \cos^{n_2+1}(\alpha_s)$	99.7607	1
Gaussian	$I = I_0 * e^{-\left(\frac{\alpha_s-\alpha_0}{\sigma}\right)^2}$	97.3051	0.9964
Sum of 2 Gaussians	$I = I_{01} * e^{-\left(\frac{\alpha_s-\alpha_{01}}{\sigma_1}\right)^2} + I_{02} * e^{-\left(\frac{\alpha_s-\alpha_{02}}{\sigma_2}\right)^2}$	99.7916	1

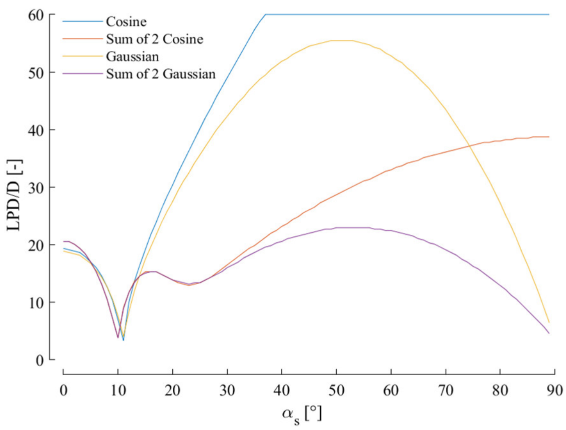

Figure 1: Comparison between the LPD obtain using different LID models for an LED with narrow-beam optics.

References:

[1] Bergen A. A practical method of comparing luminous intensity distributions. *Lighting Research and Technology* 2012; 44(1): 27–36.

APPLICATION OF CONE FUNDAMENTALS TO EVERYDAY PHOTOMETRY

Tony Bergen[1]

[1] Australian Photometry and Radiometry Laboratory, Melbourne, Australia

Correspondence: tony@aprlab.com.au

In 2024 we will celebrate 100 years since the publication of the spectral luminous efficiency function for photopic vision, $V(\lambda)$, adopted by the CIE as the function that links the photometric and radiometric systems. Other than for some specialised applications, all photometers are designed to have a spectral responsivity that matches the $V(\lambda)$ function. However, it is also well known that $V(\lambda)$ is not a perfect match to human vision, and in particular it underestimates the visual response in the blue region.

Two key CIE technical reports [1][2] describe the human perception of colour in physiological terms, taking into account the spectral response of the long-wave (L-), medium-wave (M-) and short-wave (S-) sensitive cones and correcting for the spectral absorbance of the other parts of the eye that transmit the light before it reaches the cones. These are referred to as "cone fundamentals". In particular, the second publication includes a cone-fundamental-based spectral luminous efficiency function, $V_F(\lambda)$, which is a more accurate match to human vision than the $V(\lambda)$ function.

However, the situation is more complicated than simply redefining photometry in terms of the $V_F(\lambda)$ function. By definition, the luminous flux of sources determined when applying the $V_F(\lambda)$ function will differ from the luminous flux determined when applying the $V(\lambda)$ function as shown in Figure 1. Also, requiring a change of photometer design to match the $V_F(\lambda)$ function would potentially result in a worldwide upheaval taking a generation to transition!

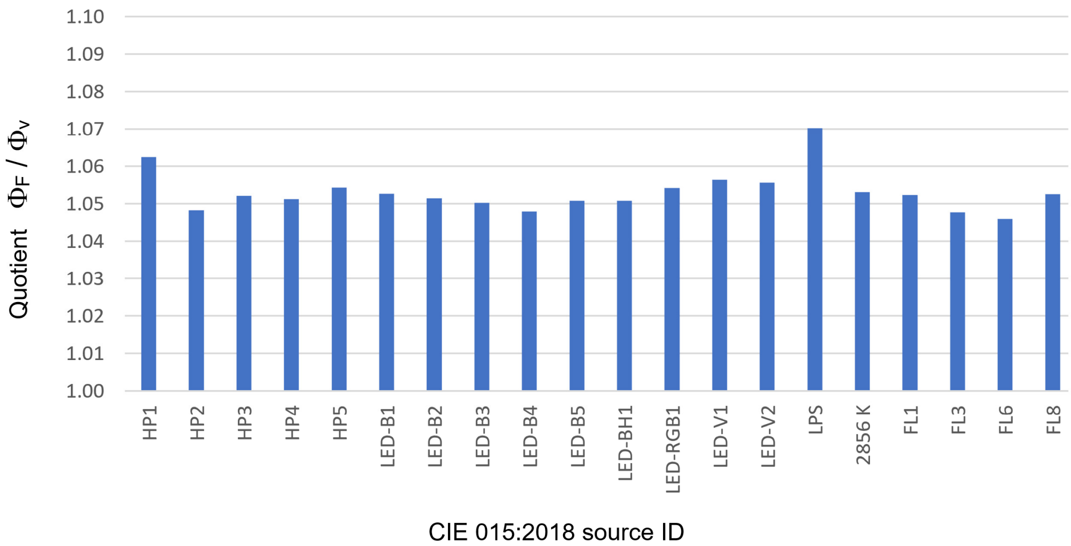

Figure 1: Quotient of the luminous flux of a variety of sample source types under a cone-fundamental-based photometric observer $V_F(\lambda)$ to the luminous flux under the CIE standard photometric observer $V(\lambda)$.

Furthermore, the $V_F(\lambda)$ function is still just a single function, whereas human vision has a large diversity in parameters such as the age of the observer, the field of view, photopigment type, and life factors.

This presentation will summarise the history of these CIE photometric observers and outline some of the issues faced in shifting to cone-fundamental-based photometry.

