International Conference

Shaping light for health and wellbeing in cities

Light also shapes urban spaces and social life, thus influencing people's behaviour, moods, and sense of security, as well as social relationships, easing or hampering socialisation and participation in civic life.

WWW.ENLIGHTENME-PROJECT.EU

International Conference proceedings
Shaping light for health and wellbeing in cities

ISBN 9788854970823
DOI 10.6092/UNIBO/AMSACTA/6863

This work is licensed under the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.
To view a copy of this license, visit http://creativecommons.org/licenses/by-nc-sa/4.0/

Editors:
Elisa Conticelli, Giulia Marzani, Simona Tondelli
Alma Mater Studiorum, University of Bologna, Italy

ENLIGHTENme links:

www.enlightenme-project.eu

You Tube ENLIGHTENme Projet channel

Graphic design by PMopenlab srls
Pictures and photos in the conference proceedings by their respective authors.

This e-book reflects the author's views; the programme authorities are not liable for any use that may be made of the information contained therein.

Table of Contents

Project Partners

Denmark	Gate21
Estonia	Tartu City Tartu Ulikool
France	LUCI Association
Germany	EURICE – European Research and Project Office GmbH ICLEI European Secretariat Gmbh (Iclei Europasekretariat Gmbh)
Italy	Alma Mater Studiorum - Università Di Bologna Azienda Unita' Sanitaria Locale Di Bologna Comune Di Bologna Fondazione per L'innovazione Urbana Health City Institute Neri Spa Oengineering Srl
Spain	Fundación Tecnalia Research & Innovation
Sweden	Uppsala Universitet
The Netherlands	Chrono@Work Bv Gemeente Amsterdam Stichting Vu
United Kingdom	London School of Economics and Political Science Lumie University of Surrey
USA	Icahn School of Medicine at Mount Sinai

INNOVATIVE POLICIES FOR IMPROVING CITIZENS' HEALTH AND WELLBEING ADDRESSING INDOOR AND OUTDOOR LIGHTING

What is ENLIGHTENme?

With a growing world population and rising urbanisation comes an underestimated by-product: more human exposure to electric light. This includes public outdoor lighting and the artificial glow created by highly urbanised areas, but also light exposure at the individual level from interior lighting in buildings and light-emitting screens. Inappropriate and disruptive light exposure at night, or too little light exposure during the day, profoundly affects people's biological clock, health and wellbeing. Older adults over 65 years of age are particularly prone to these impacts. Knowledge about the role lighting has on people's health and new responsive guidance for urban lighting strategies have the potential to substantially mitigate any possible impacts.

ENLIGHTENme brings together experts from different scientific fields and sectors, such as urban development and health research for four years to collect evidence about indoor and outdoor lighting impacts on human health and wellbeing – particularly for people over the age of 65 and other vulnerable groups. The project aims to research, develop and validate innovative solutions that will guide innovative urban lighting policies for better health in cities throughout Europe.

The ENLIGHTENme project aims to advance the understanding of how indoor and outdoor lighting affects health and wellbeing, particularly in elderly populations. It will develop innovative, evidence-based guidelines and policies for measures, technologies, and interventions that can be implemented with a dedicated Decision Support System to help both citizens and city leaders improve public health and wellbeing.

Applying a transdisciplinary approach, ENLIGHTENme examines the correlations between health, wellbeing, lighting and socio-economic factors, using a population-based medical trial and qualitative field work in three European cities: Bologna (Italy), Amsterdam (The Netherlands) and Tartu (Estonia). It combines expertise from various fields and thematic areas, including clinical and biomedical sciences, ethics and Responsible Research & Innovation (RRI), urban planning and architecture, data accessibility and interoperability, as well as social sciences and economics.

An 'Urban Lighting and Health Atlas' will anchor the research scope by collecting, systematising, and presenting existing data and good practices on urban lighting in a user-friendly online platform. In addition to the population-based medical trials, Urban Lighting Labs will be established in each ENLIGHTENme City to provide a place-based co-creation space to engage with citizens and city leaders to learn about co-design, and assess lighting interventions that can impact health and wellbeing. The interventions and findings from both research applications will be reviewed and validated by three advisory boards (Scientific Advisory Board, Health and Urban Lighting Advisory Board and Board of Lighting Companies), and will serve as the empirical foundation for better guidance and decision-making for improved public health and wellbeing. The practical tools developed by ENLIGHTENme will allow for identifying priorities in urban lighting design according to local population needs, inequalities and light exposure levels as well as comparing the impacts of different lighting scenarios and defining the technical requirements for innovative urban lighting policies for better health and wellbeing.

www.enlightenme-project.eu

Scientific Committee

Simona Tondelli - UNIBO

Elisa Conticelli - UNIBO

Giulia Marzani - UNIBO

Valerio Carelli - UNIBO

Jose Luis Izkara - TECNALIA

Aitziber Egusquiza - TECNALIA

Don Slater - LSE

Elettra Bordonaro - LSE

Toomas Haller - UTARTU

Meike Bartels - VUA

Isabelle Corten - LUCI

Mark Burton-Page - LUCI

Mirko Ancillotti - UPPSALA UNIVERSITET

Deborah Mascalzoni - UPPSALA UNIVERSITET

Ciara Staunton - UPPSALA UNIVERSITET

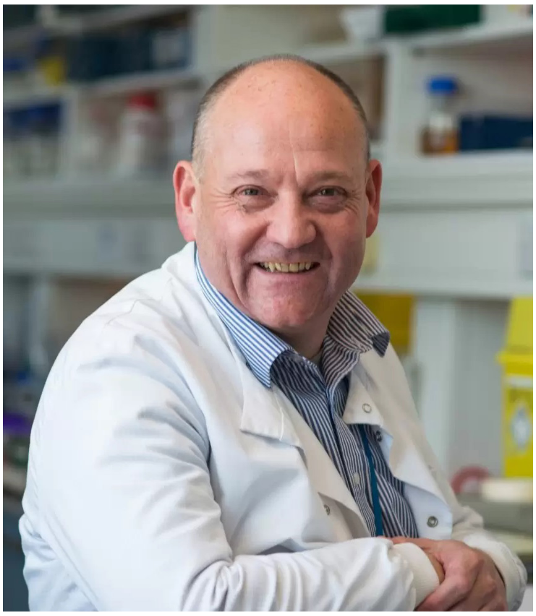
Mikkel Bille - UNIVERSITY COLLEGE LONDON

Keynote Speakers

Prof. Lucy Kimbell

University of the Arts, London

Her research looks at the emergence and development of ‘design thinking’ and the use of ‘social design’ expertise to address social and public policy issues. Lucy is currently co-investigator on two UKRI funded projects which are cross-disciplinary and co-produced with non-academic partners using design to address the contemporary issues of AI and Anti-Microbial Resistance.



Prof. Russell Foster

Oxford University

Russell was at Imperial College where he was Chair of Molecular Neuroscience within the Faculty of Medicine.
His research spans basic and applied circadian and photoreceptor biology.
For his discovery of non-rod, non-cone ocular photoreceptors he has been awarded the Honma prize (Japan), Cogan award (USA), and Zoological Society Scientific & Edride-Green Medals (UK).

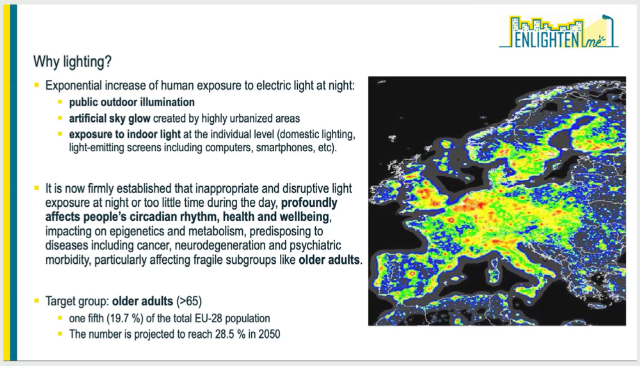
Shaping light for health and wellbeing in cities. Aims and scope of the conference

A major consequence of urbanisation is an exponential increase of human exposure to electric light at night. Public outdoor illumination and the artificial sky glow created by highly urbanised areas are the main sources of exposure. This is complemented by increasing exposure to light at the individual level through domestic lighting and light-emitting screens, or too little exposure during the day due to shift work or unregulated lifestyles.

The consequences of inappropriate and disruptive light exposure, generated by the urban environment, profoundly affects people's health and wellbeing, altering the circadian rhythm. These effects cannot be overlooked, especially when they affect vulnerable populations like older adults who suffer disproportionately.

Light also shapes urban spaces and social life, thus influencing people's behaviour, moods, and sense of security, as well as social relationships, easing or hampering socialisation and participation in civic life. Although public awareness of light-related health and wellbeing issues is increasing, there is less understanding of how health impacts derived from urban lighting are mediated by social inequalities present in cities that may determine the kind and amount of light that citizens are exposed to.

Through the international conference, titled 'Shaping light for health and wellbeing in cities', the more than 100 participants from academia, industry and local administration from across Europe, the USA and Australia investigated the multifaceted consequences light has on life in cities.



Reasons for focusing on urban lighting and effects on the target group of older adults

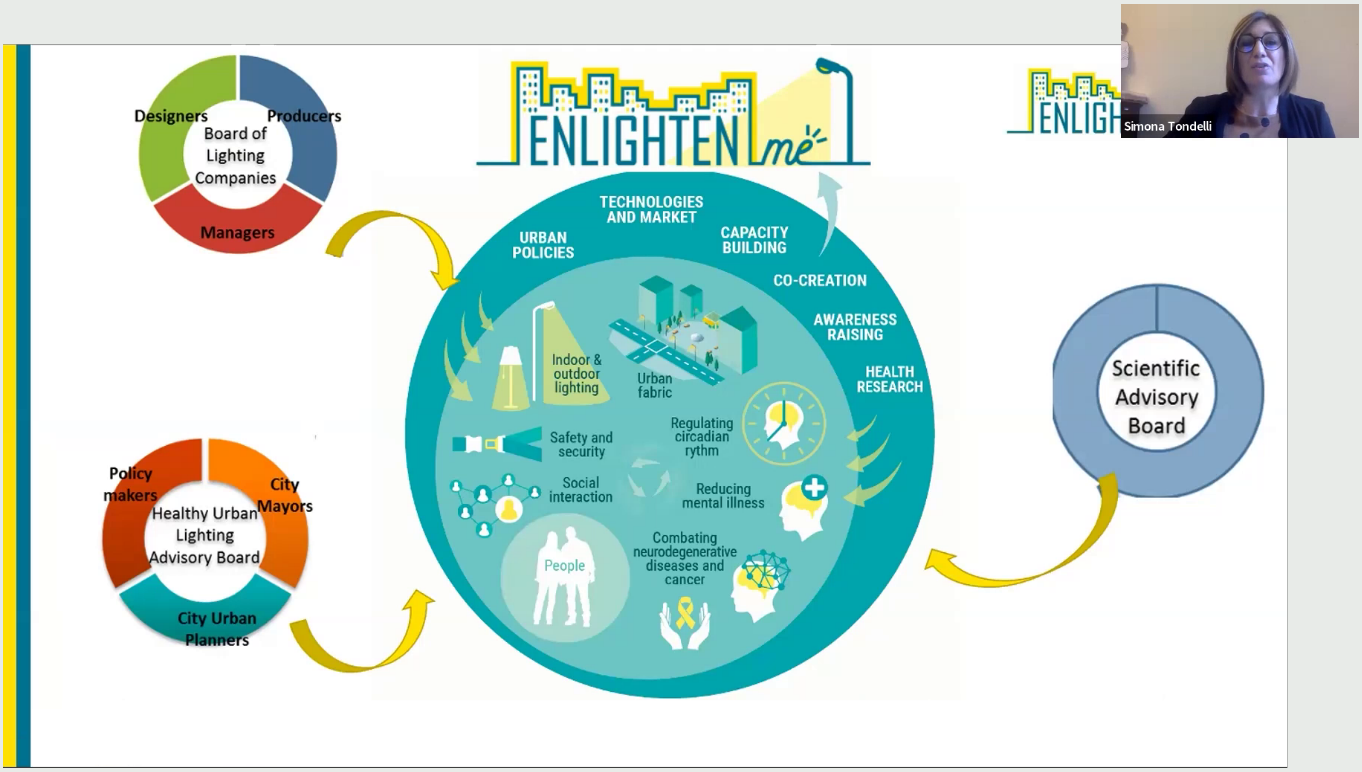
How the project objectives intersect SDGs (Sustainable Development Goals)

Simona Tondelli
Alma Mater Studiorum, University of Bologna, Italy

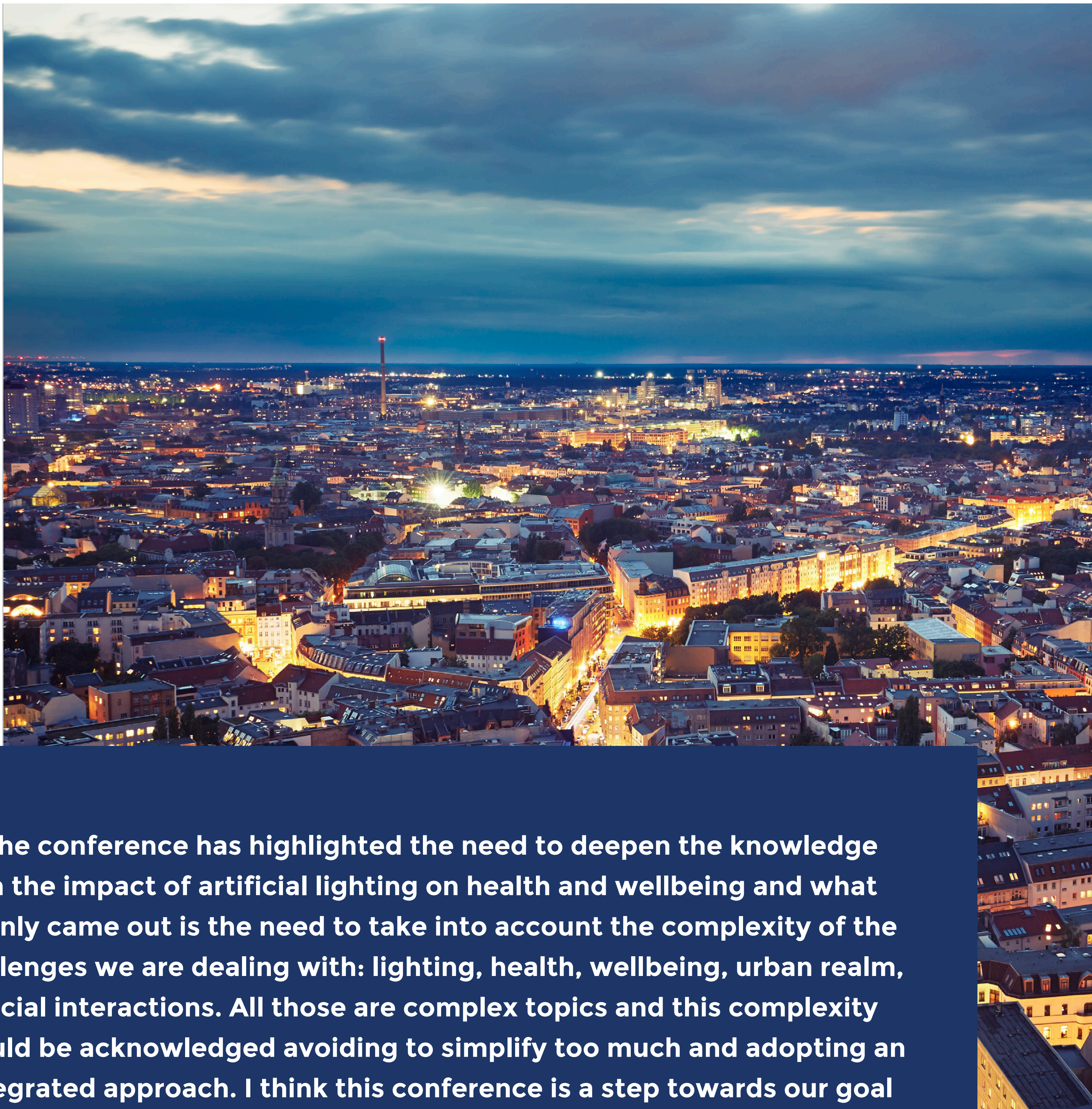
Nearly 30 academic papers were presented and discussed under the themes:

- **'Social lighting and lighting technology for urban well-being'**
- **'Artificial lighting and its implications for health, wellbeing, and circadian rhythm'**
- **'Urban analytics and innovative urban lighting policies for health and wellbeing'**
- **'Ethical legal and social aspects of urban lighting and related health studies'**

The conference emphasised how urban lighting constitutes a multidisciplinary topic that draws from several disciplines such as clinical and biomedical sciences, ethics and Responsible Research & Innovation, urban planning and architecture, data accessibility and interoperability, as well as social sciences and economics, all of which provide complementary yet also conflicting insights for further exploration.

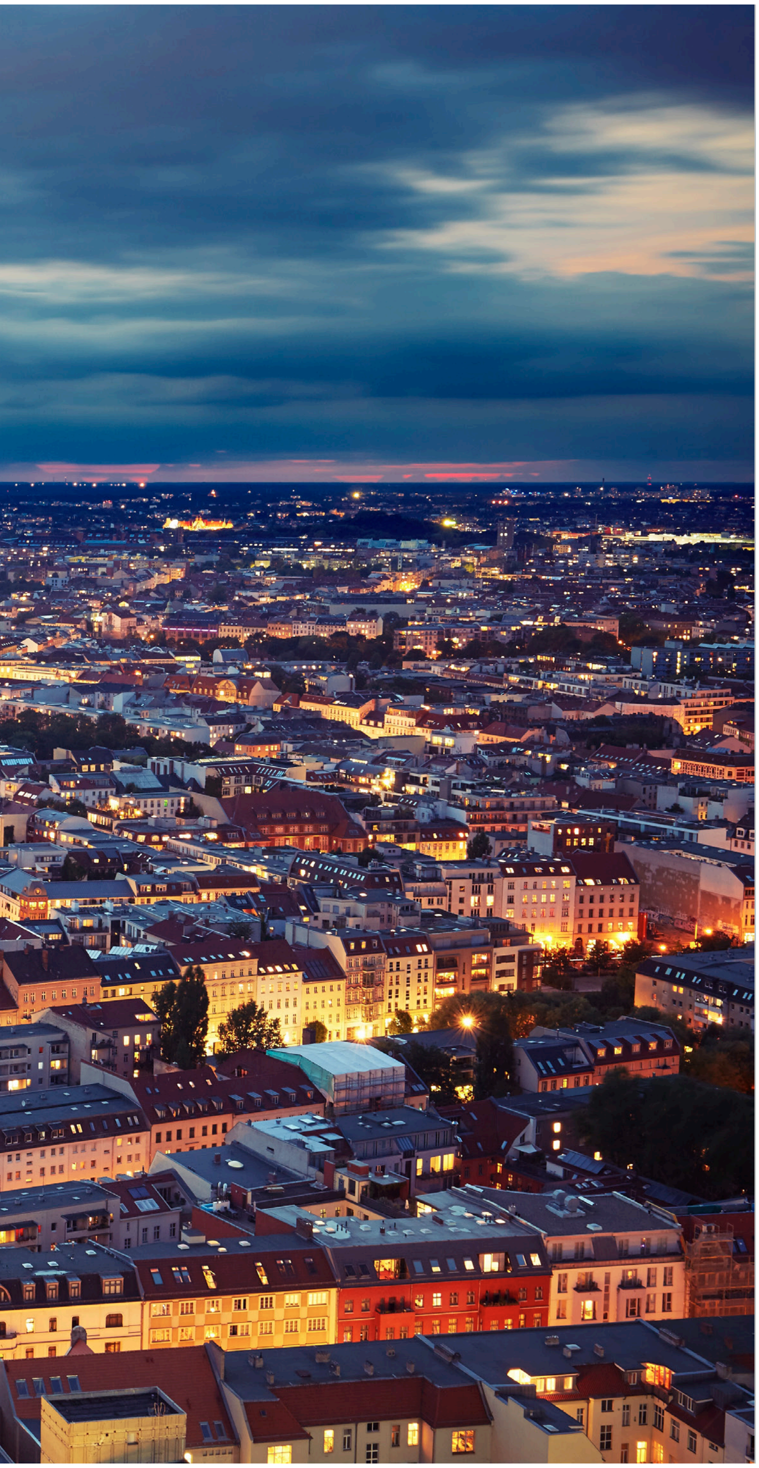


Project Paradigms and Scientific Advisory Board



"The conference has highlighted the need to deepen the knowledge on the impact of artificial lighting on health and wellbeing and what mainly came out is the need to take into account the complexity of the challenges we are dealing with: lighting, health, wellbeing, urban realm, social interactions. All those are complex topics and this complexity should be acknowledged avoiding to simplify too much and adopting an integrated approach. I think this conference is a step towards our goal to develop innovative policies for improving older adults' health and wellbeing addressing indoor and outdoor lighting."

Simona Tondelli, University of Bologna



A key take-away from the presentations and discussions was the importance of transferring research into practice: while various tools, clinical studies and ethics principles, among others, have produced invaluable results, the leap from this research into urban policies still requires a conscious and joint effort of all actors and disciplines. This is the aim and challenge of the ENLIGHTENme project.

Therefore, the insights and cutting-edge developments shared during the lively and engaging sessions of this conference will greatly contribute to the further success of ENLIGHTENme. To this end, all the expert contributions of the conference greatly support the collection of evidence on indoor and outdoor lighting impacts on health and wellbeing that will feed the ENLIGHTENme open Atlas, a tool representing current knowledge, evidence and good practices on urban lighting for health and wellbeing. The contributions are analysed based on their various domains of expertise, such as medicine, social sciences, urban and lighting design, urban planning, ethics, etc., and included in the development of tools and policy guidance to support the decision-making processes of municipalities, ensuring the integration of health and wellbeing concerns in urban lighting plans.

SOCIAL LIGHTING AND LIGHTING TECHNOLOGY FOR URBAN WELL-BEING

Chair: **Don Slater**
Discussant: **Mikkel Bille**

Urban lighting is shifting from a largely technical and engineering matter to being understood as involving complex connections between the technical and the social that municipalities need to understand better. Topics that we would like to consider include:

- How can lighting better support social goals such as inclusion, equality, diversity and quality of life, particularly for older citizens?
- How can we better understand the citizen issues and social life as a basis for better urban design, including lighting?
- How can ENLIGHTENme research connect with and contribute to wider currents in social lighting and night-time design, both in academic and professional practice?

How can innovation in lighting technology, control systems and urban design contribute to wellbeing?

PUBLIC TENDENCIES AND PERCEPTION OF BRIGHTNESS AND LIGHT IN ODENPLAN

keywords
public tendencies, movement behaviour patterns, urban lighting, transportation hub, perception

Abstract
This research paper is discussing light, and brightness in particular, in terms of perception, taking Odenplan as a case study.
Some links between light characteristics and behaviour patterns, such as lingering, have been made, raising the discussion about the qualities of the artificial lighting that would add to convivial urban spaces at nighttime, attempting at differentiating between how people think they would behave and how they actually behave in a public square, and the impact of artificial lighting on public tendencies, suggesting if people feel comfortable and safe in the space, then they tend to perceive the space brighter. The research has shown that it is hard to draw conclusions when it comes to perceived qualities of light.
Different research methods have been used with the intention of suggesting a methodology to be explored by others, including literature review, empirical study, informal interviews and word association survey.

INTRODUCTION
There has been a rising tendency for appreciation of darkness in the lighting community.
However, some users of night spaces still tend to believe that darker outdoor spaces are by default not as good as lighter ones when it comes to nighttime. There is a universal connotation of darkness as a threat, danger and evil [1]. Arup in its publication [2] points out that lit spaces tend to appear safer than dark ones, taking into account the difference between perception of safety and actual risks in the nighttime and the importance of the contrast in light levels and eye's ability to adapt [2]. The discussion around what is an «adequately lit» public space is influenced by shared beliefs and perceptions, and depends on the use of space and the goal of the user. Transport hubs can be seen as a good example of public spaces where people spend time passively and actively which allows to observe behaviour patterns in its partially unconditioned manner. Odenplan in the city centre of Stockholm is a transportation hub that has varied lighting applications and is connected to several transportation modes, such as train, metro and bus, making it a relevant case study to focus on. As commuters identify lighting to be the most effective solution when it comes to safety, which is a primary concern in such spaces [3], it feels to be a crucial area of investigation, mapping the perceived brightness of users against the use of space, attempting at filling in the gaps in understanding public tendencies at nighttime. Additionally, there has not been much research on perception and lighting in non-commercial spaces [4] as there is no obvious monetary benefit from it, hence doing such a research on a transportation hub seems to be relevant and even more so, considering the wider use of open public spaces fostered by the pandemic situation.
This research can be seen as a step towards shaping successful functional night urban spaces, formed by observation of what encourages people to chose a certain path or linger in spaces as it is an indicator on a successful urban space, according to Shaftoe [5]. He also states that good urban places are the 'heart of democratic living' [5], referencing Carr et al. [6]. Arguably, this could be applied to both daytime and nighttime.
Moving from analysing spaces from the position of citizens' perceived needs to observing their patterns of behaviour, allows the environment to be adapted, resolving potential conflicts [7]. Public tendencies in urban spaces have been observed before, focusing on users and activity types in order to evaluate design factors that foster social activity [8], however, not focusing on the lighting as a factor at all or mentioning only daylight [5], while some studies have shown that a change in lighting conditions has an impact on the pedestrian flow [9] and, hence, impact public tendencies.
This research invites further discussion when it comes to brightness and qualities of light that is

Anastasia Angeli, *KTH Stockholm*

comfortable to stay and linger, relating observed public tendencies at Odenplan to what people perceive when looking at a photograph.

OBJECTIVES AND METHODS

Objectives of the research were:

- To search for correlation between the perception of light, dark and brightness in particular with behaviour patterns of public space users, the location and time of lingering in a transportation hub outdoors
- To identify favourable artificial lighting qualities that encourage lingering (as a marker of convivial space) to contribute to the creation of successful urban spaces at night
- To examine a methodology for urban lighting analysis to be shared and used in other urban public contexts

Analysis of existing research has been undertaken to support the paper and deepen the understanding of the topic. The literature review has been split into three sections. The following sections are also divided into these three steps, according to the method used. that have been chosen with the intention to grasp qualitative characteristics of light as opposed to measurable data.

I. Public space and movement behaviour patterns - Empirical study

First section has been based on structured observations of behaviour patterns, including that of gathering, walking and lingering, followed by creation of users' tendencies map. This was carried out through coming to Odenplan during day and night to observe and record movement of people through the space. Videos have been made to record observations on two days, rest of the observations have been done empirically in order not to influence the movement of people by directing the camera onto them. Comments and observations have been written down into the log. This has been visualised via the public tendencies map.

II. Perceived brightness - Informal interviews of users' perspective

This step has been carried out via informal on-site interviews at Odenplan during nighttime, visualised through perceived brightness mapping. Twelve people have been approached on site in the location where they would linger for a few minutes. The objective of the interviews was to understand a user perspective on perceived brightness at Odenplan and gather general thoughts and feelings on the lighting at the square, highlighting its strengths, weaknesses, opportunities and strengths. Interviews would start with inviting general comments on lighting and then followed by two formal questions:

- What do you feel about lighting at Odenplan?
- Based on your perception, how would you rate the brightness on the point where you are standing right now from 1 to 10, one being very dark and 10 being very bright? What about the other locations on the square?

Perceived brightness maps have been done after the interviews and then edited further to make them easier to understand, hence the maps are not a direct perception of interviewees but rather a simplification, based on the users' comments and the brightness rating they have given, hence it is to be noted that the maps have gone through the alterations and assumptions of the researcher. Another consideration is that of the language: different languages have been used when talking to people - Swedish, English and Russian - with an intention of allowing people to relate to the space more directly in the language they are comfortable with, which might have caused some inaccuracies at the stage of writing up the comments.

III. Interpretation and symbolism of night - Word associations survey

The last step was aiming at capturing further qualitative data, comparing daytime and nighttime, dealing with symbolic, assumed aspects of light. This has been done through sending two images of Odenplan to twenty people who are comfortable with sharing their thoughts with the researcher, achieved through individually contacting a mix of people from different backgrounds that the researcher has been in contact with before. To ensure people are not trying to please the researcher, the purpose of the study has not been specified.
Questions that have been asked:

- Which 5 words regarding the quality of light and space come to your mind when you see each of these two photographs?
- Have you been in that space before?
- Do you think you would choose to linger there at nighttime? How about daytime?

This step has been added in order to investigate how much of our perception is assumed by comparing the associations people would have when shown photographs of Odenplan and noticing whether those who have been to the space give a different set of words to those who have not been.

RESULTS AND DISCUSSION

This section highlights key discussion points that came up through all of the research sections, followed by suggestions.

A general reflection on the main introduction question of whether brighter spaces feel better, hence would invite people to linger in the space, it could be mentioned that the correlation seems to be opposite when it comes to users of the nighttime environments. If people feel comfortable and safe in the space for one reason or another, then they tend to perceive the space brighter. Hence, in the word associations survey people were picking up on the symbolic aspects of the darkness, based on the photograph, while experiencing the space in person the perception shifts from interpretation to experience of light.

Qualities of natural light do not directly transfer to artificial light when it comes to perception (comfort, uniformity and movement), while people tend to want to spend time in the direct sun in Stockholm, not many people stand under the direct light from the artificial lighting fixture at night. However, it seems that artificial lighting at Odenplan seems to attempt to mimic daylight in the way it is treated: shining from above at a sharp angle, aiming at being evenly distributed and lighting horizontal surfaces. While there is not much that artificial lighting shares with it at a psychological and mental levels. Step III has also proved that symbolic perception of night is different to that of daytime, however Step I has shown that currently people do use Odenplan in a similar manner throughout day and night, which might be caused by artificial lighting being treated as daylight.

It could be that different people are spending time in Odenplan during different times of the day that would have different behaviour patterns regardless of the light qualities but due to the different population coming to the square, their reasons to be there and temperature outdoors, making the research outcomes dispersed across various other factors making it impossible to draw conclusions of perception of light. Hence this paper can be seen as an attempt to come up with a methodology to research the light perception that could be developed further.

Tendency of people to perceive the position they are standing at brighter comparing to what is further away links the outcomes to the specificities of visual system that impacts human interpretation of light and its qualities.

The initial preference of the researcher towards integrated lighting typologies has been questioned as currently some of the fixtures allow users of the space to lean against it. This is to point out that if lingering is seen as a valuable pattern of behaviour, urban design should be considered in order to achieve that. A question that should be raised, however, is whether lingering is a behaviour the city wants to encourage in transportation hubs.

CONCLUSION

It is proved to be hard to draw conclusions when it comes to lighting in open public environments and its perception due to a variety of physical and mental elements that influence one's reaction and behaviour. Diversity should be considered when it comes to planning for lighting in public spaces. In order to create spaces that suit the needs of different people, more research has to be done to make sure all feel safe and welcome.

REFERENCES

1. Lakens, D., Semin, G. R., and Foroni, F. (2012) But for the bad, there would not be good: Grounding valence in brightness through structural similarity. Journal of Experimental Psychology: General. 141. pp. 584-594.
2. Arup (2015) Cities Alive: Rethinking the Shades of Night. London: Arup.
3. Hess, D. B. (2012) Walking to the bus: perceived versus actual walking distance to bus stops for older adults. Transportation. 39 (2). pp. 247–266.
4. Wänström Lindh, U. (2012) Light Shapes Spaces: Experiences Of Distribution Of Light and visual spatial boundaries. University of Gothenburg Art Monitor: Gothenburg.
5. Shaftoe, H. (2008) Convivial Urban Spaces: Creating Effective Public Places. UK: Routledge. United Nations . (2 0 1 2) The future we want . Available from http : / /sustainabledevelopment. un.org/futurewewant.html [Retrieved 18.03.2021].
6. Carr, S., Francis, M., Rivlin, L. and Stone, A. (1992) Public Space. Cambridge: Cambridge University Press.
7. Jarvis, R. K. (1980) Urban Environments as Visual Art or as Social Settings? A Review. Town Planning Review. 51 (1). pp. 50–66.
8. Ridings, J. and Chitrakar, R. M. (2020) Urban design frameworks, user activities and public tendencies in Brisbane's urban squares. Urban Design International. 19 February. Available from: https://link. springer.com/article/10.1057/s41289-020-00113-x. [Retrieved 16.03.2021].
9. Unwin, J., Symonds, P., and Laike, T. (2017) Does lighting affect pedestrian flows? A pilot study in Lund, Market Harborough and Dublin. In: Proceedings of the Lux Europa 2017 European Lighting Conference - Lighting for Modern Society. Ljubljana, Slovenia: Lighting Engineering Society of Slovenia.

REDESIGNING THE LIGHT IN THE HISTORICAL CENTRE OF ENNA

keywords
lighting project, urban health, lighting technologies, energy saving, historical centre of Enna

ABSTRACT
The lighting survey carried out on a portion of the historical centre of Enna revealed some critical issues that affect the liveability of this urban space. Init ially , the posit ion , num ber , lamps and supports of the lighting systems on site were identified. Then, the horizontal illuminance was verified which, according to the type of urban area, must provide an average illuminance of 15 lux and a ratio between the minimum and average of 0.4. The verification was carried out with Dialux Evo 9.1 soft w are: the second of the two parameters was not verified, so an intervention was needed to improve the light conditions of the site during the night hours. The new lighting project consists of replacing and implementing the existing lighting syst ems, opting for new LED lamps with luminaires that direct the light beam dow nw ards . The objectives of this proposal are to pursue the psychophysical wellbeing of a mainly elderly users, mitigate light pollution and reduce energy consum pt ion. A final lighting engineering check on the new project and a calculation of the operating costs make it possible to propose an intervention that complies with regulatory parameters, improves the liveability of the urban area, and allows significant energy savings .

INTRODUCTION
Redesigning the public lighting of a portion of the city represents an opportunity to improve the psychophysical wellbeing of the users and allows to give a critical mark to the architecture of site. In this contribution is shown the lighting analysis and the consequent proposal of intervention that have been carried out in the San Tommaso district in the historical centre of Enna. The relocation of the main services to other areas of the city has made this urban space scarcely frequented and attractive to a young audience; in this sense, the district is mostly lived by residents, many of whom are elderly. The artificial lighting study was made on the street of Via Mercato, where the main lighting gaps were identified, and on Piazza Neglia, the main square of the zone, overlooked by several prestigious buildings. After making a detailed analysis of the existing illumination, a new lighting design is proposed that meticulously follows regulatory standards and "redesigns the light" onta the street and the prominent buildings. While examining different lighting projects, such as the interventions of Ferrara Palladino e Associati at the university village of Milan Bovisa and in Piazza alla Scala [1], or those of Piazza del Popolo in Faenza by Coveri-Nanni and Piazza Duomo in Catania by Salvatore Grassia [2], or even the illumination of the walls of Santa Rosa in Florence and of the statue of Neptune in Messina by Philips lighting [3], the new lighting project for the San Tommaso district in Enna is an original and specific proposal for an intervention which, in accordance with current regulations, seeks to interpret the socio-spatial contest in an appropriate manner. The objective of this project is to improve the psychophysical wellbeing of the users, mitigate light pollution and lower the energy consumption of artificial lighting.

MATERIALS AND METHODS
The first phase of the study was dedicateci to the metric and photographic survey of the project area, followed by the identification of the lighting systems in Piazza Neglia and along Via Mercato. The position, the quantity and the different types of lamps were marked in plan and in section: all these data, together with the type of lamp body, were collected in a summary table (Figure 1). After getting this information, knowing that the total lighting power of the study area is 3.940 kW, that the electrical consumption of the existing lighting is 15.299 kW/h and the cast borne by the municipality for the electrical energy is 0,12 €/kW, we will have an expenditure of 1.897 € per year for the operation of the surveyed luminaires. The second step was then focused on the verification of the horizontal illuminance present in the two areas. To carry out this study, the indications of

Gianluca Burgio, *Ph.D., Associate Professor of Architeetural Design, Università degli Studi di Enna " Kore "*
Marco Graziano, *Ph.D., Research Fellow tor eWAS projeet*
Antonio Calì, *Ph.D. Student in "Innovative Technologies tor Engineering and the Built Environment"*

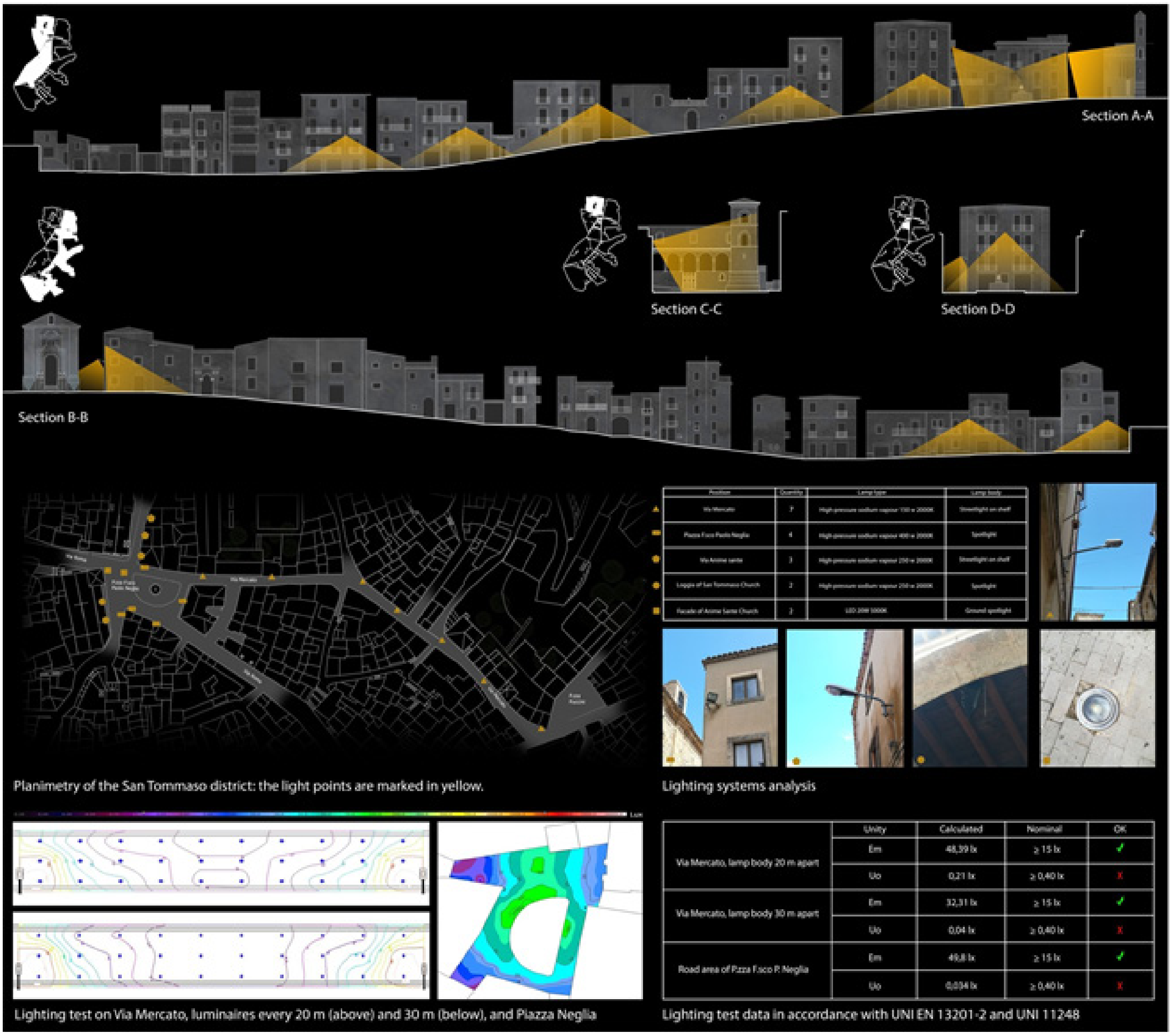


Figure 1. Planimetry and sections of the analysis area where the position of the luminaires is indicated. The top table contains the luminaire data: position , quantity, lamp type and lamp body. The lower part ofthe picture shows the results of the lighting tests carried out with Dialux Evo 9.1.

two standards were followed, UNI EN 13201-2 "Street lighting - performance requirements" and UNI 11248 "Street lighting - selection of lighting categories" [4]. These standards indicate that the urban spaces considered belong to category CE3,
i.e. local urban roads in historic town centres: routes of this type must guarantee an average illuminance (Emed) of 15 lux, and a ratio (Uo) between the minimum illuminance (Emin) and the average illuminance of 0.4. Respect for these values is fundamental to guarantee the safety and psychophysical wellbeing of the users: in the case of elderly users, constant and oversized lighting (keeping light pollution under control) of the routes is necessary, as their visual performance in terms of accommodation, acuity and adaptation decreases proportionally to the level of lighting [5]. The verification of the above-mentioned values was carried out with the software Dialux Evo 9.1: this program can be constantly updated from the normative point of view and allows the calculation of the two above-mentioned parameters; it also allows to perform a three-dimensional simulation rendering and to return Isolux images of the examination area. Firstly, two calculations were made on Via Mercato based on the distribution of the luminaires, i.e. every 20 metres and every 30 metres; the second verification was carried out on Piazza Neglia. In both cases, the result was negative, as the only parameter respected was the average illuminance of 15 lux (Figure 2, below). A new lighting design was proposed to meet these parameters.

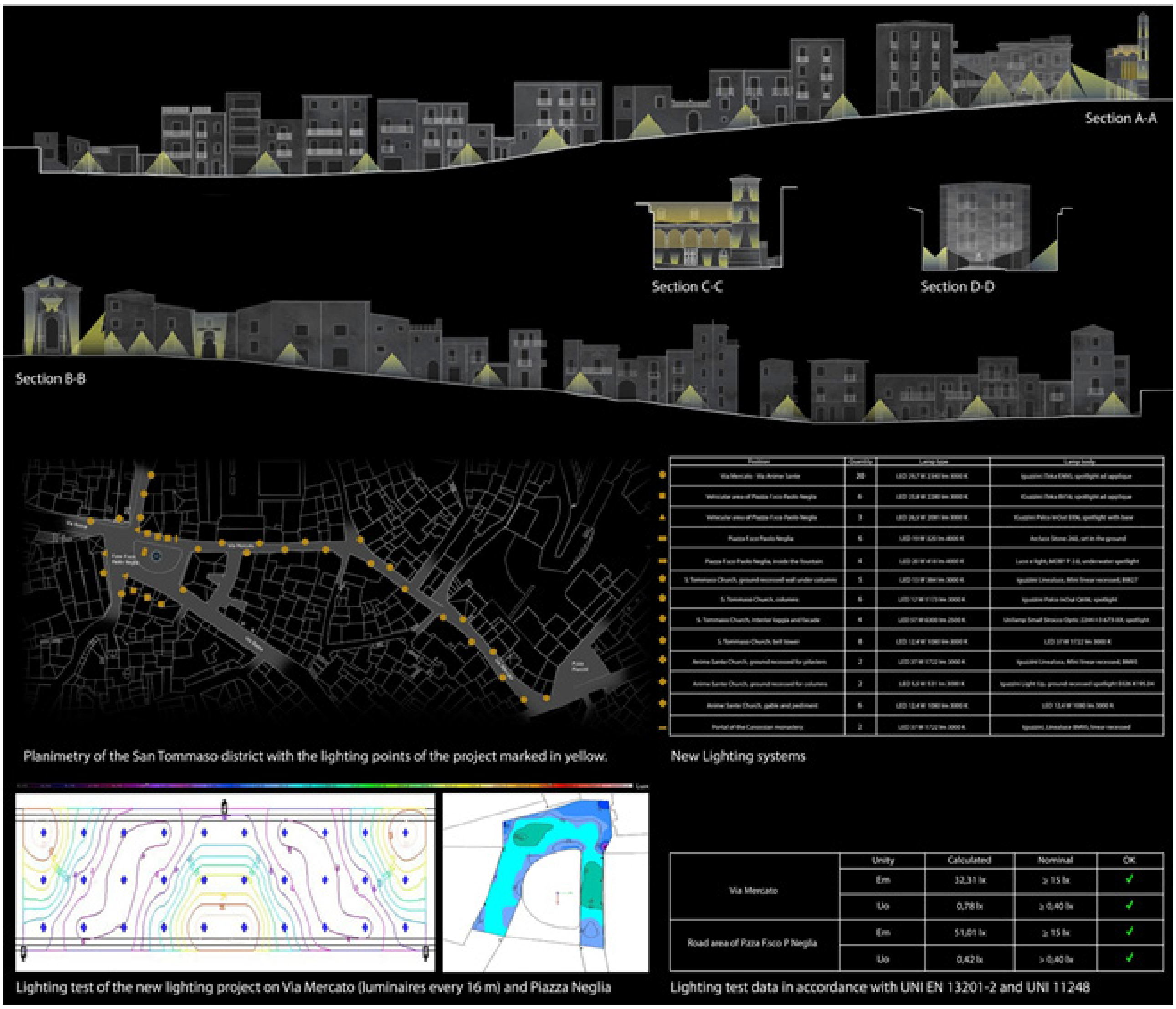


Figure 1. Planimetry and sections of the analysis area where the position of the luminaires is indicated. The top table contains the luminaire data: position , quantity, lamp type and lamp body. The lower part ofthe picture shows the results of the lighting tests carried out with Dialux Evo 9.1.

RESULTS AND DISCUSSION

The proposed intervention focused on two types of work: on the one hand, the lighting on the street was redesigned to achieve a suitable level of safety for pedestrians; on the other hand, this project also focused on the lighting of the valuable buildings by interpreting the architectural volumes. The arrangement of LED lighting systems and lamp bodies that mitigate the dispersion of light brings several advantages such as visibility, colour rendering and energy saving. The positioning and typology of the lighting points was studied in detail to obtain the best night-time yield and the least contamination of the facades by the supports. The quincunx arrangement of the lamps along Via Mercato every 16 metres and the positioning of lights outside and inside the fountain in Piazza Neglia make it possible to obtain illuminance in line with the regulations in farce. The proposed lighting system has a high luminous efficiency of between 17 and 90 lumens/watt, the current one does not exceed 80 lumens/watt. The colour rendering index (CRI) is 80, while the two current lamp types have a CRI of no more than 20. The total electricity consumption of the installation is 1.718 kW, with a yearly consumption of 6,670 kW/h. Therefore, the cast for energy will be 827,20 € during the year. Compared to the electricity consumed today, this represents a saving of approximately 50%.

CONCLUSION

The lighting project for the San Tommaso district makes it possible to improve the visual perception and safety of users during the night. The lower energy costs due to the use of new LED technologies and the choice of equipment that limits light pollution make this proposal a valuable tool that can be made available to the Enna municipality for future interventions.

REFERENCES

1. Palladino, P., Coppedè, C., (2012). La luce in archite tt ura, Maggioli , Santarcangelo di Romagna
2. Ravizza, D., (2006) . Architetture in luce, FrancoAngeli, Milan
3. Università degli Studi di Roma “La Sapienza”, Department of Technical Physics. (20 11). Illuminazione urbana e scenari di progettazione . Available on: htt ps://w w w.enea.it/ it/ Ricerca_sviluppo/documenti/ ricerca-di-sistema-elettrico/illuminazione-pubblica/rds-195.pdf [O1/10/2021)
4. Cesi Ricerca. (2009) . Linee Guida Operative per la realizzazione di impianti di Pubblica Illuminazione . Available on: htt ps://w w w.st udiopet rillo .com/files/Linee%20guida% 20per% 20il% 20dimensionament o%20di% 20impiant i% 20di% 20pubblica% 20illuminazione.pdf
5. Michel, L., (1995). Light: The shape of space, John Wiley & Sons Inc., New York.

INCLUSIVE ACCESSIBILITY H24. A REFLECTION ON THE URBAN PLANNING OF FRAIL PEOPLE

keywords
urban lighting, human-oriented lighting, urban accessibility, social inclusion, public space

ABSTRACT
The interest in public space as an attractor of human activities generally emerges during the day, when natural light reveals spaces and their characteristics and allows - or not - their use. Seen as a "borderline", the passage from day to night leads to the analysis of elements and strategies that allow everyone and, the most fragile people, to be able to experience the city in equal measure, guaranteeing well-being and safety.
This study aims to be a reflection on the theme of urban lighting for the benefit of the entire population, those who encounter obstacles that, inevitably, increase at night. Starting from the review of the literature on the subject, good lighting is here interpreted as a further opportunity for inclusion that supports well- being centered on the person as well as on the quality of the places to live.