References:

[1] CIE 170-1:2006, Fundamental Chromaticity Diagram with Physiological Axes — Part 1

[2] CIE 170-2:2015, Fundamental Chromaticity Diagram with Physiological Axes — Part 2: Spectral Luminous Efficiency Functions and Chromaticity Diagrams

cie Australia

ACCURATE DAYLIGHT PREDICTION FOR AN INTEGRATIVE LIGHT SIMULATOR (ILIS)

Lim Jiun Ann[1], Khong Yin Jou[1], **Vineetha Kalavally**[1]

[1] Department of Electrical and Computer Systems Engineering, School of Engineering and Intelligent Lighting Laboratory, Monash University Malaysia.

Correspondence: vineetha@monash.edu

Introduction

While the world of lighting is focused on energy savings using LED retrofits, smart lights of the future must also consider how best to harness natural daylight to integrate visual comfort with non-visual benefits from lighting in a built environment [1]. There is ample evidence to show that exposure to poorly designed indoor lighting can raise the possibility of developing circadian rhythm sleep-wake disorders, which occurs due to a discrepancy between the body's natural circadian rhythms and external light-dark patterns [2, 3]. However, if daylight is coupled with artificial lighting, then in addition to achieving energy savings, indoor lighting can be implemented with minimal to zero adverse outcomes and can even enhance sleep, emotional state, and overall health of occupants [2]. Therefore, including accurate daylight prediction in the implementation of an integrative light simulator is an effective approach and the first step to designing smart lighting control of spectrally tuneable lamps that promote energy-efficiency and human wellbeing. This paper proposes an integrative light simulator with the ability to utilize photometric inputs from weather data to accurately predict illuminance and spectral distribution from daylight in a built environment.

Method

The integrative light simulator was designed and tested in a Python environment with lighting simulations performed using Radiance with ray-tracing features in Honeybee [4]. Daylight simulation was then performed using the Honeybee Point-In-Time Grid-Based (PITGrid) model yielding the internal daylight illuminance of each of a range of sensor grids at a specific time. A python script retrieves the current weather data by calling the API from OpenWeather and utilizes the "pvlib" library [5]. The simulated predictions are validated using real measurements from an IOT-integrated mini spectral sensor (SPECCY). Simulated daylight illuminance levels can be employed in a machine learning model to predict the spectral power density (SPD) of daylight in indoor spaces. This method paves the way for a highly accurate control over the SPD of lighting in a room including both daylight and artificial light to harness the benefits proven in laboratory scale medical research through an integrative lighting simulator (ILIS).

Results

A sky model was employed to replicate illuminance values for each sensor grid. The comparison between the simulated and measured daylight illuminances, as depicted in Figure 1, demonstrates a strong agreement. This substantiates the validity of employing such a predictive model for simulating indoor lighting in windowed rooms alongside artificial lighting.

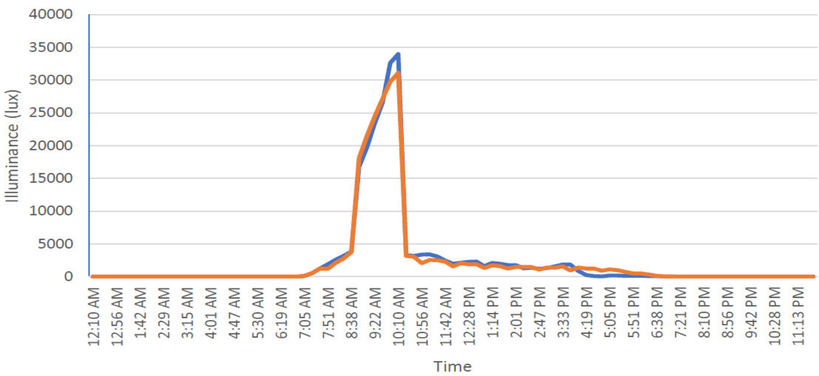

Figure 1: Validation of simulated illuminance (orange plot) against measured illuminance (blue plot)

The model also shows good correlation between measured and predicted spectral distributions and other properties such as Melanopic Equivalent Daylight Illuminance (MEDI), and Correlated Colour Temperature (CCT).

References

[1] P. R. Boyce, "The impact of light in buildings on human health," Indoor and Built environment, vol. 19, no. 1, pp. 8-20, 2010, doi: https://doi.org/10.1177/1420326X09358028.

[2] C. Blume, C. Garbazza, and M. Spitschan, "Effects of light on human circadian rhythms, sleep and mood," Somnologie, vol. 23, no. 3, p. 147, 2019, doi: https://doi.org/10.1007%2Fs11818-019-00215-x.

[3] R. G. Foster, "Sleep, circadian rhythms and health," Interface Focus, vol. 10, no. 3, p. 20190098, 2020, doi: https://doi.org/10.1098/rsfs.2019.0098.

[4] Ladybug Tools. "Honeybee Radiance Documentation." Honeybee Radiance Documentation, Version 2.1, 2023, pp. 1-50. Available: https://www.ladybug.tools/honeybee-radiance/docs/.

[5] Pvlib/pvlib-python: A set of documented functions for simulating the performance of Photovoltaic Energy Systems., GitHub. Available at: https://github.com/pvlib/pvlib-python

ABSTRACTS

Session 2

Perception and Preferences

EEG-BASED COMPARISON OF LIGHTING PERCEPTION IN REAL AND VIRTUAL ENVIRONMENTS

Gabriele Zocchi[1], Petros Kitstantas[1], **Georgios Triantafyllidis[1]**

[1] Lighting Design Lab, Aalborg University Copenhagen, Denmark

Correspondence and Presenting: gt@create.aau.dk

Introduction

This study is using electroencephalogram (EEG) to investigate the differences in perception of lighting in real and virtual environments. EEG tests were used to measure brain activity based on brain signal wave analysis to get insights on the emotional and physiological state. Comparing real and virtual environment EEG results aimed to validate VR's ability to mimic emotional responses and enhance realism. Understanding lighting impact, and emotions in real and virtual settings is essential for emphasizing VR's role in eliciting emotional responses similar to real-life experiences.

Methodology

Overall, the methodology employs EEG data analysis [1], to research the differences in the related brain activity, experienced in two different environments: real environment and virtual environment simulating the same lighting [2]. Fifteen users participated while their brain activity was continuously measured using an EEG device. The experiment included four stages in an office space, first in a real environment and then in a virtual environment: i) Experience daylight, ii) Experience daylight and electrical lighting, iii) Performing activity in daylight and, iv) Performing activity in daylight and electrical lighting. Focus has been given to changes in alpha, beta, and gamma brain waves from the EEG signals, since these are directly associated with emotional states: A reduction in gamma waves is to be considered an increase in valence, while a reduction in alpha or beta low waves is linked to an increase in arousal. The arousal-valence model [3] of emotions organizes emotions based on their level of arousal (how calm or agitated you feel) and valence (whether positive or negative). Through EEG-based identification of one's position on the arousal-valence model, a better understanding of emotions and an enhancement of emotional and bodily awareness can be achieved.

Results

Findings indicate that there is a strong positive correlation in the two environments (real and virtual environment) for alpha and beta-low waves (which are related to arousal) in every tested lighting condition. On the contrary, gamma waves (related to valence) observed wider fluctuations and sometime opposite behaviour.

References

[1] Hill A, Triantafyllidis G. "Evaluation of emotions induced by biophilic lighting patterns using EEG and qualitative methods", in Proceedings of the 30th Session of the CIE. Bind Volume 1: Part 2. Ljubljana, Slovenia: CIE. 2023

[2] Chamilothori, K., Wienold, J., Andersen, M.; "Adequacy of Immersive Virtual Reality for the Perception of Daylit Spaces: Comparison of Real and Virtual Environments", LEUKOS, 2019, Vol. 15, Issue 2-3, pp. 203-226.

[3] Garg, N., Garg, R., Anand, A., Baths, V., "Decoding the neural signatures of valence and arousal from portable EEG headset", Frontiers in Human Neuroscience, 2022, Vol. 16.

VISUAL EXPERIENCE OF ARTWORKS: RESULTS OF A STUDY CAMPAIGN ON A 2D AND A 3D MASTERPIECE AT THE NATIONAL MUSEUM OF SAN MATTEO IN PISA (ITALY)

D.Maccheroni[1,2], F.Leccese[1], G.Salvadori[1], F.Feltrin[3]

[1] University of Pisa, Pisa, Italy

[2] Zumtobel Lighting GmbH, Dornbirn, Austria

[3] Nulty+, London, UK

Correspondence: dario.maccheroni@zumtobelgroup.com

BACKGROUND. Light is one of the main factors affecting the visual experience of artworks in museums and can determine the success or failure of an art exhibition. The lighting design is not yet extensively recognized as a crucial element of museum exhibitions, but recent research studies show how different lighting arrangements can create different impressions of the artworks and affect the visual experience of museum visitors.

RESEARCH AIM. The aim was to investigate how the lighting design of exhibitions can affect the visual experience of visitors and, consequently, their appreciation of the displayed artworks, in the exact location where they are exhibited inside the museum. The study consisted in designing and evaluating various lighting configurations for two masterpieces: a 14th Century painted panel (Figure 1a) and a 15th Century marble sculpture (Figure 1b), exhibited at the National Museum of San Matteo in Pisa (Italy)

METHOD. Each art piece was evaluated under 4 different lighting configurations (using different luminaire types), with the aim of creating different lighting contrast ratios (luminance and illuminance) between the analysed artwork and its background. Those lighting arrangements were presented to different groups of observers in order to investigate the trends of personal preference.

RESULTS. The results of the surveys pointed out that, on average, the observers preferred lighting arrangements that provide a certain level of contrast, while configurations with high contrast or almost no contrast were evaluated as less pleasant, less interesting and less suitable to enhance the artworks.

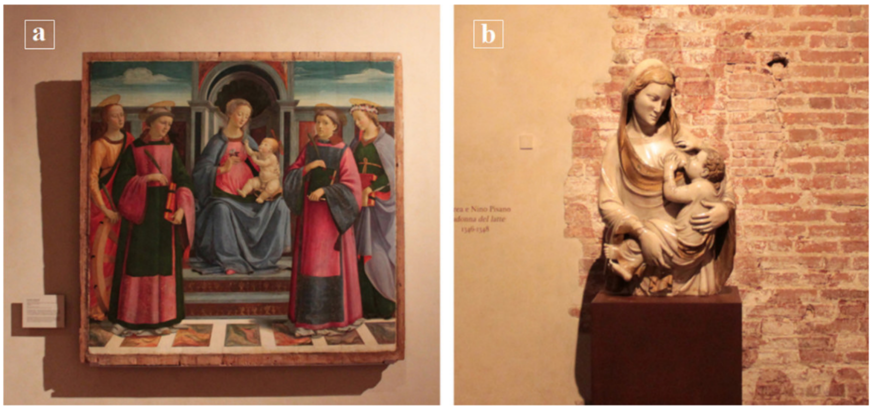

Figure 1 - Pictures of the two selected artworks as they are currently displayed at the National Museum of San Matteo.