INTRODUCTION
Public space has always been a symbol of well-being for the urban community and motivation of the customs that accompany people's daily lives. As catalysts of social interactions capable of generating and enhancing the sense of community [1], squares, parks, green areas, but also drosscapes and forgotten voids are places of living that should guarantee the meeting of the needs and rights of all users. Starting from this framework, the design and management of places to live open to social phenomena made up of relational networks, feelings, and gestural interactions between person and space and between person and person [2].
Meanwhile, the strategies advanced by the 2030 Agenda for Sustainable Development, specifically with Objective 11 "Making cities and human settlements inclusive, safe, long-lasting and sustainable", aim at rethinking urban spaces and places of being in order to make them inclusive, accessible, and safe for all. However, today we still are faced with few virtuous examples capable of recognizing and guaranteeing urban livability for the entire daily cycle. A 24 hours city, capable of ensuring use and safety - especially for the frailest people - becomes the reason and incentive for a renewed attention to the design of urban artificial lighting.
Urban planning and environmental accessibility, therefore, have to deal with an everyday life that is no longer confined to daytime life cycles, but which looks at the sunset as a "borderline" ready to break the day to give it a new beginning and mark the time of leisure, pleasure, and relaxation. In this sense, urban lighting becomes a design tool aimed at recovering the sense of places, getting back their identity, and restoring social justice especially to people placed "on the margins".
Rethinking the design and management of urban lighting according to a human-centered approach would therefore represent a fundamental starting point for creating adequate and safe conditions that allow everyone the positive use of open spaces after sunset while looking at the energy consumption and the design of the lighting fixtures.
The objective of this work precisely becomes that of broadening the vision of environmental accessibility, underlining the need to introduce in the planning processes a rethinking of artificial lighting as a mere "obstacle" to be overcome for the benefit of urban quality, equity, and social inclusion.

MATERIALS AND METHODS
The reflection on the subject has been conducted starting from the review of the scientific literature on the issues of environmental accessibility and the use of public space in a safe way h24.
Among the most important works, Casciani [3] contains a series of important considerations regarding the social dimension of urban lighting. In fact, enhancing the night-time urban

Christina Conti, Silvia Cioci, Teresa Sambrotta, *University of Udine*
Valeria Tatano, Rosaria Revellini, *University Iuav of Venice*

experience contributes positively to the cognitive, and emotional perception of people in the urban environment itself. The study of Casciani and Musante [4], in particular, highlights how the lack or the presence of proper urban lighting can determine and condition human behavior creating more or less intimate and more or less safe atmospheres.
Another example of significant interest is that of Lauria [4] which allows us to summarize the need for lighting in "hidden" places to discourage the presence of infringements or abuses and therefore dampen feelings of insecurity and uncertainty.
Urban lighting influences the observer's emotions: these sensations are often linked more to the lighting than to the place itself since light contributes to the beautification of the space in which one is located and improves the experience of the city user [6]. And again, Davoundian states that good street lighting increases physical activity, encourages people to walk and supports correct spatial perception, promoting active aging and psychological well-being, especially for people with cognitive disabilities [7].
Finally, the ARUP study [8] underlines the importance of public lighting as a driver for improving the quality of life, with possible positive economic effects. To obtain good results in this sense, however, participatory processes are also necessary that allow us to understand what the needs of the community are. In this mood, the present study took into consideration different bibliographic references - GBC Quartieri v. 2015, ITACA Scala Urbana v. 2016, BREEAM Communities v. 2012, DGNB Districts v. 2020 -, highlighting how good lighting can positively contribute to the life of the urban community. Specifically, from the review of the aforementioned literature, the theme of lighting emerges not only as an element linked to energy consumption, but also as a strategy aimed at favoring the use of public space in safety and above all aimed at making urban systems more "attractive and qualifying".

RESULTS AND DISCUSSION

The quality of the urban space has direct repercussions on the inclusion, wellbeing, health, real and perceived safety of people. But how can lighting bring about an improvement in the quality of the environment?
Considering the optimal height of the light sources to avoid glare phenomena and rethinking the location and distribution to generate different "atmospheres" in the space and escape from the generation of shadow areas, the conscious design of lighting fixtures and their location open up to attention dedicated to guaranteeing the minimum levels of visual comfort.
According to the practical guides, lighting stands out, indeed, the need to differentiate the lighting devices according to the different urban spaces - squares, pedestrian paths, streets, gardens - to be illuminated in order to encourage life and social activities. The lighting fixture, be it a streetlamp, a bar, or a led, is not only a standard element of street furniture or a part of the functional infrastructure of the city but offers itself as an element capable of modifying the perception of a place during dark hours [9].
Paying particular attention to the most fragile categories of the community, the study recognizes in the correct design of urban lighting, the element for changing the perception of the city capable of establishing new psychological, emotional, and behavioral aspects for a new human and social layer. If it is true that a place can arouse a variety of social relationships between people and that these can vary from passive to active, it is right to consider how the predominant interactions and relationships take place, in fact, through the observation of people who avoid true eye contact but through a careful "look away". Therefore, the "ability of the eyes on the streets" becomes the emblematic measure of the social quality of space because it can indicate the possibilities that

people have to look at each other and to maintain a higher degree of security of the context, helping to make individuals less vulnerable [10]. "Universal observability" [3] thus becomes an invitation factor that encourages well-being centered on the person and the quality of places through materials, finishes, and elements of urban design.

CONCLUSION

From crowded streets to courtyards for public use, what emerges from the more and less recent scientific literature, leads to understanding the different qualities that make some spaces thrive compared to those that, in contrast, they tend to be less lived while remaining peculiar to their cultural value, their tradition and the history they represent. It is verifiable, indeed, how difficult it can be to find a perfect match between places of living and quality: some places of great quality - catalysts of values, customs, and heritage -, may inevitably be denied in the recognition of the identity of the person or group. It is in this sense that we are committed to planning to guarantee wellness and wellbeing and, therefore, to improve, one step at a time, the quality of life of the people who live in our cities.

Rethinking the design of urban space 24 hours a day, making urban lighting the protagonist of environmental planning, becomes an emblematic goal of a continuous and wishful search for equity and social justice aimed at (re) giving space to the frailest categories of citizens.

ACKNOWLEDGEMENT

Christina Conti, Associate Professor of Architectural Technology, University of Udine.
Silvia Cioci, Postdoctoral Research fellow in Architectural Technology, University of Studies of Udine.
Teresa Sambrotta, Temporary Research Associate in Architectural Technology, University of Studies of Udine.
Valeria Tatano, Full Professor of Architectural Technology, University Iuav of Venice
Rosaria Revellini, Ph.D. student in Architectural Technology, University Iuav of Venice.

REFERENCES

1. Carr, S., Francis, M., Rivlin, L. G., & Stone, A. M., (1992). Public Space, Cambridge University Press, Cambridge.
2. Goffman, E., (1967). Interaction ritual: essays on face-to-face behavior, Anchor Books Doubleday & Company, Garden City N.Y.
3. Casciani, D., (2020). The human and social dimension of urban lightscapes, PoliMI SpringerBriefs, Milano.
4. Casciani, D., Musante, F., (2016). What does light do? Reflecting on the active social effects of lighting design and technology in Crabu, S., Giardullo, P., Miele, F., Turrini, M., eds, Sociotechnical Environments. Proceedings of the 6th STS Italia Conference 2016, 693-709.
5. Lauria, A., (2017). Piccoli spazi urbani. Valorizzazione degli spazi residuali in contesti storici e qualità sociali, Liguori Editore, Napoli.
6. Calvillo Cortés, A. B., Falcón Morales, L. E., (2016). Emotions and the urban lighting environment: a cross-cultural comparison, SAGE Open, 6, 1.
7. Davoudian, N., (2019). Urban Lighting for People. Evidence-Based Lighting Design for the Built Environment, RIBA Publishing, London.
8. Arup, (2019). Cities Alive. Rethinking the shades of night, ARUP, London.
9. Carmona, M., Heath, T., Oc, T., Tiesdell, S., (2002). Public places—urban spaces: the dimension of urban design, 1st edn. Elsevier/Architectural Press, Amsterdam.
10. Jacobs, J., (1961). The death and life of great American cities, Random House, New York.

IMPACT OF LIGHTING ON HEALTH AND WELL BEING OF LIFE FORMS CONTENT CURATION OF THE WEB FOR THE PAST TEN YEARS

keywords
content curation, street lighting, life forms, one health, scoop.it

ABSTRACT
Impact of public lighting on heath and well being of life forms either human, animal and vegetal is more and more of concern since the last decade. We have been using content curation of information circulating on the web with Scoop.it to build and maintain a content hub on Street Lighting, Innovation and Design since 2011. Apart from technical developments, societal consequences of public lighting appeared as an increasingly major topic of interest on internet. We survey the information collected from the web on health and wellbeing related posts and discuss the knowledge gathered. The topic focusing initially on light pollution, supported by ecologists and dark side movement is more and more of concern for every actor of the lighting industry and for civil society, not only in western countries but also in the global world. Technical developments of lighting, economical aspects, ecological approaches, quality of life of humans and all type of living forms animal and vegetal became over the years major research interests and policy arguments in order to harmonize development and safeguarding the planet.

INTRODUCTION
Street and public lighting is now an essential development pattern of planet earth and of human society. Consequences for security at night were among the first objectives of such implementation in previous centuries. Progress in energies availability and light sources allowed to build infrastructures first in cities then almost everywhere in the world.
More recently, technical developments with for instance introduction of LEDs gave hopes for savings, in some countries/cities willing to reduce their costs. Sun lighting and off-grid technologies is now offering opportunities in remote locations. Ecology movements developped in the past decades with for instance the Dark Sky movement in the eighties in reaction to obvious consequences of city lighting, such as disappearance of stars visibility in many world areas and to well-being, health and safety of both people and wildlife.
Evolution of human societies with migration of countryside populations to urban environments had major consequences on requirements for city management. In a more and more global world, new countries also became major actors either of lighting industry and as purchasers of lighting material for their populations. Health and Well being (in a changing urban environment) was a major initiative and programme proposed by ICSU (now ICS) at the end of last century [1]. It related not only to humans but also to every life forms on earth which might be impacted by environmental modifications. One Health emphasized this approach at the beginning of 21st century [2].
Diffusion and accesibility of information on the internet allowed awareness of the interest of the subject by lay people, city officials and policy makers but paradoxically information overload requires to collect ie find, select, elevate relevant material to help interested endusers students, as well as researchers and professionals discover or keep abreast of information. Content curation tools appeared on the internet at the same time. They allow to collect information by specialists, to build content hubs and share knowledge. Content and digital curation became a core competency for information literate individuals researchers and professionals [3,4].
We present a content hub initially devoted to Street Lighting Innovation and Design, where impact of public lighting on health and well being of life forms is more and more pregnant :
https://www.scoop.it/topic/lighting-innovation-design.

Gilbert C Faure, **Claire M Faure,** *Université Lorraine*

MATERIALS AND METHODS

Relevant Information on street, road and public lighting was obtained/selected from material proposed by the web crawling engine of the content curation tool Scoop.it using keywords such as « street lighting» and « public lighting ». Other information found in parallel on social networks such as Twitter, Linkedin and Facebook is also curated. Information was elevated and keywords coined accordingly. Every collected information linked to its original source is posted on the following Scoop.it webpage and is freely available. It can be reposted on various social networks.
To analyze material collected over the years, the inside search engine of the curation tool used either keywords or natural language such as health, well-being, safety, security.. ; among life forms, fishes, birds, insects, bats, bees, moths, pollinators, biodiversity.. ; among consequences of lighting, light pollution, dark sky.. ; among world countries and continents : USA, Europe, Africa, Asia...

RESULTS AND DISCUSSION

The content hub collected more than ten thousands posts during the past 10 years, while for instance 30% more lights were present in France during the same period of time. In 2015, while LEDs and solar lighting represented 40% of posts, this societal watch found already almost 10% of information encompassing light pollution, costs of lighting, security and ecology concerns respectively of lights restriction and lights overuse.
Major technical developments of lighting influencing health and well being relied mainly, du ring the same period, on LEDs implementation and usage of presence detection to first make savings and then reduce light pollution in cities and countryside villages. Recently, light colors changes make the solution not as efficient as previously thought.

Technical developments of lighting, economical aspects, ecological approaches, quality of life of humans and all type of living forms animal and vegetal become over the years research interests and policy arguments in order to harmonize development and planet safeguard. Light pollution per se was indeed the initial ecological concern. Between 2012 and 2016, satellite measurements revealed that the global area polluted by artificial light grew by 2 each year. Light pollution (>500 posts) and Dark sky movement (>125 posts) have been widely present in the content hub. Now dark sky tourism information increase in many world areas.
Ecology concerns for animals and other life forms (insects, plants) are more and more do- cumented concerning numbers of individuals, changes in behaviour and comportement, consequences on reproduction and biodiversity. Many species are listed on posts such as birds (>50 posts) and consequences for migration, fishes, turtles, bats... insects, moths, bees, pollinators appearing in biodiversity consequences.

Human health appeared in a few studies in USA linking breast, prostate, thyroid cancers to blue light of LEDs and lighting at night, as reported by newspapers in various countries. More documented in night-shift workers are influence of circadian disruption rythms by public lighting [5].
Well being of humans related first to security and safety (>400 posts) during the night, and public lighting influencing many human activities, such as leisure, education and commerce at night. Groups such as women and isolated elderly seem to be the more fragile human subgroups. This appeared as a big concern on the internet in UK some years ago, when light cuts policies appeared to reduce costs of lighting. In France, similar policies are now appearing in many small cities and villages and/or try to use new techniques (LEDs, and presence detection) to lower costs

of lighting, with similar concerns. Developped and developing countries might have different approaches acccording to their needs and cultural habits. Indeed, Africa (>300 posts) and developing countries are of course willing to increase access to electricity for lighting in cities . Solar energy and off-grid technical solutions should help them to access better life conditions not only in cities but also in more remote areas.
All those aspects are integrated in the sustainable development approach of public and street lighting integrated into the smart city solutions (>1500 posts) which include smart lighting systems. This is now emphasized not only in big cities such as London, New York or San Diego but also in countryside villages in Europe, America, Asia and Africa.
Content curation can be defined as the process of collecting, analyzing, displaying and sharing information in order to derive new insights and knowledge and present these findings to a broader audience. Content curation by information and/or competent professionals involved in selecting, agregating and sharing relevant information on a regular basis is a mean to focus the area of searching and untangle the information overload jungle. The collection of information from social networks (Twitter, Linkedin, Facebook) allows to gather other type of information coming from local newspapers reporting more and more lighting local policies.
This content hub is a collection of information visible on the web related to street and public lighting. Collecting information from various types of publications, specialized journals as well as general press, and on social networks, it covers not only technical innovations but more and more societal consequences of lighting such as health and well being of all types of life forms.

CONCLUSION

The Scoop.it Content Hub « Lighting Innovation Design » sampled and curated web information on impact of lighting on health and wellbeing of life forms during the past ten years and intend to pursue the effort to made more easily information available on this sensitive topic.

ACKNOWLEDGEMENT

GCF is an associate member of research group PIXEL belonging to CREM (Centre de Recherche sur l'étude des médiations), Université Lorraine. Nancy France

REFERENCES

1. Gatzweiler, F.W., et al., (2017). Advancing Health and Wellbeing in the Changing Urban Environment. In: Advancing Health and Wellbeing in the Changing Urban Environment. Urban Health and Wellbeing (Systems Approaches), Springer, 1 -48, Singapore.
2. Laaser, U., Lueddeke, G., Nurse, J., (2016). Launch of the One Health Global Think-Tank for Sustai- nable Health & Well-being 2030 (GHW-2030), South Eastern European Journal of Public Health SEEJPH, 6, 1840
3. Ungerer, L.M., (2016). Digital Curation as a Core Competency in Current Learning and Literacy: A Higher Education Perspective, International review of Research in Open and Distributed Leaning, 17, 1-27.
4. Singh, M., (2018). Digital Literacy: an Essential Life Skill In the Present Era of Growing and Global Educational Society. Journal of Advances and Scholarly Researches in Allied Education, 15, 8, 62-67
5. Chepesiuk, R., (2009), Missing the Dark: Health Effects of Light Pollution, Environmental Health Perspectives, 117,1 , A20-27.

PLANNING ARTIFICIAL LIGHT AT NIGHT FOR PEDESTRIAN VISUALDIVERSITY IN PUBLIC SPACES

keywords
artificial light, night, planning, visualdiversity, lightwalk

ABSTRACT
This paper makes the case for pedestrian visualdiversity in planning artificial light at night in public spaces. A preliminary literature review showed that limited research and applications have been developed addressing and acknowledging pedestrian visualdiversity, defined here as the condition and the needs of visually impaired pedestrians in public spaces at night. To further research this gap, open-ended interviews with experts in the field of artificial lighting and health were conducted by the authors. The interviewees confirmed the scarcity of studies and projects targeting pedestrian visualdiversity and provided insights on five related issues, i.e., contrast, glare, illuminance, light colour and the use of new technology. Against this backdrop, firstly materials and methods of the study are illustrated, while the aforementioned five issues are discussed subsequently by reporting recommendations shared by the interviewees. In conclusion, a framework for the application of lightwalks is presented as an inclusive experiential method for involving visualdiverse pedestrians in assessing and planning ALAN in public spaces.

INTRODUCTION
For decades planning artificial light at night (ALAN) has been mostly addressed as a technical issue to provide sufficient lighting levels in cities. More recently, municipalities have developed integrative lighting strategies and plans which account for ALAN from multiple perspectives, e.g., as an economic issue, as a prerequisite for activity extension into the night, as an environmental stressor for human and planetary health, and as a resource for shaping place identity and providing information and orientation in public space. Regarding the latter aspect, a preliminary literature review showed that little research and applications have been developed addressing and acknowledging pedestrian visualdiversity1, defined here as the condition and the needs of visually impaired pedestrians in public spaces at night. To counterbalance this lack of findings, open-ended interviews with experts in the field of artificial lighting and health were conducted by the authors. The interviewees confirmed the scarcity of studies and projects targeting pedestrian visualdiversity and provided insights on five issues which can be problematic for visualdiverse pedestrians, i.e., contrast, glare, illuminance, light colour and the use of new technology. Against this backdrop, this paper first illustrates materials and methods of the study and then discusses these five issues reporting recommendations shared by the interviewees. In conclusion, it suggests a framework for the application of lightwalks as an inclusive experiential method for involving visualdiverse pedestrians in assessing and planning ALAN in public spaces [1, 2].

MATERIALS AND METHODS
A preliminary literature review and open-ended interviews were conducted to research pedestrian visualdiversity and planning ALAN in public spaces.

2.1 A preliminary literature review
A preliminary review was conducted researching six pairs of key-words in several databases such as Google Scholar, Researchgate and Pubmed, taking into account results from the research fields of sociology, planning, disability studies, universal design and light planning. Specifically, the following pairs of key-words were used: artificial light and partially sighted adults, artificial light and visually impaired people, artificial light and disabled people, artificial light and impaired night vision, impaired night vision and public spaces, pedestrians at night and visual abilities. Publications of associations for blind and visually impaired people and institutions for integrative planning and design (mainly from the German speaking countries) were also scanned., including the “Lichtkonzept Berlin” - an exemplary urban lighting plan released by the Municipality of

Antonella Radicchi, **Dietrich Henckel**, *Technische Universität Berlin, Institut für Stadt- und Regionalplanung*

Berlin [3] which also does not provide lighting requirements for visually impaired pedestrians.

2.2 Open-ended interviews

Preliminary open-ended interviews were conducted with experts in the fields of artificial lighting and health, who were recruited through the authors' personal networks and via the "Allgemeiner Blinden- und Sehbhindertenverband" in Berlin and the "Unione italiana ciechi e ipovedenti". Overall, six experts were interviewed via email or over the phone. Interviews with other three experts are currently being held.

RESULTS AND DISCUSSION

3.1 Results emerging from the preliminary literature review

The results emerging from the preliminary literature review highlighted six main themes: 1) medical aspects of visual impairment and artificial light; 2) requirements and solutions for indoor lighting especially in the workplace; 3) the design of artificial light for traffic signs, signposts, the illumination of potential barriers (e.g. steps) or point of potential danger, legibility of lettering; 4) street lighting at night for driving performance and from the drivers' perspective; 5) design guidelines and standards of street lighting at night, e.g., the standards on accessibility which only tangentially refers to visual impairment issues [4, 5].

3.2 Results from the open-ended interviews

The outcomes from the interviews conducted with the experts confirmed the preliminary literature review's findings, i.e., the scarcity of studies and guidelines for planning ALAN in public spaces addressing the needs of visualdiverse pedestrians. On the contrary, the experts highlighted the numerous studies addressing indoor lighting for workplaces, suggesting that individually diverse impairments can be addressed more easily in controlled indoor settings rather than in public spaces, where the variable factors to consider are numerous and complex. Furthermore, the experts provided insights on five topics which can be problematic for visualdiverse pedestrians which deserve further studies to achieve inclusive planning of ALAN. These five issues are related to contrast, glare, illuminance, light colour and the use of new technology.

3.2.1 Contrast

Contrast perception depends on illuminance, and luminance-dependent contrasts that are sufficiently perceived during the day can no longer be recognized at night by visualdiverse pedestrians, as can easily be observed (e.g., stairs). The experts agreed that crucial requirements, i.e., enough contrast and light uniformity, should be equally implemented both indoor and outdoor. For what concerns the lighting levels, the experts highlighted that providing general recommendations is difficult due to the various types of visual impairment with different degrees of sensitivity.

3.2.2 Glare

Glare depends on excessive luminance or extreme differences in luminance in the field of vision. Having physiological and psychological effects, limiting visibility and reducing comfort the visually impaired and the elderly are more sensitive to glare. To avoid it, the experts recommended that low bollard luminaires radiating upwards or floor luminaires in walking areas should be not installed. Moreover, the risk of glare depends on the shielding of luminaires and the ratio of height of poles to distance between light poles, i.e., the greater the distance between poles, the higher the poles have to be which increases the risk of glare. Accordingly, the experts suggested that uniform illumination should be provided in public spaces and islands of light and dark sections in-between should be avoided. These measures can prevent the creation of areas perceived as dangerous (“Angsträume”) and solve problems with light-dark adaptation for visually impaired people.

3.2.3 Illuminance and light colour

The experts highlighted that it depends on the type of vision impairment whether higher – rather than the recommended minimum – illuminance levels might be required by visually impaired people.
Also, the adoption of light colour for artificial lighting similar to daylight was recommended to favour optimal contrast perception.

3.2.4 New technology in ALAN design and planning

New developments of digital technology for ALAN include the application of motion detectors or targeted lighting to provide lighting only when needed. The experts stressed that the implementation of these new technologies can be problematic for visually impaired people with delayed adaptation, because they make orientation for the further distance on the path more difficult, standing in a light- bubble in the midst of darkness. Moreover, caution is recommended in the application of the motion detectors for security-related reasons depending on the contexts. Similarly, other devices for lighting “on demand”, e.g., activating luminaires via apps or sms, should also be critically considered. In addition, the experts discussed the importance of “being seen” when planning ALAN, stressing that crossing aids such as pavement extensions or central islands should be illuminated similarly to pedestrian crossings.

CONCLUSION

Limited research and applications have been developed addressing pedestrian visualdiversity in planning ALAN in public spaces. This paper discussed five issues which can be problematic for visualdiverse pedestrians, i.e., contrast, glare, illuminance, light colour and the use of new technology, recommending that they should be further researched and considered in planning practice.
A study for the main train station in Munich developed by the Deutsche Bahn showed that the above-mentioned requirements are achievable, if they are carefully designed and specification of the luminaires are observed [6]. Further studies are recommended which may include a systematic literature review, additional interviews with experts in different knowledge areas, workshops, focus groups and lightwalks. Regarding the latter method, the authors are planning to conduct a lightwalk with visualdiverse pedestrians, building on the expertise gained through conducting lightwalks and combined sound- and lightwalks in the past years in Berlin, Rome and Florence [1, 2].