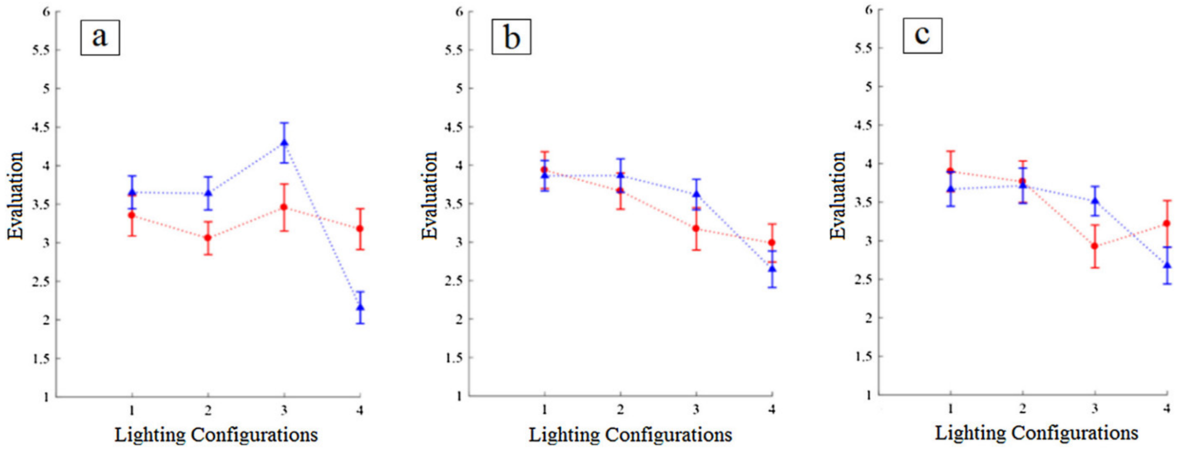

Figure 2 - Plotted results for painting (red) and sculpture (blue) experiment: 'Contrast perception' (a), 'Enhancement of the Artwork' (b), 'Personal Preference' (c). The Evaluation on the y-axis is a preference where a higher number indicates a higher preference.

CHROMATICITY PEFERENCES FOR DIMMING WHITE LED LIGHTING – VARIATIONS IN CCT

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

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

Correspondence: croc5716@uni.sydney.edu.au

When a white LED light is dimmed, there is usually no significant shift in correlated colour temperature (CCT) as happens when an incandescent lamp is dimmed – the LED predominantly just emits less light. To simulate the dimming of an incandescent lamp that lighting designers use to create different moods, some manufacturers have made lamps with both warm white and orange LEDs. As the light is dimmed, the ratio of the output of the LEDs changes to create the familiar feeling of warmth of a dimmed incandescent lamp.

A psycho-physical experiment using multi-channel LED luminaires has been conducted to identify CCT preferences and evaluate perceptions of naturalness when white light is dimmed and the CCT changes. Thirty participants rated "preference" and "naturalness" for dynamic lighting conditions with varying shifts in CCT in both the lower and higher directions as the light dims. Conditions included shifts in chromaticity of delta *u'v'* of 0.04 and 0.08 (in CIE 1976 *u'v'* diagram) along the Plankian locus as well as with no shift in CCT. By comparison, the shift in chromaticity of a tungsten lamp when dimmed from full to its lowest level is about 0.08.

The dynamic lighting conditions were controlled automatically via a computer program and then repeated with the participant controlling the condition with a rotary dimmer controller. The experiment was repeated to incorporate both "home/relaxing" and "office/work" scenarios.

Data analysis included a hypothesis test – "When lighting is dimmed, constant CCT is preferable to a change in CCT." This hypothesis was not rejected for most conditions except where there was a shift (delta u'v' = 0.04) to a warmer CCT in the "home/relaxing" scenario.

PERCEPTUAL AND COGNITIVE RESPONSES TO CHROMATIC LIGHT AND BACKGROUND MUSIC

Jumanah Alawadhi[1], Dorukalp Durmus[2]

[1] Pennsylvania State University, State College, PA, USA.

Correspondence: jsa5540@psu.edu

While both music and lighting have been separately studied for their psychological effects [1-3], limited research has explored their combined influence on human perception and cognition. This study aims to bridge the gap by investigating how music paired with chromatic lighting might interact to shape perceptual and cognitive responses. The primary objective is to (1) determine whether light alone has a significant impact on perceptual and cognitive responses, and (2) whether the presence of music further influences these responses.

The experiment consists of six lighting conditions: three with music and three without music. Participants are randomly assigned to either the music or no-music condition in a between-subjects design. Lighting conditions are generated using a commercially available multi-color LED system to provide similar brightness at the eye level to mitigate the Hunt effect [4]. In each group, participants are exposed to three chromatic lighting conditions (white, blue, and red) for three minutes per colour condition (nine minutes total for three conditions) while engaging in various tasks that require perceptual and cognitive processing. Participants' responses are collected using objective measures, such as accuracy and reaction times to cognitive tests, and subjective self-report measures (mood, alertness, and subjective evaluations of the physical environment) are completed using a rating scale [5]. The findings of this study will contribute to our understanding of the impact of light and music on perceptual and cognitive responses.

Understanding these interactions could have applications in areas such as immersive experiences, therapeutic environments, and entertainment design.

References

[1] Knez, I. (1995). Effects of indoor lighting on mood and cognition. Journal of environmental psychology, 15(1), 39-51.

[2] Ahmad, N., & Rana, A. (2015). Impact of music on mood: Empirical investigation. Research on Humanities and Social Sciences. ISSN (Paper), 2224-5766.

[3] Collier, J. M., Wilkerson, A., Durmus, D., & Rodriguez-Feo Bermudez, E. (2023). Studying Response to Light in Offices: A Literature Review and Pilot Study. Buildings, 13(2), 471.

[4] Hunt, R. W. G. (1952). Light and dark adaptation and the perception of color. JOSA, 42(3), 190-199.

[5] Royer, M., Houser, K., Durmus, D., Esposito, T., & Wei, M. (2022). Recommended methods for conducting human factors experiments on the subjective evaluation of colour rendition. Lighting Research & Technology, 54(3), 199-236.

DETECTION THRESHOLD OF TRAFFIC SIGNAL CHANGES

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

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

[2] Australian Photometry and Radiometry Laboratory, Melbourne, Australia

Correspondence: mschier@aprlab.com.au

Traffic signals using incandescent lamps have been replaced by LED signals in recent times, largely because of their costs both capital and running. 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 can cause a time gap between one signal switching off and another signal switching on.

The Australian standard for traffic signals, AS 2144, is in the process of being updated. 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 the gap was either not noticeable or not of a sufficient duration to cause 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). The experiment has been run with 22 participants and studied both the shortest gap between changes in signal colours that could be detected, as well as the shortest gap between changes in signal colours that may cause a concern for drivers. The results so far indicate a detection time ranging from 80 ms to 200 ms, and a “concern” time typically ranging from 500 ms to 900 ms.

ABSTRACTS

Session 3

Hazards and Risks

THE EFFECT OF COLORED AMBIENT AND DISPLAY LIGHTING ON RISK TAKING

Naser Shehab[1], Dorukalp Durmus[1]

[1]The Pennsylvania State University, State College, PA, USA.

Correspondence: nss5507@psu.edu

Lighting can impact cognitive functions, emotional states, and visual perception [1-3]. However, its influence on risk-taking behaviors has not been previously investigated. Given the ubiquity of electric lighting in indoor and outdoor settings, understanding its potential effects on decision-making is crucial. This study aims to explore whether chromatic lighting conditions can influence individuals' propensity for risk-taking.

In a psychophysical experiment, participants were asked to complete subjective surveys and an objective risk-taking task shown on a display under different ambient chromatic lighting conditions. A total of ten test conditions were generated and shown to participants. Stimuli consisted of combinations of three screen (red, green, blue) and three ambient lighting conditions (red, green, blue), plus one nominal white light. Six Philips Hue bulbs provided ambient lighting in an office that has no daylight access. Screen chromaticity was adjusted using the built-in color management settings of a laptop connected to a secondary display. Photometric and colorimetric values were measured, and brightness was matched at the eye level to reduce bias [4]. To assess participants risk taking behaviour, a balloon analogue risk task (BART) [5] was used. The number of pumps, number of explosions, completion time, and subjective questionnaire results were recorded. Results indicate that chromatic lighting, especially the opponent color contrast between ambient and display lighting, can influence risk taking behavior, as shown in Figure 1.

The findings of this study can have broad implications for safety and decision-making in environments where electric lighting plays a crucial role. The insights gained from investigating the relationship between lighting chromaticity and decision-making behaviors could inform industries, such as transportation, security, entertainment, and urban planning.

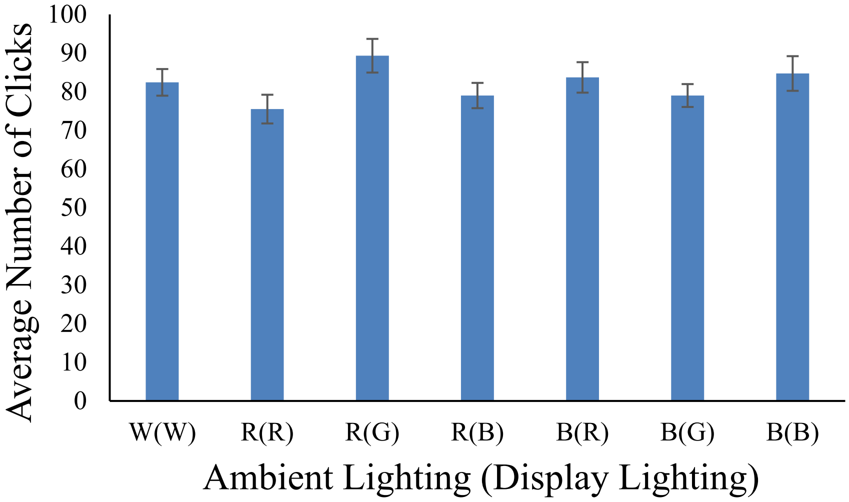

Figure 1: Number of clicks in BART under different ambient and display lighting conditions. Error bars represent the standard error of the mean.

References

[1] Shishegar, N., & Boubekri, M. (2022). Lighting up living spaces to improve mood and cognitive performance in older adults. Journal of Environmental Psychology, 82, 101845.

[2] Kong, Z., Liu, Q., Li, X., Hou, K., & Xing, Q. (2022). Indoor lighting effects on subjective impressions and mood states: A critical review. Building and Environment, 109591.

[3] Durmus, D., & Davis, W. (2017). Object color naturalness and attractiveness with spectrally optimized illumination. Optics express, 25(11), 12839-12850.

[4] Royer, M., Houser, K., Durmus, D., Esposito, T., & Wei, M. (2022). Recommended methods for conducting human factors experiments on the subjective evaluation of colour rendition. Lighting Research & Technology, 54(3), 199-236.

[5] Lejuez, C. W., Read, J. P., Kahler, C. W., Richards, J. B., Ramsey, S. E., Stuart, G. L., ... & Brown, R. A. (2002). Evaluation of a behavioral measure of risk taking: the Balloon Analogue Risk Task (BART). Journal of Experimental Psychology: Applied, 8(2), 75.

MODELLING SOLAR REFLECTIONS OFF MODERN BUILDING FACADES

M.J. Glanville[1], M. Alsailani[2], P.R. Kodali[1], R.P.M. Neto[1]

[1] CPP Pty Ltd, Sydney, Australia

[2] CPP Inc, Fort Collins, USA

Correspondence: mglanville@cppwind.com

Buildings can be examined during concept design to identify potential for sunlight to reflect off exterior cladding surfaces and create disability glare hazard onto surrounding roadways. Historically most assessment methodologies such as Hassall [1] calculate Holladay veiling luminance L_v at receiver locations assuming specular type reflections.

Modern facades are increasingly adopting metal sheet cladding products displaying both specular and highly diffuse reflective properties. In-house software has been developed based on an open-source ray tracing engine, RADIANCE, to perform solar reflection calculations off a range of surface finishes with flat to complex curvatures. The program generates view-based luminance renderings at specific locations and views which could impact road users. Subsequently, a custom script evaluates the renderings and determine the annual glare metrics. Potential ocular impacts are assessed as a function of both retinal irradiance and subtended source angles by adapting photovoltaic installation criteria by Ho [2].

Threshold increment (TI) quantifies reduction in contrast of the retinal image due to glare and is an established lighting metric used in the scotopic to mesopic range of background luminance. Published contrast thresholds e.g., Blackwell [3] and examination of the Weber-Fechner Law suggest the same TI criteria might be extended into the lower photopic range to assess traffic hazard at low background luminance settings such as dawn/dusk and shadowed locations.