ENDNOTES

(1) We propose the novel term visualdiversity adapting it from the term “auraldiversity” coined by [7]

REFERENCES

1. Henckel, D., (2018). Lichtsituationen/Lightscapes in Berlin Friedrichshain-Kreuzberg. Ergebnisse eines Light Walks im November 2017. Available at: http://unsichtbare-stadt.de/light-walks-in-berlin/ (Accessed 13.10.2021)
2. Radicchi, A., Henckel, D., (2018). Combined Sound- & Lightwalks. A perception-based method to analyze and evaluate the sonic and light environment of our cities at night, Proceedings of EURONOISE 2018, 27-31 May 2018, Crete (G), pp. 2405-2410. ISSN: 2226-5147
3. Senatsverwaltung für Stadtentwicklung, eds, (2011). Stadtbild Berlin. Lichtkonzept. Handbuch. Berlin.
4. DIN 18040-3:2014-12 Barrierefreies Bauen - Planungsgrundlagen - Teil 3: Öffentlicher Verkehrs- und Freiraum. Available at: https://nullbarriere.de/din18040-3.htm (Accessed 30.10.2021)
5. DIN EN 17210Barrierefreiheit und Nutzbarkeit der gebauten Umgebung - Funktionale Anforderungen. Available at: https://nullbarriere.de/din-en-17210-eu-norm.htm (Accessed 30.10.2021)
6. Stockmar, A., (2013). Stellungnahme: Zur Entwicklung und zum Einsatz eines neuen LED-Leuchtensystems unter Berücksichtigung der besonderen Anforderungen von Personen mit eingeschränktem Sehvermögen. Vervielfältigt (Test provided by the author).
7. Drever, J., (2017). The Case For Auraldiversity in Acoustic Regulations And Practice: The Hand Dryer Noise Story, in ICSV24, 23-27 July 2017, London (UK)

AFFECTIVE ASSESSMENT OF URBAN PARK LIGHTING

keywords
urban lighting, virtual reality, environmental psychology, lighting quality, affective assessment

ABSTRACT
Visual comfort and performance during specific tasks have been widely studied in lighting research. However, the experience of lightened environments is more complex and involves many other aspects. One of them is the affective sphere of the individuals. Lighting has been proven to add meaning to the space by sending directly or indirectly visual cues. These messages can be affective (affect, emotion, mood), cognitive (attention, imagination, perception), associative (memory, judgement) and motivational (proximity, openness, communication). Lighting allows the environmental affective and cognitive evaluation and, as a contextual cue, results in cognitive associations that may influence people's behaviours.
As the studies on the affective perception of lighting have been mainly focused on indoor spaces, this study aims to investigate the influence of different lightings conditions on people's feelings in an outdoor scenario. Participants were presented with the virtually simulated version of an existing urban park. Specifically, the park was presented at different combinations of overall illuminance and CCT. While immersed in the virtual scenario, participants judged how each of them made them feel. Results showed that participants reported being calmer at a low than higher illuminance, whereas warm colour temperatures made participants feel weaker. Finally, participants felt happier with intermediate CCT. These results suggest that the choice of lighting type should consider its influence on the users' mood.

INTRODUCTION
Lighting can influence individuals' moods and, depending on the intensity and distribution of light, can also influence the sense of security and social ties [1]. Furthermore, it has been found that different lighting conditions are associated with different behavioural reactions [2-4] and visual performance [5-8]. However, most studies about the influence of lighting on individuals have been carried out indoor, with relatively few studies dealing with outdoor spaces [8]. This has produced a gap in the literature on the effects of lighting on individuals, which becomes even more interesting to fill if we consider the recent interest in the restorativeness effects and emotional impacts that urban parks can have on users [9].
The main objective of this study is to understand the influence of the lighting of an urban park on people's feelings. To this aim, a laboratory experiment was carried out using a Virtual Reality environment.
Virtual Reality gives us a big opportunity to provide immersive and experiential research and, despite some gaps to fill in knowledge on the accuracy that the game engines reproducing light distribution, Virtual Reality (VR) may be an essential tool to assess lighting systems from different points of view, especially those linked with the city users' expectations [10]. Casciani [11] highlighted the use of virtual technology in lighting studies as an interesting and reliable tool to explore the psychological effects of lighting conditions on public streets. Furthermore, the use of simulated images of real spaces (with real lighting fixtures) and the simulation of lighting effects are easier, relatively faster and cheaper tools to test a lighting approach than mock-ups and scale models. Therefore, assessing individuals' reactions to virtually simulated lighting environments could provide lighting professionals with guidelines on creating more accessible, social and safe public spaces.

Massimiliano Masullo, Federico Cioffi, Jian Li, Luigi Maffei, *Università degli Studi della Campania "Luigi Vanvitelli", Department of Architecture and Industrial Design*
Antonio Malferà, Francesco Ruotolo, *Università degli Studi della Campania "Luigi Vanvitelli", Department of Psychology*

METHODS

The study was conducted using a dynamic virtually simulated environment, and individuals' preferences were measured with an affective evaluation scale [9].

2.1 Materials

2.1.1 VR Environment

To simulate different lighting conditions, a virtual version of an existing urban park was built in Unreal Engine 4. Once immersed in the virtual scenario, the participant sits on a virtual bench (corresponding to a real chair) and observes the scene. Participants experienced nine virtual scenarios resulting from the combination of three levels of the luminous flux of the lamps: 250, 500 and 1000 lumen; and three CCT: 2500K – Warm; 4500K – Intermediate and 6500K - Cold. The resulting three lighting conditions of the lamps setting (at the three luminous flux) produced three overall levels of the illuminance of the park that we call I1, I2 and I3.

2.1.2 Affective questionnaire

While participants were immersed in the virtual environment, they were asked to judge the scenarios using a 12-item questionnaire (Masullo et al., 2020). Participants were asked to judge by using a 9-point Likert scale (1 = Not at all; 9 = Extremely) how much the lighting was Pleasant, Unpleasant, Stimulating, Boring, Attractive and Unattractive; and how much it made them feel Calm, Nervous, Energetic, Weak, Happy and Sad.

2.2 Procedure

After receiving information about the study and providing informed consent, then the experimental session started. Participants wore the HTC Vive Pro Eye HMD and were first shown a daylight version of the park to make them comfortable with the device. When the participant felt comfortable, the night scenario and the first lighting combination were shown. At this stage, the experimenter read each adjective of the Questionnaire and asked participants to respond on a 1 to 9 scale (from not at all to extremely). Once the evaluations for each adjective were collected, the next scene was shown. To monitor the ecological validity of the experiment, the pupil diameters were recorded by the built-in eye-tracker with a sample rate of 120 Hz and synchronized with scenario change triggers.

RESULTS

Three 3x3 RM ANOVAs treated the CCT and the overall Illuminance as 3-level within-subject factors (Warm, Intermediate and Cold for CCT; I1, I2 and I3 for the overall illuminance) were carried out. The dependent variables we considered here are just responses to the adjectives "Calm", "Weak", and "Happy".
Results on "Calm" showed the main effect of the Illuminance $F(2,48)= 11.837$, $p= <0.001$, $\eta_p^2=0.330$. The post-hoc test showed that participants felt calmer when exposed to the lower intensity of the light with respect to all other light intensities (at least $p< 0.05$).
The adjective "Weak" showed a main effect of the CCT $F(2,48)= 5.054$, $p= <0.010$, $\eta_p^2=0.174$. The post-hoc test showed that participants felt weaker when exposed to the warmer light with respect to all other colour temperatures (at least $p<0.05$).
For the adjective "Happy", results showed main effects of both Illuminance $F(2,48)= 9.023$ $p= <0.001$, $\eta_p^2=0.273$ and CCT $F(2,48)= 3.534$ $p= 0.037$, $\eta_p^2=0.128$. The post-hoc test on the CCT showed that participants felt happier when exposed to the intermediate intensity of the light with respect to all

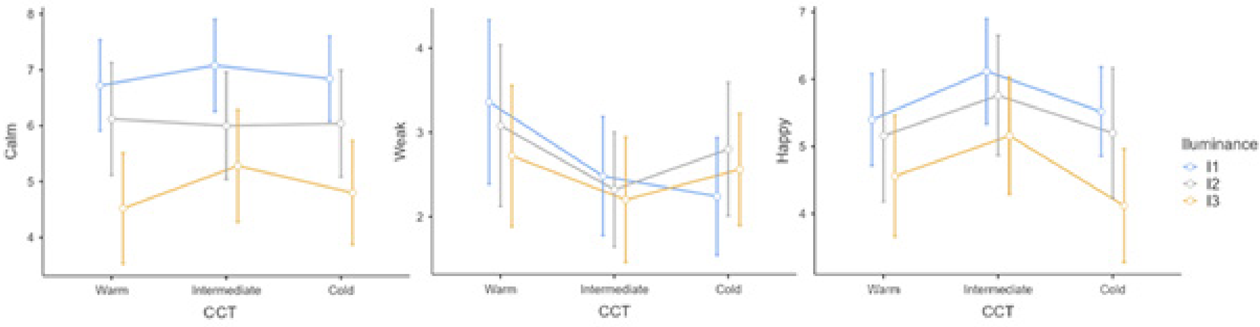


Figure 1. Marginal means and standard error related to the RM ANOVAs.

other light intensities (at least p< 0.05).
Moreover, the post-hoc test on the illuminance showed that participants felt happier when exposed to the lower intensity of the light with respect to the highest intensity light (at least p< 0.05).
The pupil diameters results confirm that all lighting conditions triggered a normal pupillary light reflex matching to the bright environment (varying from 2 to 4 mm), as with the increment of light intensity, the pupil size became narrower $F(2,48)=52.042$ $p<0.001$.

CONCLUSION

Lighting qualities add meaning to the environments, and their affective and cognitive evaluation may influence peoples' behaviours. Results showed how low overall illuminance level could induce people to feel Calm and how, as the warmer is the light, the weaker participants felt. Also, the happiness resulted moderated by the overall illuminance level.

ACKNOWLEDGEMENT

This work was supported by Programma V:ALERE 2019 “VALERE: VAnviteLli pEr la RicErca”. Project MIELE, Multisensory Investigation for ELderly-centred design of common living urban Environments

REFERENCES

1. Calvillo Cortés A, Falcón Morales L (2016) Emotions and the urban lighting environment. SAGE Open 6(1):2158244016629708.
2. Steidle A, Werth L (2014) In the spotlight: brightness increases self-awareness and reflective selfregulation. J Environ Psychol 39:40–50.
3. de Kort YAW, Veitch JA (2014) From blind spot into the spotlight. J Environ Psychol 39:1–4.
4. de Kort Y (2019) Tutorial: theoretical considerations when planning research on human factors in lighting. LEUKOS 15(2–3):85–96.
5. Blackwell, H. R. (1959). Development and use of a quantitative method for specification of interior illumination levels on the basis of performance data. Illuminating Engineering, 54, 317-353.
6. Boyce, P. R. (1973). Age, Illuminance, visual performance and preference. Lighting Research & Technology, 5, 125-140.
7. Rea MS, Ouellette MJ (1991) Relative visual performance: A basis for application. Light Res & Technol 23(3): 135–144.
8. Veitch JA, Newsham GR (1996) Determinants of lighting quality II: research and recommendations. In: Annual meeting of the American psychological association, Toronto, Canada
9. Masullo, M., Maffei, L., Iachini, T., Rapuano, M., Cioffi, F., Ruggiero, G., & Ruotolo, F. (2021). A questionnaire investigating the emotional salience of sounds. Applied Acoustics, 182, 108281.
10. Scorpio, M., Laffi, R., Masullo, M., Ciampi, G., Rosato, A., Maffei, L. Sibilio, S. (2020). Virtual reality for smart urban lighting design: review, applications and opportunities. Energies. 2020, 13, 3809.
11. Casciani D (2020) The psycho-social influence of lighting in space perception: an experimental proof of concept. Int J Archit Spat Environ Design 14(2):15–37.

IMPROVING PERCEPTIONS OF SAFETY AT NIGHT WITH LIGHT FOR MAGINALISED GROUPS IN PROFESSIONAL PRACTICE – AN ARUP LIGHTING CASE STUDY

keywords
lighting design, lighting standards, gender equity, mixed-methods, public space

ABSTRACT
In 2018, Arup conducted a research project in partnership with Monash University's XYX Lab and PLAN International to better understand how lighting affects perceptions of safety in Melbourne for women and girls. Leveraging crowdsourced data from the Free to Be Campaign of over 900 safe and unsafe night time experiences, a mixed methods analysis of technical lighting, environmental and qualitative data generated tangible, evidence based technical decisions that can be made on lighting projects to improve perceptions of safety in the built environment. The research project demonstrates the use of lighting design as a vehicle for cities to ensure that built environments are supporting and implementing gender equity goals of inclusion, equality and diversity that improve night time wellbeing. The methodology and findings from this research sets a template for professional practice to merge technical lighting design with elevating community voices of other marginalised groups, such as the aging population.

INTRODUCTION
The 2020 OECD How's Life? found a disproportion of men (80%) report feeling safer than women (50%) when walking alone at night . In a more local context, the 2019 Australia We Want study by the Community Council for Australia found that one in two women do not feel safe walking alone at night.

Everyone's experiences of the night-time is different. What can seem to be a vibrant public park for one person, can appear to be an eerie and foreboding place for another. People's night time experience of public spaces are driven by layers of an individual's lived experience, and the social and environmental factors present in the space. In creating spaces for all parts of society to feel safe and comfortable, the consideration of voices that have been historically omitted from decision making processes should be an integral design consideration. Yet, urban lighting design outcomes are often reduced to a minimum compliance approach that do not accommodate local lived experiences of marginalised groups such as gender, ethnicity, sexuality or age.

In 2018, Arup conducted a research project in partnership with Monash University's XYX Lab and PLAN International to better understand how lighting affects perceptions of safety in Melbourne for women and girls . This research project leveraged crowdsourced data from the Free to Be Campaign by XYX Lab and PLAN International, over 900 safe and unsafe night time experiences from women and girls in Melbourne – the largest of its kind in Australia.

The research demonstrates the use of lighting design as a vehicle for cities to ensure that built environments are supporting and implementing gender equity goals of inclusion, equality and diversity that improve night time wellbeing. The methodology and findings from this research sets a template for professional practice to merge technical lighting design with elevating community voices of other marginalised groups, such as the aging population.

The findings from the research allows city shapers to address key values of:
- Spatial Equity in Design
- Gender Equality
- Social and Economic Resilience
- UN Sustainable Development Goals
- The Night Time Economy

Hoa Yang, **Tim Hunt**, *Arup*

MATERIALS AND METHODS

The key intent this research aimed to challenge current compliance practices in urban lighting, and to create tangible, evidence based technical decisions that can be made on lighting projects to improve perceptions of safety in the built environment for women and girls in Melbourne, Australia. This partnership employed a mixed methods approach by applying qualitative measurements and technical analysis to an existing database of quantitative crowdsourced data (collected prior to this project).

The research is an example of how academia and industry partners can successfully come together toward achieving socially driven goals through lighting design in the built environment .

RESULTS

3.1 Findings

1. Brighter doesn't mean Safer

Brighter lights don't make people feel safer. The research has found a correlation between unsafe perceptions of space and higher brightness levels of light.

2. Layering and Context

The way light interacts with surfaces and colours in the built environment is crucial in affecting how people perceive brightness, and strongly correlated to feelings of safety and comfort. The findings suggest that a context specific, multi layered urban design approach with a considered lighting strategy is conducive to safe experiences.

3. Quality, not Quantity

The quality of the light output is more important than pure illuminance requirements once a low level of illumination is reached. The research has found that the ability to visually distinguish a bush from a person, or the colours that someone is wearing, is just as important to feelings of safety as being able to see the face of an approaching person. These issues can all be individually addressed within design solutions by specifying the right technical requirements in the light source.

4. Inclusivity and Equality

Arup's research, together with the data from the Free to Be campaign, highlight that current practices in design are not meeting the needs of the full spectrum of society. Arup has developed tools that can be easily adopted to empower, amplify and implement the needs of lived experiences, especially narratives that have previously been omitted in the design of our cities

CONCLUSION

The key finding from this research is that current codes and standards that address night time design practices do not adequately address the experiences of those who fall outside of dominant groups of society. This research has fundamentally changed the design process for shaping night time experiences in Australia, and has paved the way for the adoption of an evidence based approach to tackle social inequity globally across Arup offices.

ACKNOWLEDGEMENT

This research project was funded by Arup University. Special thanks to our partners Monash University XYX Lab and PLAN International.

REFERENCES

1. OECD (2020). Hows Life? 2020: Measuring Well-being. Paris: OECD Publishing
2. Community Council for Australia (2019). The Australia we want. Second report. [online] Canberra: Community Council for Australia.
   Available at: https://www.communitycouncil.com.au/sites/default/files/Australia-we-want-Second-Report_ONLINE.pdf
3. Arup (2019). Making Cities Safer for Girls and Women in Arup Research Review 2019. [online] Available at: https://research.arup.io/story/cities-for-girls
4. Kalms, N., Hunt, T., (2019). More lighting alone does not create safer cities. Look at what research with young women tells us.
   The Conversation [online] Available at: More lighting alone does not create safer cities. Look at what research with young women tells us (theconversation.com)

THE ROLE OF LIGHTING IN SUPPORTING TOWN CENTRE REGENERATION AND ECONOMIC RECOVERY

keywords
socio-economic value, lighting, recovery, inclusivity, night-economy

ABSTRACT
This paper rethinks the value of lighting beyond a functional add-on for safety or beautification and recognises it as a fundamental solution to improve town revenues, contributing to healthy, inclusive and sustainable lifestyles. Towns understand the economic implications of a night-time economy, but habitual night-time trends are changing and lighting must adapt according to our social needs and secure economic benefits. There is limited data placing a direct socio-economic value on lighting, so the objective was to evidence this. Nine challenges focusing on urban regeneration were identified and, collaborating with city economists, a variety of case studies responding to these challenges were investigated to gather evidence on the value of lighting.
The case studies outlined lighting interventions with positive impacts on economic development and quantified their benefits.
Ultimately, the research guides towns with investment planning for encouraging economic activity and incentivising people back into the public realm using lighting as a key resource.

INTRODUCTION
The paper explores the role of lighting in town centre regeneration and economic recovery.
We live half of our lives in darkness yet lighting after dark is so often considered only in functional terms, for example for vehicle use or to provide enough light to see the pavement ahead, rather than for human centric purposes. It looks at the potential for lighting interventions to create night-time spaces for people as well as the social and economic value of well thought out nighttime design.

The paper considers four themes
- Context: shifting focus from the cities to towns and how lighting can support recovery.
- Challenges: issues faced town centres and how their demands on them are changing
- Case Studies: evidence show the potential opportunities and their value.
- Next Steps: a business plan framework to develop a night-time design response

1.1 Context
The increase in people working from home has made suburban and smaller town centres more attractive places for people to dwell and spend their money. Sustained working from home means people want to enjoy their daily activities safely, and smaller towns bring opportunities due to their lower densities and proximity to nature. This renewed focus requires rethinking of them as places for more than just day-to-day convenience, they need to provide culture, leisure and other activities that will make them vibrant and will embrace this grown interest and make them complete. In addition to competition from online retail, COVID has brought unprecedented challenges both for people and society. Many towns have been implementing strategies to address these challenges, for example, some streets have been closed to enable social distancing. With the public reaction being generally positive, towns and cities are now looking at permanent solutions to transform the urban environment into places for people.

1.2 Role of Lighting
Light plays a vital role in our daily lives. It is fundamental to our existence, linking cultural, economic, social and political aspects of our global society. Simply put, lighting can cut form out of darkness and enhance our personal perception of safety.

Richard Morris, Bettisabel Lamelo, *Arup*

Lighting can contribute in many ways to easing the pre and post-covid challenges that town centres are facing, for example:

- Support a longer term recovery plan that supports the night-time economies
- Revitalise town centres, improve perceptions of safety, increasing footfall, dwell time and spend.
- 'Meanwhile' and long term lighting interventions promoting sustained economic and social benefit
- Lighting as a cost-effective solution ensuring a quick win for authorities and developers

MATERIALS AND METHODS

As we enter the post-covid phase it is each town's responsibility to embrace the right approaches to adapt to the 'new normal', so the research aims to help towns guide their investment towards encouraging economic activity, as well as bringing people back into the towns in a safe manner using lighting as a key resource.

The paper considers the following context of our town centres.

- How the pandemic added to renewed focus on our town centres
- Why now is the time to take action with night time design
- Why lighting can support the recovery of our town centres
- The economic value of lighting interventions
- Finally, the impact on achieving sustainability goals.

There are few studies which place a direct monetary value on improved lighting. Collaboration with economists and city planning experts researched the socio-economic value of a wide range case studies from around the world. They focused on the human factor and ways to enhance the experience and use of town centres and public space during the hours of darkness and ranged from small interventions through to large scale festivals and lighting masterplanning.

2.1 Case Studies

Case studies were chosen which responded to nine key challenges faced by town centres: ranging from attracting people back into the town centres, to reconnecting people with the natural assets and expanding beyond retail, food and beverage to multipurpose spaces for co-working and leisure.

In monetary terms, the economists investigated the financial impact in terms of the multiplier effect; namely 'direct' (e.g. retail spend), 'indirect' (spend in the supply chain) and 'induced' impact (re-spend of direct/indirect revenues in the local economy).

Research also focused on data describing the positive impact created by the lighting interventions in such terms as, increased visitor numbers, food & beverage spend, social media posts, local job creation, return on investment and cost-benefit ratio.

2.2 Sustainable Development

Beyond the economic benefits, well thought through lighting design will also help support a town achieving its sustainability goals by creating night-time environments which support well-being, social activity for all, growth and employment and the responsible use of modern technology. Partnerships are key to these goals being realised, and the development of a successful night-time strategy will be dependent on both private and public sectors working together. In the context of town centre regeneration, the research included aligning each case study with appropriate UN Sustainability Goals [1] to show the varying extent of impact and influence resultant from lighting interventions.

2.3 Business Plan

Recognising the value of lighting prompted the development of a four-step strategy to support a town's regeneration objectives. The first step was to evaluate the challenges faced by the town. Secondly, identify the parameters which will inform the lighting interventions. Thirdly, conceptualization; possible interventions are appraised and prioritized and the final step is to forma business case using research to provides social and fiscal evidence that can support it, along with existing guidance.

RESULTS AND DISCUSSION

While the research demonstrated that small and 'meanwhile' interventions can generate great impact, it is the permanent interventions that integrate multiple components (planning, landscape, etc.) that have the greatest potential to resolve town centre challenges in both the short and long terms.

The following table indicates selected positive social/economic outcome from some of the research case studies.

Project	Commentary	Statistic
B-Lit, New York, USA	Engaging a community with simple lighting interventions to build resilience, create safer places and reduce antisocial behavior.	11.2% reduction in violent crime
Croydon and Lewisham Street Lighting, UK	Community regeneration can be fostered by refurbishing street lighting systems, embracing modern technology for a sustainable solution.	7.36 benefit cost ratio
Light Neville Street, UK	Lighting can enable connections between different parts of a town by improving the perception of safety in foreboding spaces.	50,000 daily footfall
The Park, Las Vegas, USA	Encouraging dwell can be challenging, lighting plus sculptural interventions can create a point of focus and encourage social gathering.	8% increase in food sales, 2% increase in revenues in the park
Dilworth Plaza, USA	Permanent artistic interventions integrating lighting can catalyze regeneration and revenues, and have a direct impact on tourism/visitors	$2.67M annual income to City Centre District
Bradford City Park, UK	Lighting focusing on user experience to create successful, flexible and highly attractive urban spaces.	£1.3M spent in first six months since opening
Lumiere Festival Durham, UK	Lighting festivals can activate outdoor spaces and encourage economic activity, especially during winter times when footfall is reduced	£5.9M visitor spend 5.65 benefit cost ratio

Table 1: Selected Outcomes from the Case Studies

CONCLUSION

Lighting is a powerful tool integrated into projects of various scales and typologies, and it allows for a town to maximise benefits for its inhabitants when tackling regeneration projects. The research case studies evidence that lighting interventions will have multiple outcomes with a positive impact on socio-economic development, either directly, indirectly or induced.

ACKNOWLEDGEMENT

This research has been funded by Arup, a global firm of designers, advisors and experts working across 140 countries.

REFERENCES

1. United Nations Sustainable Development Goals, refer to www.un.org/sustainabledevelopment)


SOFITEL

ARTIFICIAL LIGHTING AND ITS IMPLICATIONS FOR HEALTH, WELLBEING, AND CIRCADIAN RHYTHM

Chair: **Chiara La Morgia**
Discussant: **Daan Van der Veen, Valerio Carelli**

People are born with a certain genetic make-up. This make-up makes them more or less sensible for environmental effects and exposure. What is currently known about the effects of genes and environment of health, wellbeing, and circadian rhythms? And are the effects of the environment (e.g. lightning) extra strong for older people?
In this session we will show the latest findings in the field of genetics with respect to circadian rhythm. We will also show innovative ways to study the environment by using an environment-wide approach.

CHROMATIC PUPILLOMETRY METHODS FOR ISOLATING MELANOPSIN RETINAL GANGLION CELL CONTRIBUTION TO PUPILLARY LIGHT RESPONSE

keywords
chromatic pupillometry, melanopsin retinal ganglion cells, post-illumination pupil response, pupillary light reflex

ABSTRACT

Melanopsin-containing intrinsically-photosensitive retinal ganglion cells (mRGCs) are the 3rd class of retinal photoreceptors modulating non-image forming functions of the eye as circadian photoentrainment and the pupillary light reflex (PLR). mRGCs are maximally sensitive to blue light (460-470 nm) and contribute mainly to the sustained response to light that persists also after light is switched off. mRGCs receive also extrinsic rod- and cone- synaptic inputs, so their electrophysiological activity is a combination of rod-, cone- and melanopsin-mediated light-signals. While a great deal of studies is available on animals, mRGC-investigation in humans remains at early stage due to difficulties of in-vivo mRGC-system exploration.