A case study is reviewed where façade solar reflections flagged during early design as a traffic glare dosage risk were successfully mitigated by replacing glazing with a metal screen product, Figure 1.

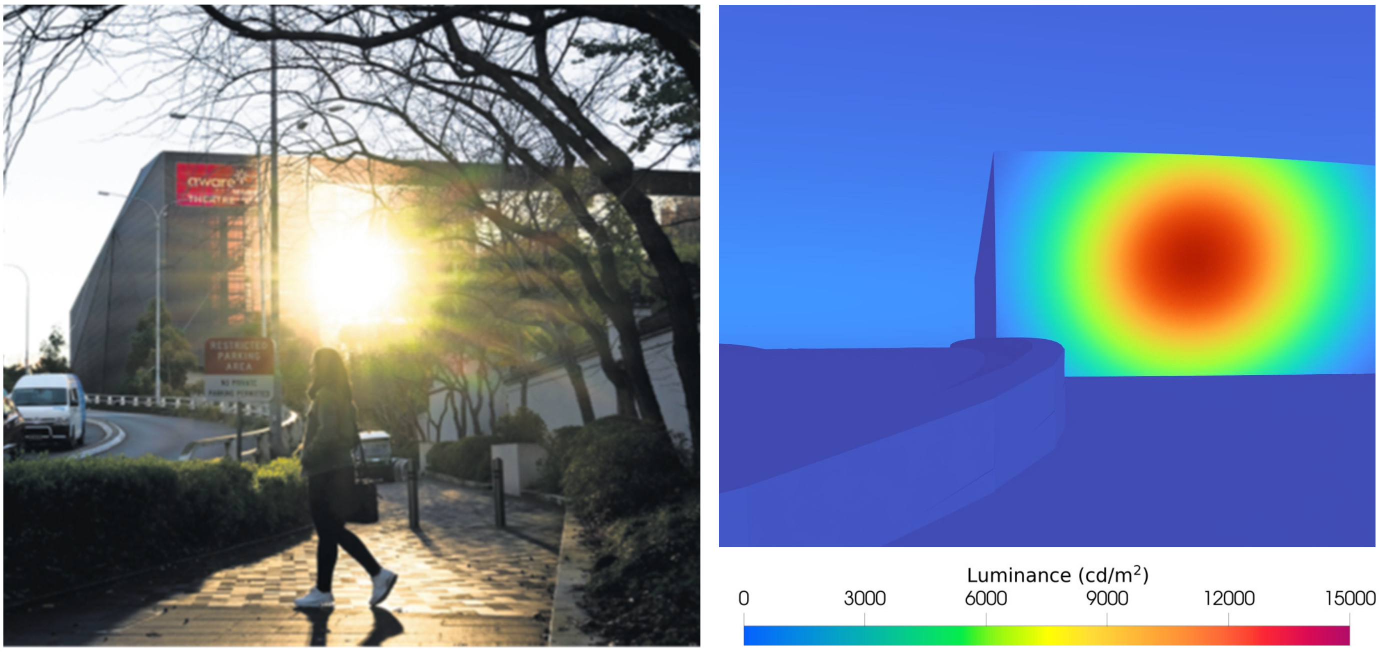

Figure 1: Winter solstice morning solar reflection off facade glazing - photograph courtesy Sydney Morning Herald (Left), Simulated luminance arriving at the viewing position (Right).

References

[1] D.N.H. Hassall, Reflectivity Dealing with Rogue Solar Reflections, Faculty of Architecture, University of New South Wales, 1991.

[2] C.K. Ho, C.M. Ghanbari and R.B. Diver, Methodology to Assess Potential Glint and Glare Hazards from Concentrating Solar Power Plants: Analytical Models and Experimental Validation, Journal of Solar Energy Engineering-Transactions of the ASME, 133(3), 2011.

[3] H. R. Blackwell, Contrast Thresholds of the Human Eye, Journal of the Optical Society of America, Vol 36 No. 11, 1946.

BLUE LIGHT EXPOSURE FROM DENTAL EXAMINATION LAMPS ACROSS AGE GROUPS: RISK ASSESSMENT.

Hind Saeed Alzahrani[1]

[1] Physics Department, Collage of science, Taif University, P.O. Box 11099, Taif 21944, Saudi Arabia

Correspondence: dodia3@hotmail.com

Background. In dental clinics, during surgical procedures or clinical examinations, medical teams rely on medical examination lights to enhance concentration and visual acuity. However, a recent study on dental LED headlamps recorded that extensive exposure to high-intensity light is a likely health hazard [1]. As the discrepancy in transmittance among observers of different ages is significant in short-wavelength light [2], the aim of this study was to further seek to investigate the impact of such lamps on ocular health across various age groups.

Methods. A Hopoocolour OHSP350S spectrometer was used to measure the spectrum irradiance of 17 different types of dental examination lamps (DELs) produced by 17 different companies. For direct viewing at a distance of 30 cm and indirect viewing at distances of 30 cm, 50 cm, and 100 cm, the blue weighted radiances (LB) were calculated. The computation of the maximum daily exposure length (tmax) was limited to direct light viewing for individuals aged 1 to 70 years.

Result. The peak blue spectral radiances of LED-based DELs range from 440 to 450 nm. It is safe to see any of the tested DELs indirectly. Based on DEL properties and light transmission through the human eye at various ages, the direct viewing LB values were found to range from 3 to 483 W.m-2.sr-1. Luna has the longest tmax value, with the lowest mean blue light radiance of 0.09 ± 0.05. With the greatest mean blue light radiance of 4.75 ± 3.41, SKEMA 6 had the shortest tmax value.

Conclusion. Cumulative direct light viewing causes less retinal tissue damage as people age from 1 to 70. The reduction in damage to the retinal tissue increases with mean blue light brightness. Decisions about avoiding blue light were influenced by the computation of maximum tolerable ocular exposure limits for DELs and ages.

References

[1] Price, R.B., et al., The potential ‘blue light hazard’ from LED headlamps. Journal of Dentistry, 2022. 125: p. 104226. https://doi.org/10.1016/j.jdent.2022.104226

[2] Lund, D., et al. A computerized approach to transmission and absorption characteristics of the human eye. in CIE. 2012.

ABSTRACTS

Workshop

Understanding LED performance: Evidence-based approaches to supporting stakeholders of energy efficient lighting programs

UNDERSTANDING LED PERFORMANCE: EVIDENCE-BASED APPROACHES TO SUPPORTING STAKEHOLDERS OF ENERGY EFFICIENT LIGHTING PROGRAMS

Steve Coyne[1], Gillian Isoardi[1]

[1] Light Naturally, Brisbane, Australia

Correspondence: steve@lightnaturally.com.au

As LED technology has matured to dominate the lighting product market, the need for information that provides understanding of LED product performance has escalated. Assessing advances in product performance is centred on the ability to evaluate both existing products (benchmarking) and evaluating ongoing, innovative product research and development (streamlined product testing and predicting performance trends).

The International Energy Agency, Energy Efficient End-use Equipment, Solid State Lighting (IEA 4E SSL) Annex takes an evidence-based approach to understanding LED product performance. Using comprehensive market data from registries, surveys, real product testing and by initiating leading edge research; the SSL Annex provides support to governments looking to implement energy efficient policies in lighting. Key to this activity, is the development of recommendations on parametric limits for product performance and research into test methods that reduce the time and cost burden for government, industry and consumers.

This workshop highlights several activities that exemplify evidence-based approaches to LED product analysis. This begins with benchmarking results that provide a snapshot of product performance in precise markets and provide a basis for the prediction of future trends. Such benchmarking data show notable difference between claimed and tested data variation between regulated and unregulated markets. Further discussion includes the application and limitations of product data available through a range of publicly accessible databases and product registers. This analysis highlights the value of different policy instruments in different lighting markets and, in some situations, the influence of external economic factors.

The ongoing efforts of the SSL Annex activities aim to ensure that energy efficient lighting policy is driven by real data that accurately reflects a rapidly changing market.

ABSTRACTS

Session 4

Germicidal UV Applications

COMPARING THE EFFECTIVENESS OF GERMICIDAL ULTRAVIOLET RADIATION TO HIGH EFFICIENCY PARTICULATE AIR FILTRATION USING A BACTERIOPHAGE BIOAEROSOL MODEL

Shane A Landry[1], Dinesh Subedi[1], Jeremy J Barr[1], Isabelle Magnin-Bougma[1], **Simon A Joosten[1]**

[1] Monash University, Melbourne, Australia

Correspondence: simon.joosten@monash.edu

Purpose/Objective:

We aimed to use our previously established model of bioaerosol (bacteriophage ϕx174) to assess the relative effectiveness of:

1. Germicidal ultraviolet (GUV) radiation
   a. 254nm upper room source
2. High efficiency particulate air (HEPA) filtration

To extract/inactivate ϕx174 bioaerosol in a simulated virus exposure experimental design.

Material/Methods:

We nebulized 9mL of 10^8 CFU/mL of ϕx174 into a sealed simulated clinical room of dimensions 4.0m x 3.25m x 2.3m size. The nebulization process lasted 30mins during which time aerosol was mixed using two pedestal fans.

Bioaerosol samples were taken using 37mm cassettes (SKC Inc., Eighty Four, PA, USA) with 1.0µm polytetraflouroethylene filters attached to GilAir-5 (Sensidyne Industrial Health and Safety Instrumentation, St-Petersburg, FL, USA) sampling pump calibrated to run at 3L/min and using Sartorius Gelatin Filters attached to a Sartorius AirPort MD8 pump (Sartorius AG, Gottingen, Germany) calibrated to run at 50L/min. Both samplers were run for 30mins during nebulization and at 10min intervals for 40-60mins (depending on protocol) during the sampling phase.

3 separate conditions were run twice, in randomized order over 6 separate trial days. Control (no mitigation), GUV and HEPA filter.

The GUV device used was 254nm “upper room” UV device. The HEPA device used was IQAir Healthpro 250 (IQAir, Goldach, Switzerland) set to run at 470m^3/hr.

Results:

In the current setup, the HEPA filter appeared superior to GUV at time points T10, T30, T40 see Figure 1.