Given that rods, cones, and mRGCs play different roles in mediating the PLR, light-stimuli can be designed to preferentially stimulate each photoreceptor classes, providing a read-out of their function.

Chromatic pupillometry measures pupillary responses to different wavelengths and intensities of light in order to differentiate rod-, cone- and mRGC-contribution to PLR. We here report the proposed metrics of our chromatic pupillometry protocol as indirect and direct measures of the mRGC contribution to the PLR.

Chromatic pupillometry can be used to assess functionality of rods, cones and mRGC photoreceptors and can be proposed to evaluate mRGC dysfunction in neurodegenerative disorders.

INTRODUCTION

Melanopsin-containing intrinsically-photosensitive retinal ganglion cells (mRGCs) are the 3rd class of retinal photoreceptors modulating the non-image forming functions of the eye including circadian photoentrainment, sleep regulation and the pupillary light reflex (PLR)[1]. mRGCs are maximally sensitive to blue light (460-470 nm) and they contribute mainly to the sustained response to light (i.e. Post-Illumination Pupillary Response, PIPR) that persists also after light is switched off[2, 3]. mRGCs receive also extrinsic synaptic inputs from rods and cones[3], so their electrophysiological activity is a combination of rod-, cone- and melanopsin-mediated light-signals[3].

Some neurodegenerative disorders, including Alzheimer's disease and Parkinson's disease, are characterized by circadian and sleep dysfunction even in early phases of disease[4]. In this setting, a an early mRGC dysfunction or loss, which has been already demonstrated in post-mortem AD retinas[5], may contribute to the circadian and sleep dysregulation documented in these patients.

While a great deal of studies is available on animals, mRGC-investigation in humans remains at early stage[6-11] due to objective difficulties of in-vivo mRGC-system exploration.

MATERIALS AND METHODS

Given that rods, cones, and mRGCs play different roles in mediating the PLR[12, 13], light-stimuli can be designed to preferentially stimulate each photoreceptor classes, providing a read-out of their function[12]. Chromatic pupillometry measures pupillary responses to different wavelengths and intensities of light in order to differentiate rod-, cone-, mRGC-contribution to PLR[14]. Different metrics applied to chromatic pupillometry have been evaluated in assessing the mRGC contribution to PLR.

Martina Romagnoli[1], Giulia Amore[2], Pietro Avanzini[3], Gaetano Cantalupo[4,5], Michele Carbonelli[2], Pietro D'Agati[6], Jason C. Park[7], Alfredo A. Sadun[8], Valerio Carelli[1,2], Chiara La Morgia[1,6] ,
[1]*IRCCS Istituto delle Scienze Neurologiche di Bologna, Programma di Neurogenetica, Bologna, Italy.*
[2]*Dipartimento di Scienze Biomediche e Neuromotorie, Università di Bologna, Bologna, Italy.*
[3]*Consiglio Nazionale delle Ricerche (CNR), Istituto di Neuroscienze, Sede di Parma, Parma, Italy.*
[4]*Child Neuropsychiatry, Department of Surgical Sciences, Dentistry, Gynecology and Pediatrics, University of Verona, Verona, Italy.*
[5]*Child Neuropsychiatry Unit, University-Hospital of Verona, Verona, Italy.*
[6]*IRCCS Istituto delle Scienze Neurologiche di Bologna, UOC Clinica Neurologica, Bologna, Italy.*
[7]*Department of Ophthalmology and Visual Sciences, University of Illinois at Chicago, Chicago, Illinois, USA.*
[8]*Department of Ophthalmology, Doheny Eye Institute, University of California, Los Angeles, Los Angeles, USA.*

RESULTS AND DISCUSSION

We here report all the proposed metrics (Tab.1) of our chromatic pupillometry protocol[14, 15](Fig.1) as indirect and direct measures of the mRGC contribution to the PLR. Specifically, data were analyzed using custom MATLAB scripts: we evaluated PLR entity and its dynamics, by way of the previously described protocol[15] and of a new curve fitting's approach consisting in exponential fitting of the rod-mediated constriction phase of the PLR and of the mRGC-mediated PIPR re-dilation phase, as detailed in fig. 1C and 1E, respectively.

Metrics	Definition
PLR metric Peak amplitude [rod-contribution to PLR in fig.1A]	Difference between the normalized baseline and the minimum normalized PLR after light-stimulus onset.
PLR metric Contraction onset timing [rod-contribution to PLR in fig.1B]	Time taken to start pupil constriction from light-stimulus onset.
PLR metric Average slope [rod-contribution to PLR in fig.1B]	(Peak amplitude) / (contraction peak timing – contraction onset timing)
PLR metric Constriction velocity [rod-contribution to PLR in fig.1C]	By exponential fitting of the constriction phase of PLR curve in the form: y = A-B*e (-lambda*x) where A is a constant, lambda is the constriction velocity, x is time in msec.
PIPR metric PIPR [mRGC-sustained in fig.1A]	Difference between the normalized baseline and the median normalized PLR over 5-7 sec time interval from light-stimulus offset.
PIPR metric AUC early [mRGC-sustained in fig.1D]	Area under the curve over 5-7 sec time interval from light-stimulus offset.
PIPR metric Re-dilation velocity [mRGC-sustained in fig.1E]	The global rate constant of the exponential modelled PLR curve during the re-dilation phase.

Table 1. Description and definition of the proposed PLR metrics during light stimulation and PIPR metrics after light Offset.

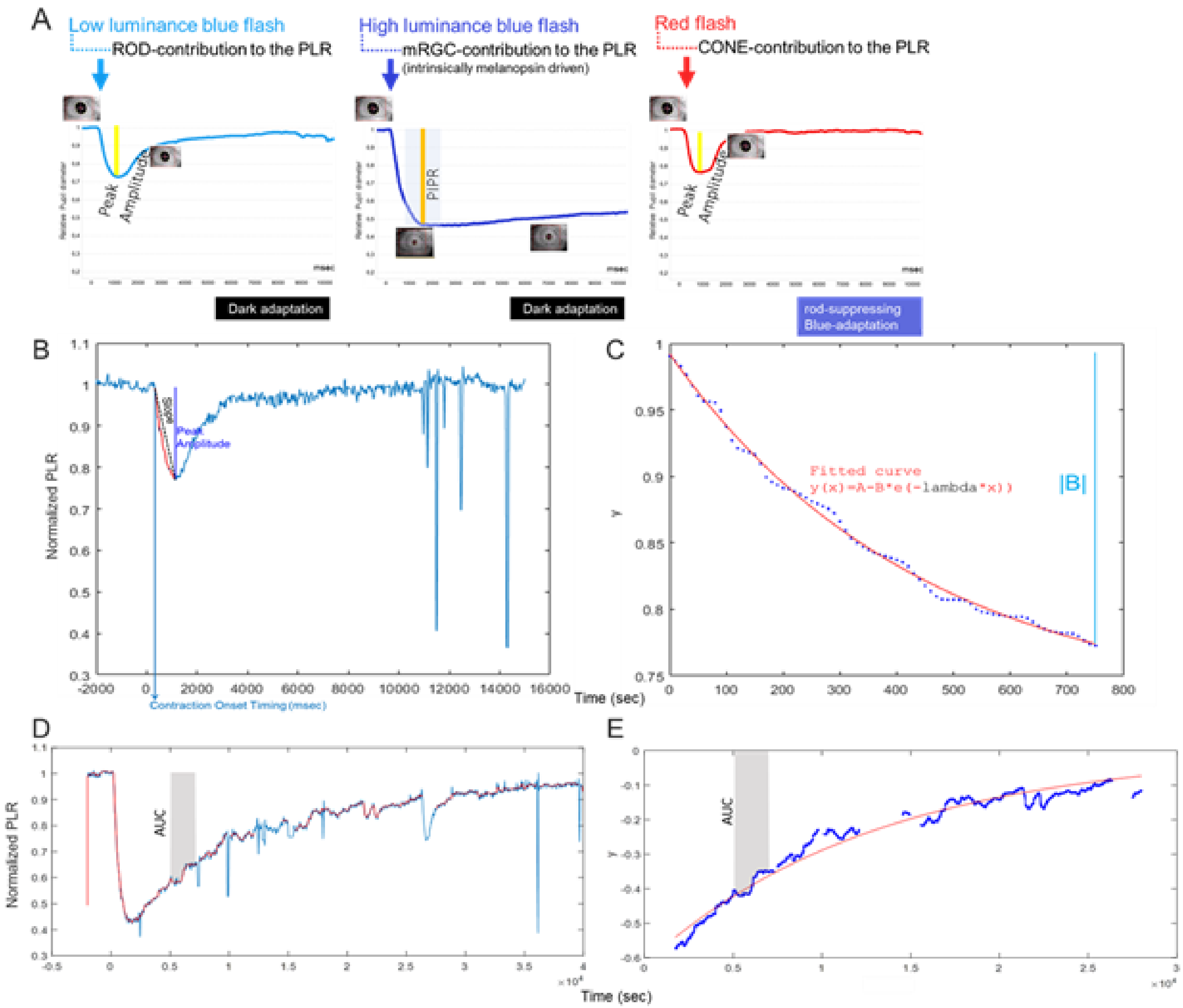


Figure 1. Chromatic pupillometry protocol14, 15: stimuli consist of short/long wavelength light 1sec-flash; for all conditions (rod/mRGC/cone) each stimulus is presented 3 times consecutively; the calculated pupillometric parameters are described in table 1. To measure directly m-RCG sustained response to PLR, PIPR is reccomended.

CONCLUSION

Chromatic pupillometry can be used to assess functionality of rods, cones and mRGC photoreceptors. Given the role of mRGCs in circadian photoentrainment, their functional evaluation using chromatic pupillometry mRGC-related responses may be proposed as an early biomarker of mRGC dysfunction in neurodegenerative disorders characterized by circadian and/or sleep dysfunction.

ACKNOWLEDGEMENT

This work was supported by the Italian Ministry of Health Young Researcher Project Grant (GR-2013-02358026 to CLM).

REFERENCES

1. La Morgia C, Carelli V, Sadun AA. Retina and melanopsin neurons. Handb Clin Neurol 2021;179:315-29.
2. Adhikari P, Zele AJ, Feigl B. The Post-Illumination Pupil Response (PIPR). Invest Ophthalmol Vis Sci 2015;56(6):3838-49.
3. Do MTH. Melanopsin and the Intrinsically Photosensitive Retinal Ganglion Cells: Biophysics to Behavior. Neuron 2019;104(2):205-26.
4. Uddin MS, Tewari D, Mamun AA, et al. Circadian and Sleep Dysfunction in Alzheimer's Disease. Ageing Res Rev 2020:101046.
5. La Morgia C, Ross-Cisneros FN, Koronyo Y, et al. Melanopsin retinal ganglion cell loss in Alzheimer disease. Ann Neurol 2016;79(1):90-109.
6. Hannibal J, Hindersson P, Ostergaard J, et al. Melanopsin is expressed in PACAP-containing retinal ganglion cells of the human retinohypothalamic tract. Invest Ophthalmol Vis Sci 2004;45(11):4202-9.
7. La Morgia C, Ross-Cisneros FN, Sadun AA, et al. Melanopsin retinal ganglion cells are resistant to neurodegeneration in mitochondrial optic neuropathies. Brain 2010;133(Pt 8):2426-38.
8. Hannibal J, Christiansen AT, Heegaard S, et al. Melanopsin expressing human retinal ganglion cells: Subtypes, distribution, and intraretinal connectivity. J Comp Neurol 2017;525(8):1934-61.
9. Ortuno-Lizaran I, Esquiva G, Beach TG, et al. Degeneration of human photosensitive retinal ganglion cells may explain sleep and circadian rhythms disorders in Parkinson's disease. Acta Neuropathol Commun 2018;6(1):90.
10. Esquiva G, Lax P, Perez-Santonja JJ, et al. Loss of Melanopsin-Expressing Ganglion Cell Subtypes and Dendritic Degeneration in the Aging Human Retina. Front Aging Neurosci 2017;9:79.
11. Esquiva G, Hannibal J. Melanopsin-expressing retinal ganglion cells in aging and disease. Histol Histopathol 2019;34(12):1299-311.
12. Rukmini AV, Milea D, Gooley JJ. Chromatic Pupillometry Methods for Assessing Photoreceptor Health in Retinal and Optic Nerve Diseases. Front Neurol 2019;10:76.
13. McDougal DH, Gamlin PD. The influence of intrinsically-photosensitive retinal ganglion cells on the spectral sensitivity and response dynamics of the human pupillary light reflex. Vision Res 2010;50(1):72-87.
14. Park JC, McAnany JJ. Effect of stimulus size and luminance on the rod-, cone-, and melanopsin-mediated pupillary light reflex. J Vis 2015;15(3).
15. Romagnoli M, Stanzani Maserati M, De Matteis M, et al. Chromatic Pupillometry Findings in Alzheimer's Disease. Front Neurosci 2020;14:780.

MULTIMODAL EVALUATION OF THE MELANOPSIN RETINAL GANGLION CELL SYSTEM IN RELATION TO CIRCADIAN RHYTHMS IN ALZHEIMER'S DISEASE

keywords
retinal ganglion cells, melanopsin, circadian, Alzheimer, pupillometry, brain functional MRI, SNPs

ABSTRACT

Melanopsin retinal ganglion cells (mRGCs) are intrinsically photosensitive photoreceptors with a crucial role in circadian photoentrainment. Circadian dysfunction is reported in AD.
In this study we evaluated the mRGC system in Alzheimer's disease patients compare to controls with a multimodal approach including neuroophthalmological evaluation, optical coherence tomography, pupillometry, actigraphy and brain functional MRI with blue and red light stimuli. Moreover, we evaluated the presence of clock genes single nucleotide polymorphisms (SNPs) in an extended cohort of AD and controls. OCT studies revealed the presence a reduced ganglion cell layer thickness in the infero-temporal sector. Actigraphic studies showed the presence of a subgroup of "circadian-impaired" subjects in the AD groups. Pupillometry showed a reduced peak amplitude of the PLR in AD compared to controls in the rod condition pointing to a possible mRGC dendropathy. Brain functional MRI showed the absence of the occipital cortex response in the AD group in response to blue light. Finally, we showed a significant association of the rs30127178 SNP in PER1 gene with AD. This study overall highlights that the mRGC system is affected in AD.

INTRODUCTION

Melanopsin retinal ganglion cells (mRGCs) are intrinsically photosensitive retinal ganglion cells mainly deputed to circadian photoentrainment and pupillary light reflex (PLR) regulation.
Circadian and sleep dysfunction is reported in Alzheimer's disease (AD) also in the early phase of the disease and contributes to dementia. Single-nucleotide-polymorphisms (SNPs) in clock genes have been previously associated to AD.

MATERIALS AND METHODS

We included 29 mild-moderate AD and 26 controls. We performed: 1) Neurophthalmological evaluation including optical coherence tomography (OCT) with retinal nerve fiber layer and ganglion cell thickness measurements 2) Actigraphic recordings of the rest-activity rhythms including non-parametric measures (IS, IV and RA) 3) Chromatic pupillometry with a protocol designed ad hoc for isolating the contribution of mRGCs to the PLR 4) Brain functional MRI (fMRI) with blue and red light stimulation. Moreover, 84 clock genes were analyzed by NGS and relevant SNPs validated in a larger cohort of AD (n=449) and controls (n=326) (Fig.1 A and B).

RESULTS AND DISCUSSION

In AD disease duration was 3.9±2.8 years and MMSEc score was 20.2±4.2. OCT showed a significant reduction of the infero-temporal GCL thickness (p=0.034) in AD, whereas the other parameters did not differ between groups. Actigraphy did not disclose significant differences for circadian parameters (IS, IV, RA). However, a subgroup of "circadian-impaired" AD was evident, and most of circadian parameters declined with aging (Fig.2). Moreover, we documented a significant increase of the total sleep time in AD patients (p=0.02). Pupillometry revealed a significant reduction of PLR peak amplitude in the rod protocol (p=0.006) which was correlated with aging in AD (Fig.3). Brain fMRI documented the absence of significant occipital cortex responses in AD with the sustained blue light stimulation at difference with controls (Fig.4). Genetic analysis in extended AD and control cohorts showed a significant association of the rs30127178 SNP in PER1 gene with AD, the G allele being protective for AD (Fig.5).

C. La Morgia[1,2], M. Mitolo[3,4], A. Santoro[5], M. Romagnoli[1], M. Stanzani Maserati[2], S. Evangelisti[4], M. De Matteis[2], F. Palombo[1], M.G. Bacalini[6], S. Capellari[2,4], P. Parchi[5,7], M. Carbonelli[4], R. Liguori[2,4], C.Tonon[3,4], R. Lodi[3,4], V. Carelli[1,4] ,
[1]IRCCS Istituto delle Scienze Neurologiche di Bologna, Programma di Neurogenetica, Bologna, Italy
[2]IRCCS Istituto delle Scienze Neurologiche di Bologna, UOC Clinica Neurologica, Bologna, Italy
[3]IRCCS Istituto delle Scienze Neurologiche di Bologna, Functional and Molecular Neuroimaging Unit, Bologna, Italy
[4]Department of Biomedical and Neuromotor Sciences, University of Bologna, Bologna, Italy
[5]Department of Experimental, Diagnostic and Specialty Medicine (DIMES), University of Bologna, Bologna, Italy
[6]IRCCS Istituto delle Scienze Neurologiche di Bologna, Laboratorio Brain Aging, Bologna, Italy
[7] IRCCS Istituto delle Scienze Neurologiche di Bologna , Programma di Neuropatologia delle malattie neurodegenerative, Bologna, Italy

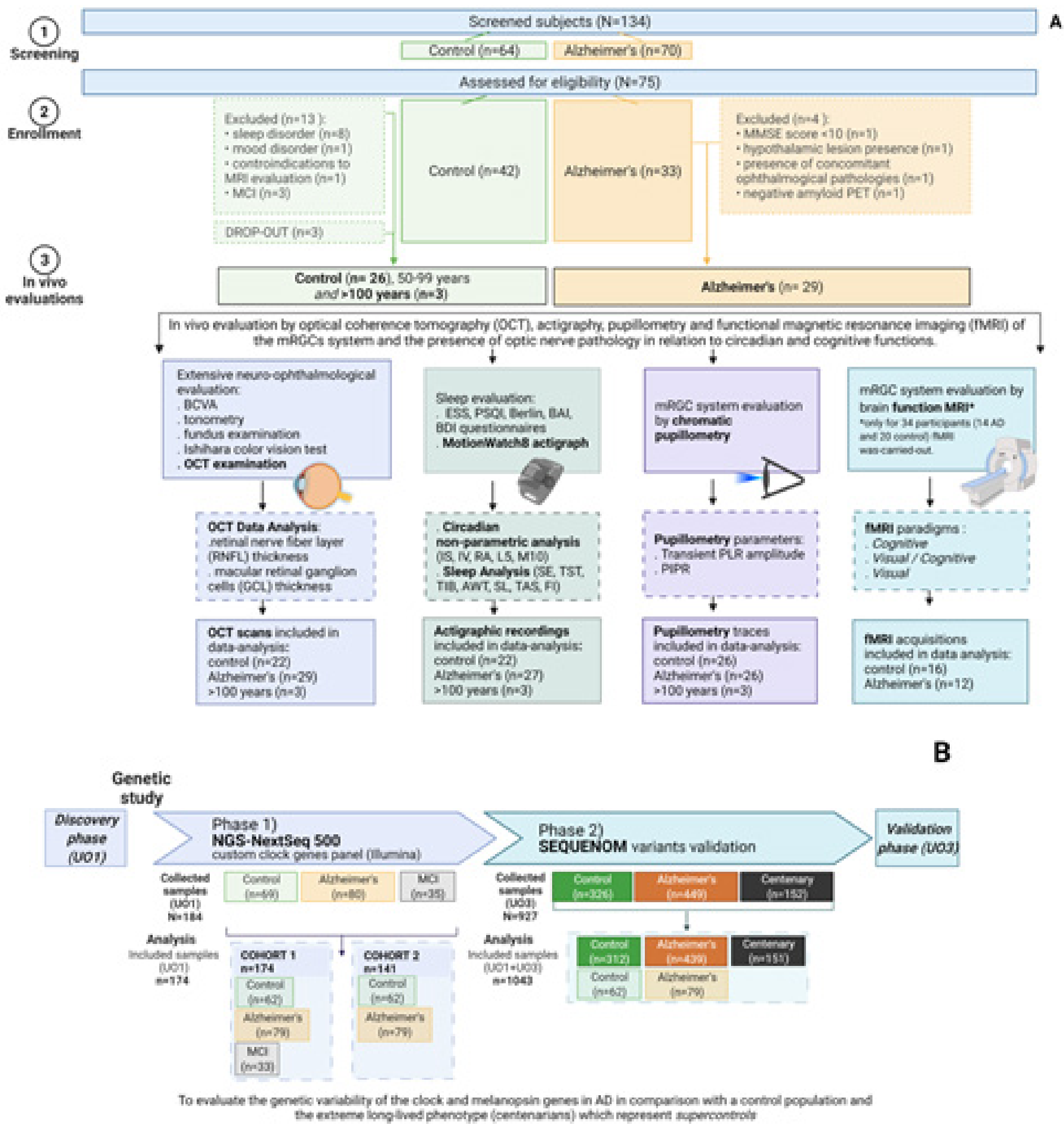


Fig.1 Flow-chart of the study

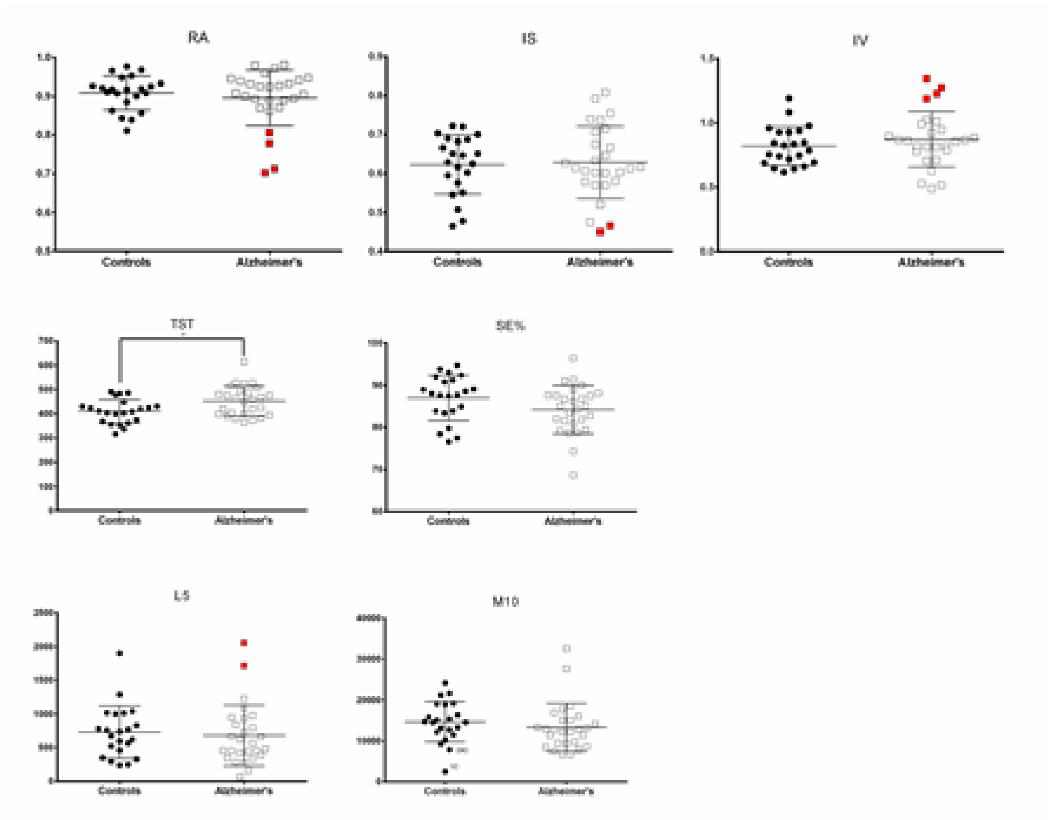
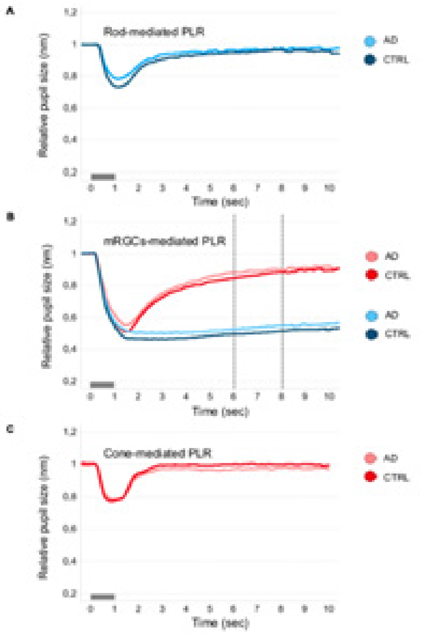


Fig.2 Non-parametric analysis of rest-activity circadian rhythm



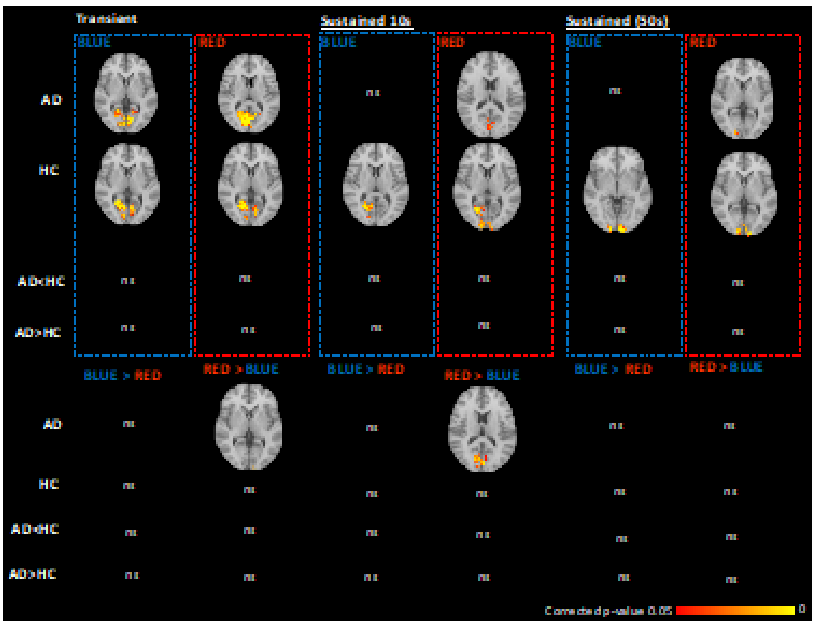


Fig.3 Chromatic pupillometry results in AD and controls

Fig.4 Brain functional MRI studies with light stimuli in AD and control

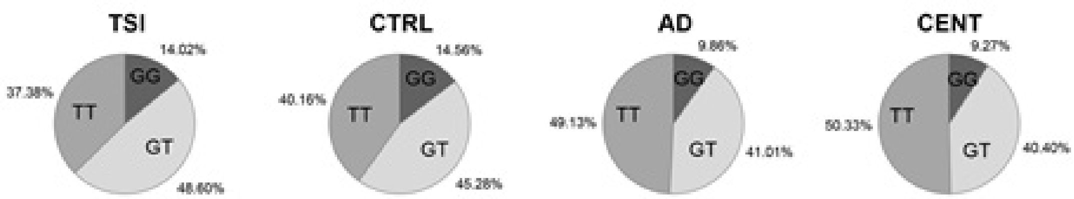


Fig.5 SNPs analysis showing the association with the rs30127178 SNP in PER1 gene

CONCLUSION

Chromatic pupillometry can be used to assess functionality of rods, cones and mRGC photoreceptors. Given the role of mRGCs in circadian photoentrainment, their functional evaluation using chromatic pupillometry mRGC-related responses may be proposed as an early biomarker of mRGC dysfunction in neurodegenerative disorders characterized by circadian and/or sleep dysfunction.

ACKNOWLEDGEMENT

This work was supported by the Italian Ministry of Health Young Researcher Project Grant (GR-2013-02358026 to CLM).

REFERENCES

1. Foster RG. Neurobiology: bright blue times. Nature 2005;433(7027):698-9.
2. La Morgia C, Carelli V, Sadun AA. Retina and melanopsin neurons. Handb Clin Neurol 2021;179:315-29
3. La Morgia C, Ross-Cisneros FN, Koronyo Y, et al. Melanopsin retinal ganglion cell loss in Alzheimer disease. Ann Neurol. 2016 Jan;79:90-109.
4. Leng Y, Musiek ES, Hu K, Cappuccio FP, Yaffe K. Association between circadian rhythms and neurodegenerative diseases. Lancet Neurol. 2019 Mar;18:307-318.
5. Do MTH. Melanopsin and the Intrinsically Photosensitive Retinal Ganglion Cells: Biophysics to Behavior. Neuron 2019;104(2):205-26.
6. Hannibal J, Christiansen AT, Heegaard S, et al. Melanopsin expressing human retinal ganglion cells: Subtypes, distribution, and intraretinal connectivity. J Comp Neurol 2017;525(8):1934-61.
7. Rukmini AV, Milea D, Gooley JJ. Chromatic Pupillometry Methods for Assessing Photoreceptor Health in Retinal and Optic Nerve Diseases. Front Neurol 2019;10:76.
8. Romagnoli M, Stanzani Maserati M, De Matteis M, et al. Chromatic Pupillometry Findings in Alzheimer's Disease. Front Neurosci 2020;14:780.
9. Daneault V, Hébert M, Albouy G, et al Aging reduces the stimulating effect of blue light on cognitive brain functions. Sleep. 2014 Jan 1;37:85-96.
10. Yesavage JA, Noda A, Hernandez B, et al. Circadian clock gene polymorphisms and sleep-wake disturbance in Alzheimer disease. Am J Geriatr Psychiatry. 2011;19:635-43.
11. Bacalini MF, Palombo F, Garagnani P, et al. Association of rs3027178 polymorphism in the circadian clock gene PER1 with susceptibility to Alzheimer's disease and longevity in an Italian population. GeroScience, accepted

GOOD LIGHT INDOORS MAKES PEOPLE HEALTHY AND HAPPY

keywords
good light, circadian rhythms, sleep, wellbeing, health, biological clock, daylight, indoor lighting, infographic

ABSTRACT

Scientific studies from recent decades make very clear that light is crucial for our health and well-being. Good light does much more than enable us to see. It is the most important “zeitgeber” for our brain and body to synchronize our internal circadian clock.
A well synchronized circadian clock enables better sleep, more daytime energy, better mood and improvements in our resistance to several diseases. The best light to synchronize our circadian clock is daylight. This has the intensity, colour and dynamics to do so effectively. Indoor lighting, however, is not intense enough and too static. During daytime it needs to be at least five times more intense and more dynamic than in current lighting practices. LED technologies make it possible to mimic the positive aspects of daylight indoors: attractiveness, dynamism, optimization and personalization. In the evening and at night, the exposure to electric light should be much lower than current practise.
This offers vital opportunities for new lighting designs and solutions and a health and well-being revolution for the more than 90% of persons with a daytime indoor activity.
In the presentation the key scientific insights in the field of good light and the guidelines to realize good light indoors will be presented in an infographic form.

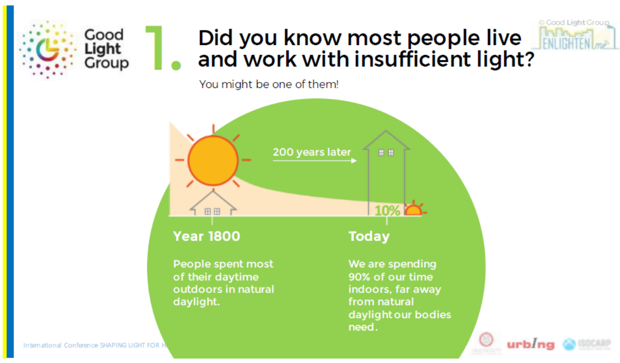
See also: A healthier and happier life | Home | Good Light Group | Foundation

PRESENTATION

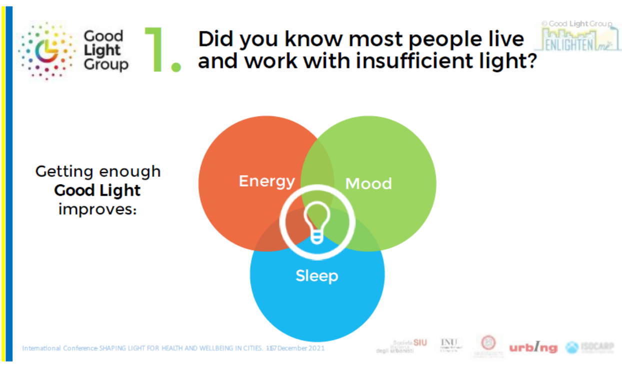
The Good Light Group is a non-profit organization that helps to spread the wealth of knowledge about the health and wellbeing effects of light to the general public. This knowledge is mainly in scientific communities and with a some lighting experts. However, the importance of light is not know to the general public. That is one of the reasons that everybody with a daytime indoor activity is still sitting in biological darkness. With negative consequences for their sleep, energy, mood and health.

Jan Denneman, *Chairman Good Light Group*

In this presentation I will give a short summary of the living situation of more than 90% of all people in the world: in insufficient light. And why this is not good for our health, since our body does need light.
Although not everything is know yet and projects like ENLIGHTENme are very important to fill in gaps. We do know enough to give already guidelines how people can improve their light situation for their health and happiness.



Homo sapiens lived for many ten-thousands of years mostly outdoors, to collect and hunt for food. Like all other living species on earth. The last 300 years, mankind moved more indoors. Especially after the industrial revolution. We spend more than 90% of our lives indoors. Shielded form nature and especially shielded from daylight.



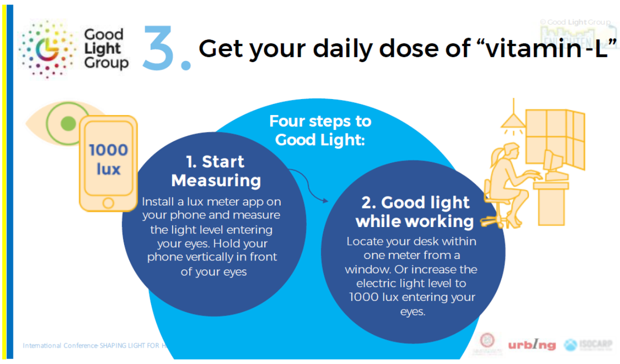
Light has an enormous influence on how well we sleep, our energy level during daytime and our mood.

People nowadays are during daytime always in dark houses, offices, factories, schools, hospitals, universities, care centres, shops, restaurants, ...

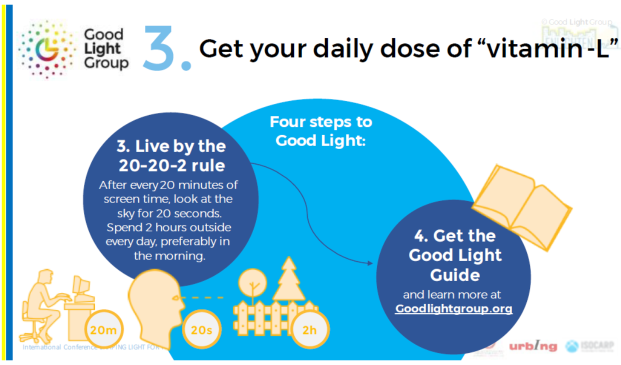
People understand that light is important for us to see. Most people are not aware that light also tells our brain what time of day it is.
It helps setting the master clock in the brain.
However, the light levels indoor are now too weak to trigger the master clock properly. We live on an earth with exact 24hr light-dark cycle and a social clock with also a 24hr rhythm.
But our body is not synchronized, with negative consequences for sleep quality, energy, mood and health.

Light is the main "Zeitgeber".

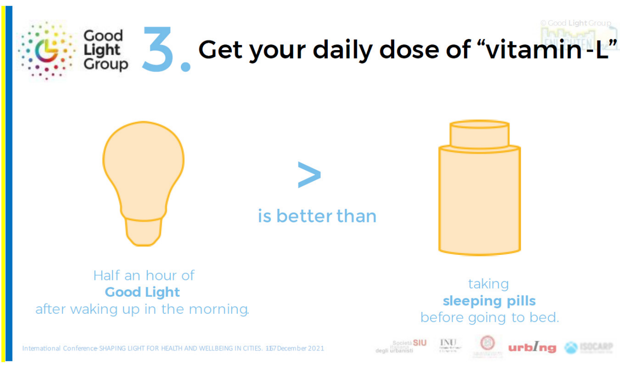
Most people have a clue about the importance of good food, good air, good exercise.
They know that this all has a positive effect on their wellbeing and health.
They are unaware that good light is also crucial for a healthy and happy life.
Good light is as important as good food!
But how to get your daily dose of "Vitamin-L"?



There are four steps to bring good light into your life, or Vitamin-L.
The first step is that people should become aware of the light they are in the whole day.
Buy a light meter or install a light meter app on your smart phone. And start discovering that that the outdoor light levels are ten to hundred times higher than indoors. And especially measure the light entering your eyes.
Locate your desk close to a window, within one meter. If this is not possible, use electric light that generates 1000 lux entering your eyes.



The third step is to live by the 20-20-2 rule. Make a habit of after every 20 minutes of concentrated work to walk to a window and look 20 seconds at the sky. And make sure to be 2 hours outdoors, preferably in the morning.
More details about good light in section **4**.
See also: Good Light Guide | Home | Good Light Group | Foundation

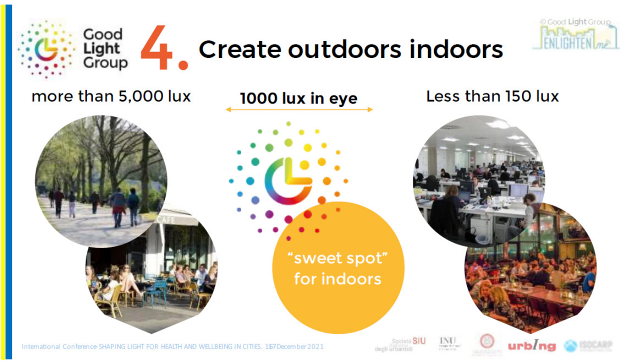


Many people do have sleeping problems. But unfortunately, they do not make the link with a distorted circadian rhythm.

We define good light, or Vitamin-L, as natural daylight or electric light that mimics daylight as good as possible.

As said earlier, our bodies need daylight. Daylight is the best. It is on and off at the right time. Has the right intensity and the right spectrum every moment of the day. If you can get a few hours of daylight every day, especially in the morning, you are set. And you don't have to worry about the light indoors.

But since most of the people spend their lives indoors, they need to worry about the light indoors!

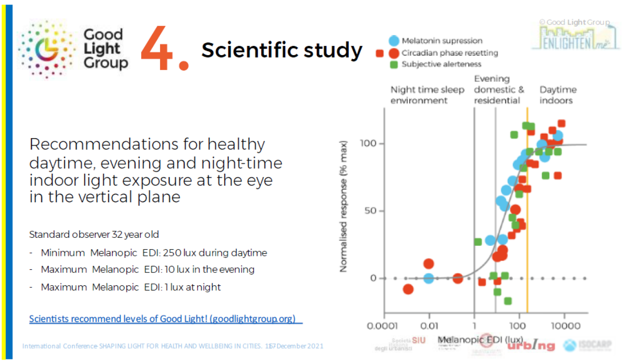


There is a huge difference between the light outdoors. That is always more that 5000 lux and reached more than 100,000 lux in summer.

Indoors is the light levels that reach our eyes are usually below 150 lux. The sweet spot to create outdoor feeling indoors is 1000 lux light intensity at the eye.

Electric light needs to mimic daylight. There are four aspects of daylight that are relevant and which are crucial for our body and brain. These four aspects are that good light is attractive, dynamic, optimized and personal.

Indoor lighting is nowadays "ambient lighting". It takes care for our vision, to create ambiance and for safety. It does however not support our health and wellbeing. Therefore, Personal Good Light is a good solution to be added to the existing ambient lighting in buildings. The Personal Good Light takes care of the health and wellbeing needs of people indoors.



Summary of the recommendations of 18 scientists about required light levels indoors.
See also: Scientists recommend levels of Good Light! (goodlightgroup.org)

Following information is available:

Infographic: A healthier and happier life | Home | Good Light Group | Foundation

Good light guide: Good Light Guide | Home | Good Light Group | Foundation
Follow

Follow us in social media, and join the group.
More info at Home | Good Light Group | Foundation
And info@goodlightgroup.org

CALCULATION TOOLS FOR THE CIRCADIAN EFFECTIVENESS OF LIGHT: A COMPARISON

keywords
circadian stimulus, circadian light, melanopic lux, melanopic equivalent daylight illuminance

ABSTRACT
A growing number of health concerns has been linked to circadian disruption, and the lack of a robust pattern of bright days and dark nights in the urban built environment is increasingly being recognized as a contributor to this disruption. For this reason, it is important for lighting practitioners to have access to tools for quantifying the circadian impacts of various light sources used indoors and outdoors. We compare three calculation tools for assessing the circadian effectiveness of light: the Melanopic Ratio spreadsheet, the luox.app calculator, and the CS Calculator 2.0. Each has a provision for estimating purported circadian lighting metrics for one or more light sources for a given light level. Comparisons are made on the basis of the types of inputs and outputs each tool includes, and on the quantitative similarity of results that should be similar when the same spectral distribution and light level is employed. The functionality, limitations and advantages of each are briefly described and discussed.

INTRODUCTION
Urban environments are characterized by numerous buildings in which people, at least in the United States [1], spend the majority of their time, and where light levels tend to be both lower than those provided by daylight outdoors and higher than those outdoors at night. In urban locations, outdoor light levels at night can be orders of magnitude higher than in unlighted areas [2] because of the proliferation of outdoor urban lighting. Many outdoor locations have light levels higher than those needed for visual performance [3] or for providing a sense of personal safety among pedestrians [4]. There have also been questions about whether and to what extent nighttime urban outdoor lighting might affect human circadian rhythms [5], although under most representative use cases, it appears unlikely that urban lighting has a large impact [6,7]. Research is also ongoing to quantify what impacts urban lighting might have on insect populations and wildlife. Discussions about the impacts of urban lighting on circadian health are not always purely objective, and quantitative tools for assessing such impacts are necessary for a rational discussion of them. For this reason, we describe and discuss several publicly available tools, their functionality, advantages and their limits.

MATERIALS AND METHODS
Three tools were identified for the purpose of this comparison; these do not exhaust all of the available calculation tools that are available but represent some different platforms (downloadable spreadsheet, webtool) that are freely available, and analysis metrics used (melanopic lux, melanopic equivalent daylight illuminance [EDI], circadian stimulus [CS]/circadian light [CL_A 2.0]) [8]. The tools investigated here include the International Well Building Institute's Melanopic Ratio spreadsheet [9], the luox.app tool developed by Dr. Manuel Spitschan and Go Free Range [10] and the CS Calculator 2.0 developed by the Light and Health Research Center at Mount Sinai [11] (see Figure 1). Comparisons among these tools include the types of input(s) and output(s) each includes, and the quantitative coherence of their calculations (e.g., to what extent do the tools produce the same results when given the same inputs).

Michael Morrison, John D. Bullough, Rohan M. Nagare, Andrew C. Bierman, Mariana G. Figueiro, Mark S. Rea, *Light and Health Research Center, Icahn School of Medicine at Mount Sinai, Menands, NY, USA*

a. b. c.

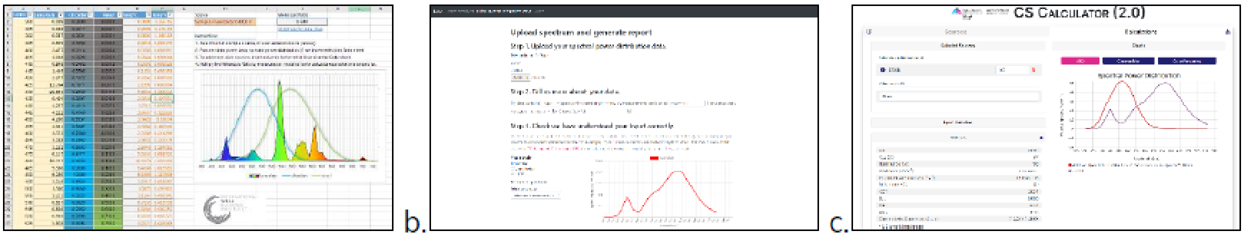


Figure 1. a: Melanopic Ratio spreadsheet; b: luox.app webtool; c: CS Calculator 2.0 webtool.

RESULTS AND DISCUSSION

3.1. Inputs and Outputs

Table 1 summarizes the key inputs and outputs of each calculation tool, as well as descriptive notes regarding required data formats, presets and defaults.

Tool	Inputs	Outputs	Notes
Melanopic Ratio	-Spectral power distribution (SPD)	-SPD graph -Melanopic lux ratio	-Spreadsheet on local device -Relative spectral calculation only -Single SPD only -380 to 730 nm spectra only -5 nm wavelength interval only -6 sample SPDs -Output ratio is multiplied by photopic lux to obtain melanopic lux
luox.app	-SPD -Photopic illuminance	-SPD graph -Illuminance (for absolute SPDs) -(x,y) chromaticity coordinates -α-opic irradiance values -α-opic equivalent daylight illuminance (EDI) values	-Webtool; can save URL -Relative or absolute SPD -Single SPD only -Data must be between 380 and 780 nm inclusive -1 to 10 nm regular integer wavelength interval required -No sample SPDs
CS Calculator 2.0	-SPD(s) -Photopic illuminance -Exposure duration -Spatial distribution scalar	-SPD, chromaticity and color rendering graphs -Illuminance (for absolute SPDs) -Irradiance -Photon flux density -CS / CL_A 2.0 values -Melanopic EDI value -α-opic irradiance values -(x,y) chromaticity coordinates -Correlated color temperature (CCT) -D_{uv} value -Color rendering index (CRI) -Gamut area index (GAI)	-Webtool; can save calculation data on local device -Relative or absolute SPD -Single or combined SPDs -Any/irregular wavelength interval and range allowed including non-integers -46 sample SPDs -CS value can be linked to nocturnal melatonin suppression -Reverse calculation: determine illuminance needed to achieve a CS value input

Table 1. Comparison of input and output parameters for each calculation tool.

A review of Table 1 shows several differences. The Melanopic Ratio spreadsheet, for example, produces a ratio than can be applied to a light source's spectral power distribution (SPD) to convert between photopic illuminance and melanopic lux. The luox.app and CS Calculator 2.0 webtools provide, among others, a quantity similar to but not exactly the same as melanopic lux, the melanopic equivalent daylight illuminance (EDI). (Melanopic lux can be divided by 1.104 to obtain the melanopic EDI value.)
Few locations are illuminated only by a single type of light source. Numerous types of sources can be used for street, parking lot, signage and other illumination applications within a single outdoor location. One potential limitation of the Melanopic Ratio and luox.app tools is that they analyze only a single source SPD. Of course a user could determine the combined SPD of any combination of light sources in a particular location ahead of time, but the CS Calculator 2.0 webtool allows the user to stipulate a photopic illuminance from several individual sources and will apply its calculations to the combined SPD.

3.2. Quantitative Comparisons

In order to compare several quantitative outputs, two SPDs (2700 K and 4000 K LEDs provided by the Melanopic Ratio spreadsheet) were evaluated by each tool for a photopic illuminance value of 18 lx at the eyes, typical of the level while standing 10 m from a streetlight [7]. Table 2 summarizes the calculation results. (Default duration and spatial distribution scalar values were used with the CS Calculator 2.0 webtool.)

Light Source	Quantity	Melanopic Ratio	luox.app	CS Calculator 2.0
2700 K LED	Chromaticity (x,y)	-	(0.4487,04067)	(0.4485,0.4067)
	Melanopic EDI (lx)	7.255*	7.2655	7
	Melanopic irradiance (mW/m^2)	-	9.6356	9.6467
	CS / CL_A 2.0	-	-	0.016 / 12
4000 K LED	Chromaticity (x,y)	-	(0.3647,0.3585)	(0.3647,0.3587)
	Melanopic EDI (lx)	12.391*	12.3715	12
	Melanopic irradiance (mW/m^2)	-	16.4072	16.411
	CS / CL_A 2.0	-	-	0.025 / 18

*Value determined by multiplying the photopic illuminance (18 lx) by the calculated melanopic ratio to obtain melanopic lux, and dividing the result by 1.104 to obtain melanopic EDI.