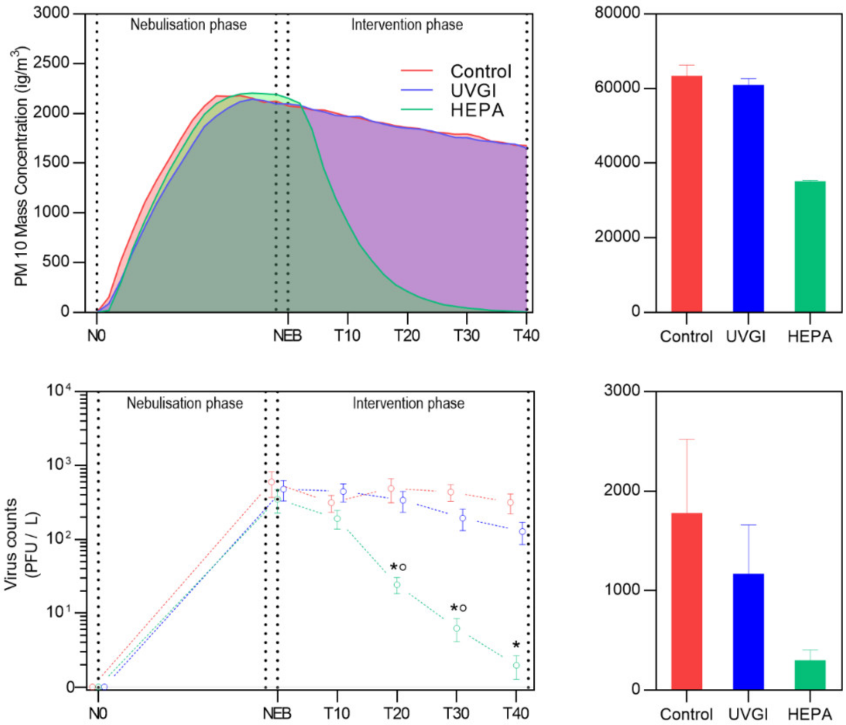

Figure 1: Virus counts (plaque forming units) per condition. Panels to the left show compiled data across 6 experimental runs at each time point in 10minute increments. Panels to the right demonstrate cumulative values (addition of values at all time points). Note the unit values are the same moving left to right. Abbreviations: PM: particle mass, PFU: plaque forming units, UVGI: ultra-violet germicidal irradiation, HEPA: high efficiency particulate air filter.

Discussion:

HEPA at 470m^3/hr appeared superior to the 254nm light source and superior to control at time points T20 and T30.

MULTISPECTRAL PHOTOCATALYCTIC DISINFECTION SYSTEM DESIGN

Urbain du Plessis[1], **Robert Gangi[2]**

[1] Virtual & Illumination Engineering Services, Melbourne, Australia

[2] Lindo Pty Ltd, Melbourne, Australia

Correspondence: urbain@advies.com.au

Photocatalytic oxidation (PCO) based disinfection of air and water is a well-known process that has been in practical use for decades. The COVID pandemic brought a new level of interest to PCO in multiple markets and fields of application.

The authors' companies are engaged in the design, production, and sales of PCO systems, their customers are predominantly in healthcare, aviation, and defence.

In the course of developing PCO disinfection products it became clear to the authors that matching the system to the application is vital to delivering useful and valuable outcomes.

The authors would present a case study on how their collaborative work evolved the initial PCO system concepts of each contributing party into a single system. This novel integration capable delivering more value across multiple domains at lower cost.

The specific project also yielded multiple patents [1].

Figure 1. Active elements of a multi-function PCO disinfection concept demonstrator, created late 2023 for a series of international heath-tech, aviation and defence conferences.

At the time of submitting this abstract the authors expect to utilise the demonstrator and associated air quality sensor system as part of the oral presentation, and to discuss how a wholistic design approach improved the overall environmental impact of disinfection practices.

References

[1] AU patent 2023903193 Ventilator with UV disinfection and AU patent 202303194 Integrated cabin light and ventilation

STANDARDISED PHOTOCATALYCTIC DISINFECTION EFFICACY MEASUREMENT

Urbain du Plessis[1], Robert Gangi[2]

[1] Virtual & Illumination Engineering Services, Melbourne, Australia

[2] Lindo Pty Ltd, Melbourne, Australia

Correspondence: urbain@advies.com.au

Photocatalytic oxidation (PCO) based disinfection of air and water is a well-known process that has been in practical use for decades. The COVID pandemic brought a new level of interest to PCO in multiple markets and fields of application.

When it comes to defining the performance of a PCO disinfection system there is very little standardisation, and equally little literature that provide clear metrics.

One of the few independent research efforts [1] into the performance of commercial products has found: "*Testing identified numerous issues related to the accuracy of claimed Germicidal UV product performance. Claims were often untestable, contradictory, ambiguous, or used incorrect units and/or terminology.*"

Another paper [2] based on the review of 320 UV-C disinfection related papers states "*Most papers evaluated bacteria immediately following irradiation and so it is unclear how effective 222-nm UVC may be in long-term sterilization of surgical sites. Additionally, literature surrounding germicidal efficacy in human wounds was scarce and literature in human surgical sites was not discovered by the author at the time of the search*."

The authors' companies are engaged in the design, production, and sales of PCO systems, their customers in healthcare, aviation and defence require trustworthy metrics on the performance of PCO system in their specific applications. The authors have engaged university laboratories [3] to perform performance testing but it quickly became obvious that their experimental design is not well suited to produce metrics that may be used to compare different light sources, and or the performance of specific light sources on different pathogens.

To overcome the challenges, we have designed a standardised test unit that will enable systematic PCO performance measurement.

Key features of the test device include:

- Exclusion of all external light.
- Exclusion of all external / uncontrolled air.
- Full temperature & humidity control.
- Standardised light-source to growth-medium distance
- Capacity to accommodate various light sources with a wide range of spectra and radiation intensities.
- Capacity to accommodate a wide range of airborne, liquid or growth-medium cultured test pathogens.
- Easy integration with automated environmental control systems, metrology hardware.
- Compact, low-cost design facilitating running multiple configurations simultaneously.

The authors aim to create a reference library that will provide clear and trustworthy data on the following:

- Disinfection rate for specific pathogens for various spectra at a specific common radiation intensity and exposure time.
- Disinfection rate for specific pathogens for specific spectra at a range of radiation intensities at a specific exposure time.
- Disinfection rate for specific pathogens for specific spectra at a specific radiation intensity over a range of exposure times.

The test device can also be modified (to a limited extent) to test products. The presentation will include a table-top example of an experimental set-up. At the time of submitting this abstract the authors expect to have the first set standardised tests complete or at least in progress.

References

[1] Jason Tuenge, Gabe Arnold, Margaret Axelson, and Jianchuan Tan. Pacific Northwest National Laboratory. Radiometric Testing of Germicidal UV Products, Round 1: UV-C Towers and Whole-Room Luminaires. September 2023

[2] Alexis Panzures, 222-nm UVC light as a skin-safe solution to antimicrobial resistance in acute hospital settings with a particular focus on methicillin-resistant Staphylococcus aureus and surgical site infections: a review, Journal of Applied Microbiology, Volume 134, Issue 3, March 2023, lxad046

[3] We are currently negotiating permission to disclose, it will be available before Jan 2024

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

Lighting the Future Together

Australia