Table 2. Calculation results with each tool and light source for 18 lx at the eyes.

When quantities are calculated by more than one tool, the values in Table 1 did not differ by more than 4%, and this occurred only when integer values for melanopic EDI were compared to values with higher calculation precision. When values of similarly high precision were compared, they did not differ by more than 0.2%. These differences are probably caused by small differences in interpolation and rounding used by each calculation tool.

CONCLUSION

As presently configured, the CS Calculator 2.0 tool provides the most comprehensive evaluation of lighting conditions among the tools that were evaluated, in terms of both circadian metrics and color metrics such as CRI, CCT and GAI. All three of the tools that were evaluated in this exercise provided comparable results for the melanopic EDI (recognizing that the Melanopic Ratio spreadsheet does not calculate melanopic EDI directly). The small differences among comparable quantities with each tool do not have practical significance. Even the lower precision for melanopic EDI values (integer values) with the CS Calculator 2.0 tool produces differences of less than 5% at the illuminance of 18 lx used in Table 2 (relative differences will be smaller at higher illuminances). Although neither of the other calculation tools include CS or CL_A 2.0, these values are included in Table 2 to illustrate the relatively small circadian impact that 18 lx of any white light source spectrum is likely to have. CS values can be used to predict the amount of nocturnal melatonin suppression that would be caused by light with the input characteristics [8]. The CS values of 0.016 and 0.025 in Table 2 for 2700 K and 4000 K sources correspond to predicted melatonin suppression percentage values of 1.6% and 2.5%, respectively. A predicted suppression of 10% is considered an approximate threshold for the human circadian system [6], so these outdoor lighting scenarios are unlikely to have a substantial impact on the human circadian system. It is hoped that these comparisons can help inform decision-making by urban lighting stakeholders.

ACKNOWLEDGEMENT

Preparation of this publication and of the CS Calculator 2.0 was supported by the Light and Health Research Center at Mount Sinai through its Light and Health Partnership, including Axis Lighting, USAI Lighting and GE Lighting, A Savant Company.

REFERENCES

1. Environmental Protection Agency, (1989). Report to Congress on Indoor Air Quality: Volume 2, EPA/400/1-89/001C, Environmental Protection Agency, Washington, DC.
2. Li Q, Yang GX, Yu LH, Zhang H, (2006). A survey of the luminance distribution in the nocturnal environment in Shanghai urban areas and the control of luminance of floodlit buildings. Lighting Research and Technology, 38, 185–189
3. Bullough JD, (2010). Lighting Answers: Dynamic Outdoor Lighting, Rensselaer Polytechnic Institute, Troy, NY.
4. Leslie RP, (1998). A simple cost estimation technique for improving the appearance and security of outdoor lighting installations, Building and Environment, 33, 79-95
5. American Medical Association, (2016). Human and Environmental Effects of Light Emitting Diode Community Lighting, American Medical Association, Chicago, IL.
6. Figueiro MG, Rea MS, Bullough JD, (2006). Does architectural lighting contribute to breast cancer? Journal of Carcinogenesis, 5, 20
7. Rea MS, Smith A, Bierman A, Figueiro MG, (2012). The Potential of Outdoor Lighting for Stimulating the Human Circadian System, Rensselaer Polytechnic Institute, Troy, NY.
8. Rea MS, Nagare R, Figueiro MG, (2021). Modeling circadian phototransduction: Quantitative predictions of psychophysical data, Frontiers in Neuroscience, 15, 615322
9. International Well Building Institute, (2017). Melanopic Ratio [spreadsheet], International Well Building Institute, New York, NY (https://standard.wellcertified.com/sites/default/files/Melanopic%20Ratio.xlsx).
10. Spitschan M, (2021). luox: Platform for Calculating Quantities Related to Light and Lighting [software], University of Oxford, London, UK (https://luox.app/).
11. Light and Health Research Center, (2021). CS Calculator 2.0 [software], Icahn School of Medicine at Mount Sinai, Menands, NY (https://cscalc.light-health.org/).

USING POLYGENIC SCORES FOR CIRCADIAN RHYTHM TO PREDICT WELL-BEING, HEALTH, AND SLEEP

keywords
circadian rhythm, well-being, twin design, polygenic score, gene-environment correlation

ABSTRACT
Though associations between the circadian rhythm and diseases are being widely explored, associations with well-being and mental health outcomes are currently underinvestigated. To that end we will use polygenic scores (PGSs) for the circadian rhythm to predict an expansive range of well-being, health and sleep traits. The data comes from an independent sample from the Netherlands Twin Register (NTR). We will use PGSs for both objective circadian rhythm measures (relative amplitude), as well as subjective measures (morningness). In addition, we will apply a within-family design to explore signs of a passive gene-environment correlation. This extended abstract describes the study protocol. We expect that this study will provide us with a better understanding of the genetic association between the circadian rhythm and well-being.

INTRODUCTION
When it comes to the circadian rhythm, associations with physical traits and diseases are widely being explored, as opposed to associations with mental health and well-being. Phenotypically speaking, being a morning person is positively correlated with more subjective well-being[1]. Genetically speaking, being a morning person is also genetically correlated with subjective well-being meaning that the genetic variants that make one a morning person also have a positive contribution to one's subjective well-being[1,2]. Unfortunately, most studies that look at these association often don't measure well-being directly by using validated well-being measures or only measure well-being in disease cases[3].
Therefore the purpose of this study is to get a better understanding of the genetic association between the circadian rhythm and well-being. To that end we will use polygenic scores (PGSs) of the circadian rhythm to predict an expansive range of mental health and well-being measures in an independent sample. We use PGSs for both objective circadian rhythm measures (relative amplitude), as well as subjective measures (morningness). The outcome measures include a.o. subjective well-being, psychological well-being, sleep traits and general health. With this study we aim to expend the current knowledge on the relationship between circadian rhythm and well-being, from a genetic point of view.

MATERIALS AND METHODS

2.1 Predictor variables: PGSs
Summary statistics will be used to make PGSs for relative amplitude (continuous)[4]. Relative amplitude is the difference in activity between the most active 10-h period and the least active 5-h period in a complete 24-h period. This means that a high relative amplitude indicates a greater distinction between activity levels during the most and least active periods of the day, compared to a low relative amplitude. The GWAS was performed in a sample of 71,500 UK Biobank participants. We retain variants for which the effect allele frequency (EAF) is $0.01 \leq EAF \leq 0.99$. Variant EAF and effect sizes are aligned with the NTR reference for the 1000 genomes variants. Discovery variants that are not part of this reference are discarded.

Summary statistics from a meta-GWAS on morningness[2] will be used as one of the subjective measures of circadian rhythm. In that study, participants from the UK Biobank and 23andMe (697,828 in total) participants were coded as either a morning person or an evening person (binary). We retain variants for which the effect allele frequency (EAF) was $0.01 \leq EAF \leq 0.99$. Variant EAF and effect sizes are aligned with the NTR reference for the 1000 genomes variants. Discovery variants that are not part of this reference are discarded.

The processed summary statistics are taken as input for the LDpred 0.9 software. For estimating

Anne Landvreugd[1,2], René Pool[1], Michel Nivard[1,2] & Meike Bartels[1,2],
[1]*Department of Biological Psychology, Faculty of Behavioral and Movement Sciences, Vrije Universiteit Amsterdam, The Netherlands*
[2]*Amsterdam Public Health Research Institute, Amsterdam University Medical Centre, Amsterdam, The Netherlands*

the target LD structure we (1) use a selection of unrelated individuals in the NTR sample and (2) selected a set of well-imputed variants in the NTR sample. The parameter ld_radius is set by dividing the number of variants in common (from the output of the coordination step) by 12000. Note that for the coordination step we provide the median sample size as input value for N. For the LDpred step we apply the following thresholds for fraction of variants with non-zero effect (in addition to the default infinitesimal model): --PS=0.5,0.3,0.2,0.1,0.05,0.01.

We use the plink2 software package for generating the PGSs by applying the --score option to the input weighted effect sizes and the genotype data set. As scoring genotype data sets, we use the entire NTR sample or a subset of (non)transmitted paternal or maternal alleles. The latter subsets were generated by taking data from trios in the NTR genotype data set. Of each set of weighted effect sizes (infinitesimal model and additional threshold, see above) we calculate the NTR PGSs over all genotype data sets. We utilize the scores of the entire NTR sample for our analyses.

2.2. Outcome variables

2.2.1 Well-being

- *The Subjective Happiness Scale*[5] is a four-item survey where the items are rated on a Likert scale from 1 (strongly disagree) to 7 (strongly agree).
- *The Satisfaction with Life Scale*[6] is a five-item survey where the items are also rated on a Likert scale from 1 (strongly disagree) to 7 (strongly agree).
- *Quality of Life* (QoL) was measured using the Cantril Ladder[7], where participants were asked 'Where on the scale would you put your life in general?'
- *The Short Flourishing Scale*[8] consists of 8 items that participants rated from 1-7 ('strongly disagree' – 'strongly agree') on a Likert scale.
- *The adult self-report (ASR) of The Achenbach System of Empirically Based Assessment*[9] was used to measure the DSM *depressive problems scale* (N ~ 15985). Fourteen items were rated from 0-2 (0 = not true, 1 = somewhat true, 2 = very true). An example item is: 'I worry about the future'.
- In addition to the sum scores for the ASR DSM *depressive problems scale*[9], the data will also include the fourteen individual items of the scale (N ~ 15985).

2.2.2 Health

- *Self-rated health* was assessed using a single item: 'How would you rate your general health?'[10]. Participants rated the item on a 5-point Likert scale ranging from 'Bad' to 'Excellent'.

2.2.3 Sleep

- A single item was used to assess chronotype (N ~ 7987): 'Are you a morning-active or evening-active person?' The scale ranges from 1-5 with 1 representing a morning-active person and 5 representing an evening-active person.

2.3 Analyses

2.3.1 Polygenic score prediction

In the first analysis, we will test whether the PGSs for moningness and relative amplitude can be used to significantly predict the well-being, health, and sleep traits. For this, we will apply Generalized Estimation Equation (GEE) modeling[11] with a conditional covariance matrix to account for the fact that observations for family members are dependent. We will include age, age^2, sex, and the first 10 principal components (PCs) as covariates. For the GEE estimation, we will handle a Bonferroni-corrected significance value (0.05/14 = 0.0037. This is based on the 7 scale outcome measures and the two kinds of PGSs) and we will estimate 95% confidence intervals around the R^2's using the R-package ,Psychometrics[12].

If the PGSs are able to significantly predict the DSM depressive symptoms sum scores, we will perform as sensitivity analysis to test whether the association between the PGSs and the depressive symptoms scale is essentially driven by the sleep related items in that scale. To this end, we will regress the PGSs on the fourteen individual depressive symptoms items, while handling an adapted Bonferroni-corrected significance value (0.05/42 = 0.001. This is based on the 7 scale outcome measures, the 14 ASR DSM outcome measures and the two kinds of PGSs).

2.3.2 Within-family design

As a follow up analysis for the significant predictions we will apply a within-family genetic design to detect passive gene-environment correlations (prGE). The theory behind this design is that parents generate an environment for their offspring that is partially evoked by their own genotypes. Therefore, there is a correlation between the offspring phenotype and genotype that is induced by the fact that the parental genotype causes the offspring genotype and also shapes the offspring environment. That's why an estimate of the effect of a PRS on an outcome not otherwise adjusted for the family environment is likely to include both direct genetic effects and indirect effect through prGE. We are able to disentangle these direct genetic and indirect effects by using a within-family design applied to dizygotic (DZ) twin pairs. The intuitive reasoning behind the model is as follows: 1) siblings share the same parental genetic influences that have shaped their environment, 2) using within-family further rules out bias due to population stratification and assortative mating[13] and 3) using DZ twins rather than sibling further controls for parental age, family income at a given age, pregnancy risk factors[13]. Our study will use morningness and relative amplitude as predictors, and the previously mentioned variables on well-being, health and sleep as outcome variables.

ACKNOWLEDGEMENT

The authors thank all the NTR participants, who participate in this study.

REFERENCES

1. O'Loughlin, J., Casanova, F., Jones, S. E., Hagenaars, S. P., Beaumont, R. N., Freathy, R. M., Watkins, E. R., Vetter, C., Rutter, M. K., Cain, S. W., Phillips, A. J. K., Windred, D. P., Wood, A. R., Weedon, M. N., & Tyrrell, J. (2021). Using Mendelian Randomisation methods to understand whether diurnal preference is causally related to mental health. Molecular Psychiatry. https://doi.org/10.1038/s41380-021-01157-3
2. Jones, S. E., Lane, J. M., Wood, A. R., van Hees, V. T., Tyrrell, J., Beaumont, R. N., Jeffries, A. R., Dashti, H. S., Hillsdon, M., Ruth, K. S., Tuke, M. A., Yaghootkar, H., Sharp, S. A., Jie, Y., Thompson, W. D., Harrison, J. W., Dawes, A., Byrne, E. M., Tiemeier, H., … Weedon, M. N. (2019). Genome-wide association analyses of chronotype in 697,828 individuals provides insights into circadian rhythms. Nature Communications 2019 10:1, 10(1), 1–11. https://doi.org/10.1038/s41467-018-08259-7
3. Bromundt, V., Wirz-Justice, A., Boutellier, M., Winter, S., Haberstroh, M., Terman, M., & Münch, M. (2019). Effects of a dawn-dusk simulation on circadian rest-activity cycles, sleep, mood and well-being in dementia patients. Experimental Gerontology. https://doi.org/10.1016/j.exger.2019.110641
4. Ferguson, A., Lyall, L. M., Ward, J., Strawbridge, R. J., Cullen, B., Graham, N., Niedzwiedz, C. L., Johnston, K. J. A., MacKay, D., Biello, S. M., Pell, J. P., Cavanagh, J., McIntosh, A. M., Doherty, A.,

Bailey, M. E. S., Lyall, D. M., Wyse, C. A., & Smith, D. J. (2018). Genome-Wide Association Study of Circadian Rhythmicity in 71,500 UK Biobank Participants and Polygenic Association with Mood Instability. EBioMedicine, 35, 279–287. https://doi.org/10.1016/J.EBIOM.2018.08.004

5. Lyubomirsky, S., & Lepper, H. S. (1999). A Measure of Subjective Happiness: Preliminary Reliability and Construct Validation. Social Indicators Research, 46(2), 137–155. https://doi.org/10.1023/A:1006824100041
6. Diener, E., Emmons, R. A., Larsem, R. J., & Griffin, S. (1985). The Satisfaction With Life Scale. Journal of Personality Assessment. https://doi.org/10.1207/s15327752jpa4901_13
7. Cantril, H (1965). The pattern of human concerns. New Brunswick,NJ: Rutgers University Press
8. Diener, E., Wirtz, D., Tov, W., Kim-Prieto, C., Choi, D. won, Oishi, S., & Biswas-Diener, R. (2010). New well-being measures: Short scales to assess flourishing and positive and negative feelings. Social Indicators Research. https://doi.org/10.1007/s11205-009-9493-y
9. Achenbach, T. M., & Rescorla, L. a. (2003). Manual for the ASEBA Adult Forms & Profiles. English.
10. Eriksson, I., Undén, A. L., & Elofsson, S. (2001). Self-rated health. Comparisons between three different measures. Results from a population study. International Journal of Epidemiology. https://doi.org/10.1093/ije/30.2.326
11. Halekoh, U., Højsgaard, S., & Yan, J. (2006). The R package geepack for generalized estimating equations. Journal of Statistical Software. https://doi.org/10.18637/jss.v015.i02
12. Schwarzer G (2007) meta: An R package for meta-analysis. R News 4:40–45
13. Selzam, S., Ritchie, S. J., Pingault, J. B., Reynolds, C. A., O'Reilly, P. F., & Plomin, R. (2019). Comparing Within- and Between-Family Polygenic Score Prediction. American Journal of Human Genetics. https://doi.org/10.1016/j.ajhg.2019.06.006

URBAN ANALYTICS AND INNOVATIVE URBAN LIGHTING POLICIES FOR HEALTH AND WELLBEING

Chair: **Elisa Conticelli**
Discussant: **Aitziber Egusquiza, Mark Burton-Page**

Even if there is an increased concern about the effects of exposure to artificial lighting on health and wellbeing, they are not enough considered in the current urban policies yet. Instead, urban lighting policies suffer from a sectorial approach mainly oriented to reducing energy consumption and CO2 emissions, as well as improving urban safety or strengthening city branding.

Human health and wellbeing implications due to urban lighting is a topic that remains rather unexplored in the current urban lighting plans.

The aim of this session is to emphasize innovative urban lighting policies and plans, good practices and pilot actions embracing diversified goals among which wellbeing and health promotion is comprised. Notably we really welcome contributions presenting urban modelling and spatial statistics for lighting, health and wellbeing, strategies for reducing negative effects on health and wellbeing due to artificial lighting, ensuring an equal and free access to urban lighting, creating a safe and comfortable environment, fostering cultural identity and urban atmosphere, and supporting environmentally friendly mobility. Case studies incorporating quantifications of economic savings through reduced light pollution, optimizing energy consumption and promoting healthier populations are appreciated as well.

HUMAN CENTRIC OUTDOOR PUBLIC LIGHTING

keywords
light pollution, human centric lighting, lighting design, outdoor lighting

ABSTRACT
At the 2009 Professional Lighting Design Convention in Berlin, French lighting designer Roger Narboni declared that "architectural lighting is dead" - setting a challenge to move away from simply brightening roads to lighting for people. Lighting design have become an essential element in city beautification, by proposing diversified, attractive lighting schemes and by corresponding to the new expectations of town dwellers. If we overabound lighting design with excessive requirements, we will likely define flat and indistinct outdoor lighting and we could fail to achieve basic requirements such as face recognition and pleasantness. In this paper we will discuss a possible balance between lighting common requirements (i.e., minimum visual requirements or light pollution mitigation) and a more human centered outdoor lighting.

INTRODUCTION
EU member countries have common standards that define performance and energy criteria for artificial outdoor lighting (such as EN 13201 or EN 12464 series, eco-design requirements, etc.).
Unfortunately, there is no EU standards for limiting light pollution – and only few Countries have adopted specific laws on the subject (Czech Republic, France, Germany, Slovenia and also Spain and Italy, but only for some of their Regions).
If we wanted to combine the common requirements of EU common standards and light pollution laws, we would find that the only fixtures allowed are full cut-off luminaires, aimed at maximizing the height and the distance between the poles and at minimizing the lumen needed to satisfy the minimum illumination requirements (mainly the luminance/illuminance of the road/pavement surface). Moreover, many light pollution policies narrow down also the range of permitted lighting sources (i.e., LED with CCT lower than 3000K or HPS lamps).
While this could be a feasible option for road lighting, it is a poor choice for all other applications. When we are designing for social interaction, accent and façade lighting, historical heritage, etc. we need a wider choice of luminaires and technical solutions. Therefore, we must try to define new criteria that should aim at decreasing energy consumption and light pollution, without limiting the design options available.

MATERIALS AND METHODS
Our proposal derives from our experience in public lighting and our participation in some of the most important regulatory tables about lighting, sustainability, and environment. Conclusions are drawn from our work in co-chairing the regulatory table for Italian Green Public Procurement for Public Lighting.

RESULTS AND DISCUSSION
3.1 Road lighting
According to the publication of the International Commission on Illumination CIE 115:2010 "Lighting of roads for motor and pedestrian traffic" [1] there are four main purposes of road lighting:
1. Provide visual conditions so that all users can perform the needed driving tasks and proceed safely,
2. Allow pedestrians to see hazards and to orientate themselves,
3. Allow pedestrians to recognize other pedestrian's face, and to give an adequate sense of security,

Matteo Seraceni
Hera Luce

4. Improve the appearance of the environment particularly during the hours of darkness, e.g. to increase the readability of an urban area.

In the lighting of individual roads or public spaces the relative importance of these items should be evaluated, since the needs differ. Indeed, EU standards and current practice aims to fulfill only minimum ground illuminance (or luminance) and uniformity, leaving in the background points (3) and (4).

LED streetlights usually produce very directional light rather than a "diffused light" (as in old HID luminaires): This creates a specific, well-lit area while avoiding light trespass and wasting flux outside the area to be lit (Figure 1). Nevertheless, with a full cut-off luminaire, for broad streets, it is almost impossible to achieve good vertical illuminance (if we don't want to use extremely high mounting height).

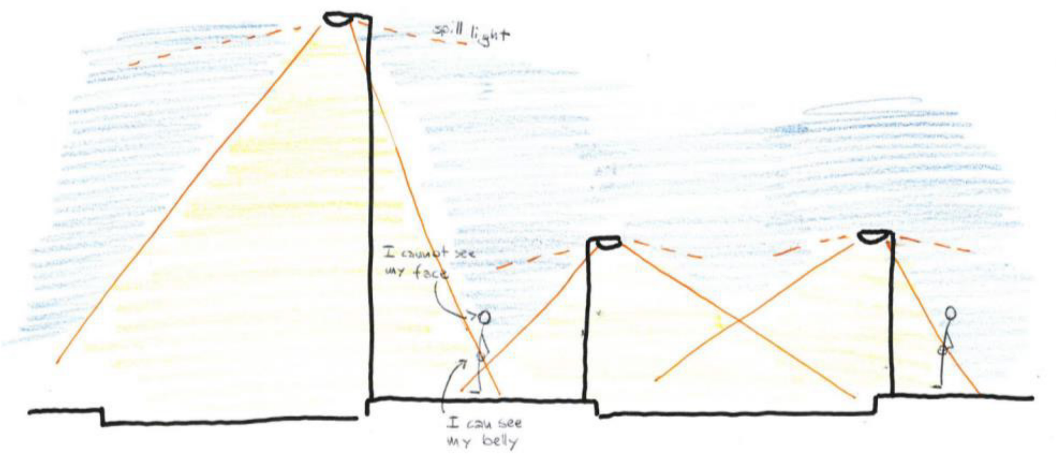


Figure 1. Full cut-off LED light beams

It is not uncommon to see good lit roads, but with sidewalks (or nearby surroundings) poorly lit, where it is almost impossible to recognize people's faces.

3.2 Light pollution

Light pollution is what we could call a side effect of anthropogenic light propagation into the nocturnal environment. The first studies were focused on its impact on the starry sky; nowadays light pollution has widened its meaning by including effects as sky glow, light trespass, over-illumination, and glare - but also by including adverse effects on wildlife and human health.
Common guidelines for lowering light pollution could be summarized in four points:

a) Reduce upward luminous flux and direct light only over "useful" area,
b) Use the lowest possible intensity to satisfy minimum requirements for every area,
c) Avoid cold white light,
d) Adapt exterior lighting to times of use.

Private lighting plants are primarily responsible for light pollution so, without both public and private regulations, all efforts could be ineffective.

In some ways, points (a) and (b) have a lot in common with the previous paragraph.
For the man depicted in Figure 2, having a dark surrounding would be good while on his private property, but could be disappointing in public places. The definition of "useful light" may vary depending on the contest. For example, in urban environments it might be desirable to use some light provided by the road lighting installation enhancing building façades or providing vertical illuminance for social interactions: In these cases, the luminous flux onto the facades or upon people must be regarded as useful light although it might lower the energy efficiency of the road lighting as such.

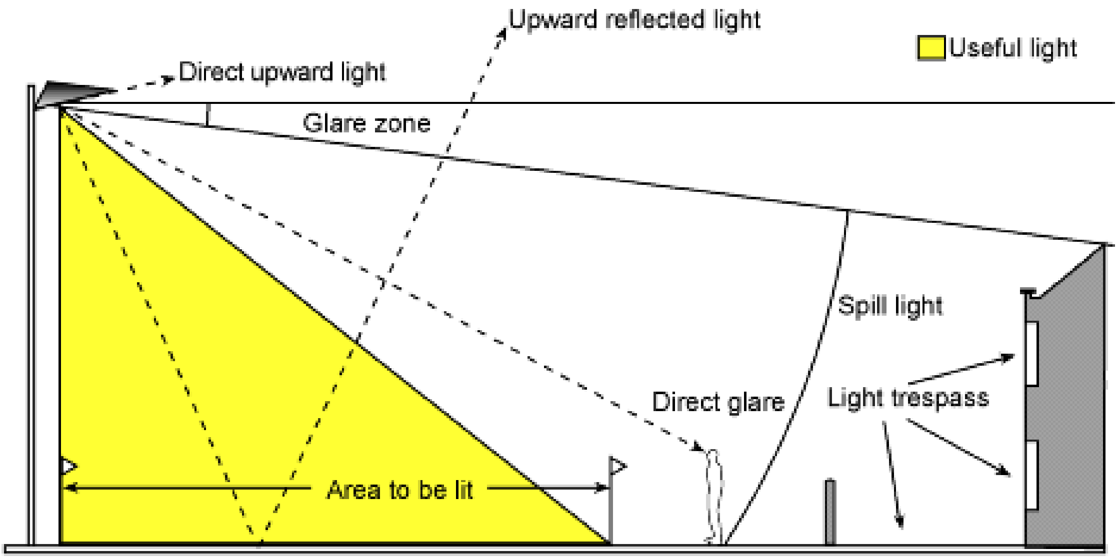


Figure 2. Figure Header

Many articles claim that blue rich light (or cold white light) could double (or more) the impact on starry sky than other sources (see point (c)). However, this is strictly true under specific conditions: a scattered monochromatic light, under good meteorological conditions and without any kind of reflection or obstacle in its path. For instance, buildings can block or drastically change the spectrum of a luminaire.
For the last point, we find that adapting the luminous flux in relation to traffic volume, time, or other influencing parameters, is a good way to reduce light pollution as well as energy consumption, without diminishing the functionality of outdoor lighting.

3.3 Circadian effects of outdoor lighting

It is known that light has a great effect on circadian rhythms. For what we know, although there is still much to discover about, we could assume that outdoor light levels could have very little impact on circadian system [2].

But outdoor lighting could also have adverse effects on plants and animals – with each species differently affected by different parts of light spectrum. So, it is impossible to define a generic strategy not to harm any living being – apart from switching off lighting when it is not needed.

3.4 Beyond road lighting

In recent years, the human and social dimension of urban "lightscape" has become a new theme of interest of both research and design practice in the lighting domain [3].
In comparison to energy, technical, and economic issues, the social and experiential value of urban public lighting is difficult to estimate and is rarely considered when policy decisions are made.
Nevertheless, we can list some of the best practices regarding urban public lighting:

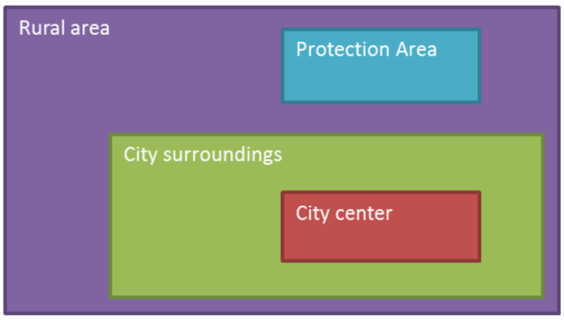
- people should have the right light for their needs,
- vertical (and semicylindrical) illumination could provide a better metric for public places,
- uniformity is more important than luminance or illuminance values,
- accent bright lighting among specific urban elements and paths may attract visual attention,
- individual districts and activities must be provided with character identification, such as specific color temperature or original lighting patterns,
- illumination should follow the rhythm and pace of social life,
- dark areas are equally important and essential as lit areas.

CONCLUSION

The idea of outdoor public lighting is based on three (mostly) antithetical positions: seeking economic savings and technical performance based on quantitative measures (i.e., EU lighting standards); reducing at most outdoor lighting, in every case (i.e., light pollution laws); concurring to urban amenity city beautification and stimulating night-time activity.
This diversity of views makes the policy making exercise particularly challenging. For this reason, we could start by highlighting the points in common between the aforementioned approaches:

- in meeting places, we should grant good face recognition, even with low mounting height luminaires, but also façade lighting or accent lighting. In town centers and city surroundings, light beams would be likely shielded by surrounding buildings;
- conversely, in rural areas, we have limited barriers. Within specific area of environmental protection, we should use the lowest luminous flux and grant near-dark sites;
- street lighting can have nearly-zero upward flux without compromising their performances;
- outdoor lighting should be used only when needed.

Italian GPP have aimed at providing a simple yet effective upward light limitation, that can ensure the highest levels of safety and well-being and, at the same time, can allow the right vertical illuminance where needed.
We used four lighting zones based on European town planning scheme: LZ0: No ambient lighting (protection zones), LZ1: Low ambient lighting (rural zones), LZ2: Moderately ambient lighting (residential and commercial zones outside city centers), LZ3: High ambient lighting (town centers). Then, we have established an uplight rating for every correspondence between zones and applications (i.e., street lighting, pedestrian lighting, etc.).



	U1 (lm)	U2 (lm)	U3 (lm)	U4 (lm)	U5 (lm)
UH	≤ 50	≤ 150	≤ 400	≤ 600	≤ 1000
UL	≤ 50	≤ 100	≤ 200	≤ 300	≤ 500

	LZ1	LZ2	LZ3	LZ4
Street lighting	U1	U1	U2	U2
Area lighting, roundabout, parking lot	U1	U2	U3	U3
Pedestrian area and bike lane lighting	U1	U2	U3	U4
Green area lighting	U1	U2	U3	U4
City center with historic lantern	U2	U3	U4	U5

Figure 3. . Italian GPP criteria for reducing light pollution

Moreover, we suggest that in city centers, where direct light is just a small part of overall light pollution, there should be no restrictions in lighting sources color temperature.
And, finally, we strongly believe that providing light only where and at the time and in the quality required, could increase the quality of nocturnal public spaces while reducing light pollution and saving energy.

REFERENCES

1. Technical Report CIE 115:2010 “Lighting of roads for motor and pedestrian traffic”, 2nd edition, Vienna.
2. Bellia, L., Seraceni, M., (2013). A proposal for a simplified model to evaluate the circadian effects of light sources, Lighting Research & Technology, Vol 46, Issue 5, 2014.
3. Casciani, D., (2020). The Human and Social Dimension of Urban Lightscapes, Polimi Springerbriefs, Milano.

FRAMEWORK FOR EVALUATING URBAN LIGHTING ALTERNATIVES BASED ON ENERGY, LIGHT POLLUTION AND PERCEIVED SAFETY

keywords
street lighting, light pollution, perceived safety, light trespass, energy efficiency

ABSTRACT
To be sustainable, outdoor lighting in urban areas must balance the benefits provided to the population against its costs and potential negative impacts. The transition from conventional outdoor light sources such as high-intensity discharge (HID) lamps to light emitting diode (LEDs) has resulted in opportunities to retrofit and redesign urban streetlighting installations throughout the world. To help specifiers evaluate different LED systems with wide variations in lighting performance, an evaluation tool framework has been developed which allows the user to prioritize performance outcomes (i.e., energy efficiency may be of primary importance in one case, and perceptions of safety in another case). The tool uses inputs generated from lighting design software and a ranking methodology to assess the relative performance outcomes, which include energy usage, uplight contributing to sky glow, vertical illumination contributing to light trespass, and high angle light contributing to glare. The outcomes also include predicted ratings of personal safety from the lighted environment based on a newly published and validated model that includes the average light level, the uniformity of illumination, and the correlated color temperature (CCT) of the lighting. In this extended abstract we introduce the evaluation framework and describe the model for predicting perceptions of personal safety. It is hoped that this framework can form the basis for rational comparisons among lighting alternatives using a range of relevant criteria (eventually including impacts on insects and wildlife) to help specifiers make selections that will enhance the sustainability of outdoor lighting while maintaining useful performance.

INTRODUCTION
Outdoor lighting in urban areas is installed for multiple reasons [1]. Reducing traffic crashes and crashes involving pedestrians is one [2], enhancing pedestrians' feelings of safety and personal security is another [3]. At the same time, expenses for urban lighting are large and streetlighting costs, including energy consumption, are among the largest line items in many U.S. municipal budgets. Further, there is a rapidly growing body of knowledge about the potential negative consequences of outdoor lighting at night, including (but not limited to) light pollution impacts [4] such as contributing to sky glow, the increased brightness of the nighttime sky; to light trespass, where light falls on adjacent properties and can potentially disturb residents or wildlife; and to glare, which reduces the ability of pedestrians and drivers to see comfortably at night.

Regarding pedestrian safety, it has been shown [5,6] that in order to have sufficient visibility for older pedestrians to see potential obstacles and elevation changes in walking areas, an illuminance of 2 lux is sufficient to ensure high levels of visual performance. Yet feelings of personal safety appear to require higher levels overall. Further, these perceptions are based not only on the light level, but are also influenced [3] by the degree of uniformity of the illumination outdoors, and by the spectral distribution of the lighting, which can be characterized by its CCT. Higher CCTs have relatively more short-wavelength (blue) content, which results in outdoor scenes that are perceived by people as brighter and hence "safer" [7] than others with lower-CCT sources. Using a scale model setup, a laboratory study to assess perceptions of safety from outdoor lighting varying in level (E, illuminance in lux), uniformity (U, max:min illuminance ratio) and CCT (C, in kelvins) resulted in a quantitative model [7] to predict ratings of perceived safety (S) from very unsafe (–2) to very safe (+2):

$$S = 2 - 4[1 + (\frac{E(2\log C - 5.55)}{0.67U + 4.49})^{1.75} \qquad \text{(Eq. 1)}$$

Kasia Kozak, *Lighting Research Center, Rensselaer Polytechnic Institute, Troy, NY, USA*
John D. Bullough, Jennifer A. Brons, *Light and Health Research Center, Icahn School of Medicine at Mount Sinai, Menands, NY, USA*

This model was validated in outdoor field evaluations of real-world outdoor lighting installations in five parking lots illuminated to varying light levels to varying degrees of uniformity and by sources varying in CCT [8]. Predicted ratings and actual ratings were strongly correlated (r^2 = 0.98).

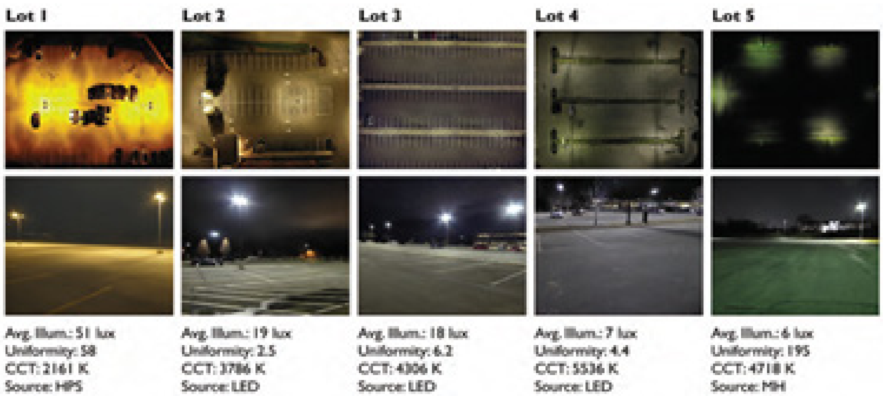


Figure 1. Installations used to validate the outdoor lighting safety prediction model.

The city of Troy, New York in the U.S. is an example of an urban community looking to improve its streetlighting system and increase energy efficiency. The city includes a compact urban downtown area, which is surrounded by residential neighborhoods that have high levels of foot traffic at night. Locations in each of these types of areas were selected as test cases. Presently, the streetlighting system is owned and operated on the city's behalf by the local electric utility. The city has been negotiating with the utility and with the New York State public service commission to purchase the streetlighting system and replace the HID luminaires with LED ones to reduce operating costs and hopefully, improve the visual impacts of the lighting.

MATERIALS AND METHODS

The existing conditions in each location (downtown and residential) were measured and documented as summarized in Table 1. The downtown location had very high light levels and that the levels in the residential area were quite low. The downtown location was illuminated by cobrahead luminaires with high pressure sodium lamps, and the residential area by teardrop luminaires with metal halide lamps. The data in Table 1 were used to develop simulations of these areas using photometric software (AGi32). This allowed development of models to estimate the illuminances on the facades of buildings in each area, which would have been impractical to measure. It also provided a basis for testing alternative lighting systems based on the energy use (in W) for each alternative, the uplight (U) and glare (G) ratings of the luminaires based on the North American IES TM-15 [9] (accounting for light output directed upward and at high angles from the luminaire), the maximum illuminance (in lux) on adjacent building facades, and the predicted safety rating (S) for the installation based on Eq. 1. The alternative systems consisted of LED luminaires and retrofit kits (for the teardrop luminaires).

Downtown Location:

East Sidewalk Average	39 lux	Driving Lane Average	90 lux	West Sidewalk Average	52lux
East Sidewalk Maximum	75 lux	Driving Lane Maximum	225 lux	West Sidewalk Maximum	102 lux
East Sidewalk Minimum	10 lux	Driving Lane Minimum	28 lux	East Sidewalk Minimum	24 lux
Average:Min	4	Average:Min	3	Average:Min	2

Residential Location:

East Sidewalk Average	3 lux	Driving Lane Average	3 lux	West Sidewalk Average	4 lux
East Sidewalk Maximum	6 lux	Driving Lane Maximum	8 lux	West Sidewalk Maximum	10 lux
East Sidewalk Minimum	.1 lux	Driving Lane Minimum	1 lux	East Sidewalk Minimum	1 lux
Average:Min	29	Average:Min	3	Average:Min	4

Table 1. Existing lighting condition measurement summary.

RESULTS AND DISCUSSION

The simulations and analyses resulted in the data as summarized in Figure 2 for one alternative in the downtown location. From these data, Table 2 shows how each criterion is weighted for this location (yellow cells) and the overall highest-ranked (green cell) alternative, denoted F.

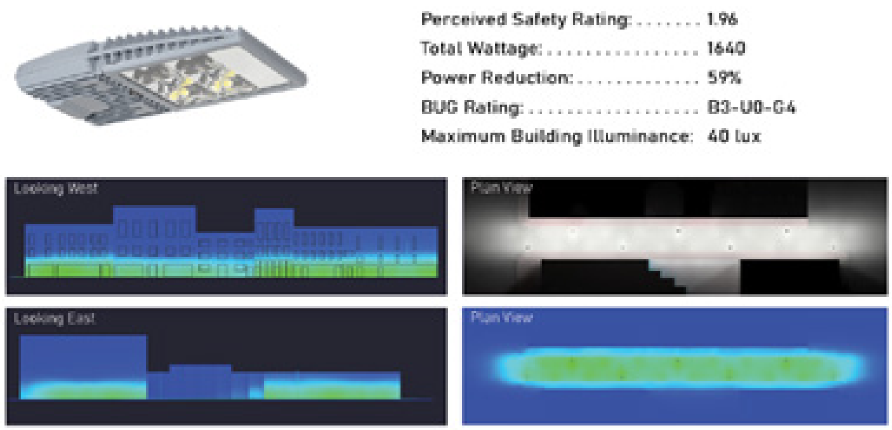


Figure 2. Example of data collected for one alternative for the downtown location.

Fixture	Percieved Safety Rating Rank	Weighting Value	Energy Savings Rank	Weighting Value	Uplight Rank	Weighted Factor	Glare Rank	Weighted Factor	Building Illuminance Rank	Weighted Factor	Simulation Rank
Weighting Factor		0.4		0.3		0.1		0.1		0.1	
A	10	4	16	4.8	0	0	5	0.5	17	1.7	13
B	1	0.4	16	4.8	1	0.1	4	0.4	15	1.5	8
C	2	0.8	14	4.2	1	0.1	3	0.3	10	1	5
D	4	1.6	5	1.5	1	0.1	2	0.2	4	0.4	0
E	9	3.6	6	1.8	1	0.1	2	0.2	10	1	6
F	3	1.2	9	2.7	1	0.1	2	0.2	7	0.7	1
G	14	5.6	3	0.9	1	0.1	2	0.2	6	0.6	9
H	15	6	1	0.3	1	0.1	1	0.1	3	0.3	7
I	10	4	7	2.1	1	0.1	3	0.3	12	1.2	10
J	7	2.8	7	2.1	1	0.1	3	0.3	8	0.8	3
K	10	4	2	0.6	1	0.1	2	0.2	5	0.5	2
L	5	2	10	3	1	0.1	2	0.2	9	0.9	4
M	16	6.4	11	3.3	1	0.1	1	0.1	16	1.6	14
N	17	6.8	4	1.2	1	0.1	1	0.1	1	0.1	11
O	13	5.2	11	3.3	1	0.1	1	0.1	14	1.4	12
P	8	3.2	13	3.9	1	0.1	1	0.1	1	0.1	9
Q	6	2.4	15	4.5	1	0.1	1	0.1	12	1.2	11

Table 2. Summary of ranked comparisons for the downtown location lighting alternatives.

CONCLUSION

The results from these analyses provide a basis for comparing, and for objectively selecting, urban lighting alternatives based on criteria that will measurably reduce energy use and light pollution while maintaining perceptions of safety and security. Other criteria based on circadian stimulus, color appearance, adaptive control or impacts on insects or wildlife could also be included in this framework, which can be incorporated into the public municipal planning process. Importantly, the relative weightings of the criteria as illustrated in Table 2 (yellow cells) can be adjusted; if a municipality wishes to increase the relative importance of light trespass in an area, for example, the weighting factor for that criterion can be increased and the overall simulation rank will be adjusted accordingly. For example, in the residential area, criterion weighting values were 0.3 for perceived safety, 0.2 for energy savings, 0.1 for uplight and glare, and 0.2 for light trespass. This was used in response to the fact that in a residential urban neighborhood, light trespass affecting people trying to sleep at night could be a larger concern than in a downtown location with fewer residential properties.

ACKNOWLEDGEMENT

The analyses summarized here were part of the first author's Master's in Lighting project [10] at Rensselaer Polytechnic Institute's Lighting Research Center.

REFERENCES

1. Leslie. R., Rodgers. P., (1996). Outdoor Lighting Pattern Book, McGraw-Hill, New York, NY.
2. Bullough, J., Donnell, E., Rea, M., (2013). To illuminate or not to illuminate: Roadway lighting as it affects traffic safety at intersections, Accident Analysis and Prevention, 53, 1, 65-77
3. Bullough, J., Snyder, J., Kiefer, K., (2020). Impacts of average illuminance, spectral distribution, and uniformity on brightness and safety perceptions under parking lot lighting, Lighting Research and Technology, 52, 5, 626-640
4. Brons, J., Bullough, J., Rea, M., (2008). Outdoor site-lighting performance: A comprehensive and quantitative framework for assessing light pollution, Lighting Research and Technology, 40, 3, 201-224
5. Bullough, J., (2010). Lighting Answers: Dynamic Outdoor Lighting, Rensselaer Polytechnic Institute, Troy, NY.
6. Fotios, S., Cheal, C., (2009). Obstacle detection: A pilot study investigating the effects of lamp type, illuminance and age, Lighting Research and Technology, 41, 4, 321-342
7. Rea, M., Bullough, J., Akashi, Y., (2009). Several views of metal halide and high pressure sodium lighting for outdoor applications, Lighting Research and Technology, 41, 4, 297-320
8. Bullough, J., Brons, J., Snyder, J., Gallant, P., Singlehurst, R., (2020). Toward uniformly safe parking lot lighting, Canadian Consulting Engineer, 61, 4, 15-17
9. Illuminating Engineering Society, (2020). Luminaire Classification System for Outdoor Luminaires, ANSI/IES TM-15-20, Illuminating Engineering Society, New York, NY.
10. Kozak, K., (2020). Evaluating LED Streetlighting Upgrades for Troy, New York (M.S. Project), Rensselaer Polytechnic Institute, Troy, NY.

CHALLENGING CURRENT URBAN LIGHTING POLICIES: CASE FOR A SHIFT OF FOCUS TO ALERTNESS

keywords
arousal, alertness, anxiety, urban lighting, safety

ABSTRACT
Current research on street lighting for pedestrians is heavily focused on visual performance. We argue that more research is needed on other psychological concepts also important for pedestrians' attention and safety – alertness, arousal and anxiety.

INTRODUCTION
Urban street lighting plays an essential role in ensuring people's safety after dark. Yet, given the current environmental issues and threat of climate change, there is a growing demand for more sustainable urban lighting. Such sustainable lighting should be more efficient in energy consumption and minimize the negative outcomes of light pollution. Research on street lighting for pedestrians has therefore focused on minimal required illuminance for various visual performance tasks, such as the effect of lighting on obstacle detection [2,3] or face recognition [2,3,4,5]. However, it could be argued that it is pedestrians' general attentiveness to their environment, rather than their visual performance, that is important for their safety. Despite this, the psychological concepts related to individual's attention, such as alertness and arousal, have not been considered in street lighting research to date. Lighting policies based on research overlooking such concepts might be incomplete. We make a case for considering a shift in urban lighting research to focus on concepts important for pedestrians' attention and safety; alertness, arousal and anxiety.

THEORETICAL FRAMEWORK PROPOSAL

2.1 Alertness
Alertness can be defined as a cognitive state of readiness and openness to respond to stimuli and to process incoming information [6,7,8]. A person is very alert if they notice any minor changes in their environment and adjust their behaviour accordingly. Conversely, someone is not alert if they fail to notice and respond to something important happening in their surroundings. Therefore, a person's attention is strongly, although not exclusively, influenced by their level of alertness.
Overall, increased alertness is associated with performance benefits; an increase in alertness has been linked with enhanced processing speed of incoming stimuli (i.e. faster response time) and with greater efficiency of such processing (i.e. increased response accuracy) [6,7].

2.2 Arousal
Arousal is defined as a general state of both cognitive and physiological nature, whereas alertness is explicitly a cognitive state [7]. Thayer [9,10] introduced a two-dimensional model of arousal. The energetic dimension is tied in with circadian rhythm and voluntary motor activity and ranges from feelings of drowsiness to vigour. The second dimension, which is labelled tense arousal [10], is expected to be connected with various emotions and stress reactions, in particular with anxiety. To the best of our knowledge, no investigation has been done yet on how these two dimensions of arousal are related to alertness and attention.

2.3 Anxiety
Heightened arousal—in particular tense arousal—can be related to concepts of fear or anxiety. Anxiety is a long-term and future-oriented state of readiness to expected or potential unspecified threat [11]. The evolutionary function of anxiety is to detect and deal with threats [12,13]. As such, anxiety is associated with increased arousal and physical readiness (i.e., the flight or fight response; [9]), but also with increased alertness (i.e., heightened cognitive readiness, and maximal

Richard Jedon, Antal Haans, Yvonne de Kort, *Eindhoven University of Technology*

receptiveness; [11,13]), with threatening information being processed faster, and with ambiguous information more likely to be considered as threatening [12].
Anxiety thus facilitates stimuli-driven and reflexive attention [13,14], much like increased extrinsic alertness. This begs the question if alertness and anxiety are not in fact the same function of the organism, changing in their definition only by the context of the situation.

THEORETICAL FRAMEWORK APPLICATION

Above we have described three different concepts: alertness as a cognitive state of enhanced readiness and openness to stimuli, arousal as a more generalized and both physiological and cognitive state, and anxiety as an emotional, future-oriented state of readiness to unspecified threat. From the previous discussion, it becomes clear that all three psychological constructs--alertness, arousal, and anxiety--are interrelated and have their influence on attention and, consequently, safety (e.g., attentiveness may prevent trips and accidents).
Research on the relationship between these psychological concepts and light has been scarce. To our knowledge, only Burtt [1] focused on such a relationship, in particular between uniformity of light and attention. According to Burtt, mere range of individuals' sight is insufficient for their safety if they are also not attentive to their surroundings and able to react to possible dangers. Therefore, to test pedestrians' performance under different lighting conditions, he employed an auditory two choice task, a short memory task, and a motor coordination task in a field study with a subsequent controlled laboratory experiment. In general, his findings suggest better performance on all three tasks under non-uniform lighting conditions. In Burtt's explanation, these positive performance outcomes were caused by two factors. First, by changes in the intensity of illumination through which the pedestrians walked. Second, by the alternations between the illuminated areas under the lamps and the dark, unlit, regions in between them.
Burtt's study, despite asking relevant research questions, received little attention. In particular, no replication of Burtt's study, or its parts, has been done to our knowledge. We therefore conducted a conceptual replication of Burtt's outdoor experiment (currently under review). We measured participants performance in an auditory two choice task (i.e. their response speed and accuracy) while they were walking alone after dark along four streets with different lighting conditions. Results from our pilot study suggest similar relationships to those reported by Burtt; the fastest reaction times were measured on the street with the lowest uniformity of light.
Applying the proposed theoretical lens to Burtt's experiment and our pilot study, we could argue that perhaps the changes in illumination and the contrast created by alternative bright and dark regions led to an increase in the participants' arousal, which might have then benefitted their attention - measured through the speed and accuracy of their responses. But we are still in the dark about the nature of such arousal. The areas in the shadow might have increased the tense arousal dimension and/or the lit areas might have promoted alertness. We will need a better understanding of the influence of different dimensions of arousal on individual's attention and safety and whether these results were mediated through increases in alertness, anxiety or both. This would also have implications for both social and traffic safety of pedestrians.

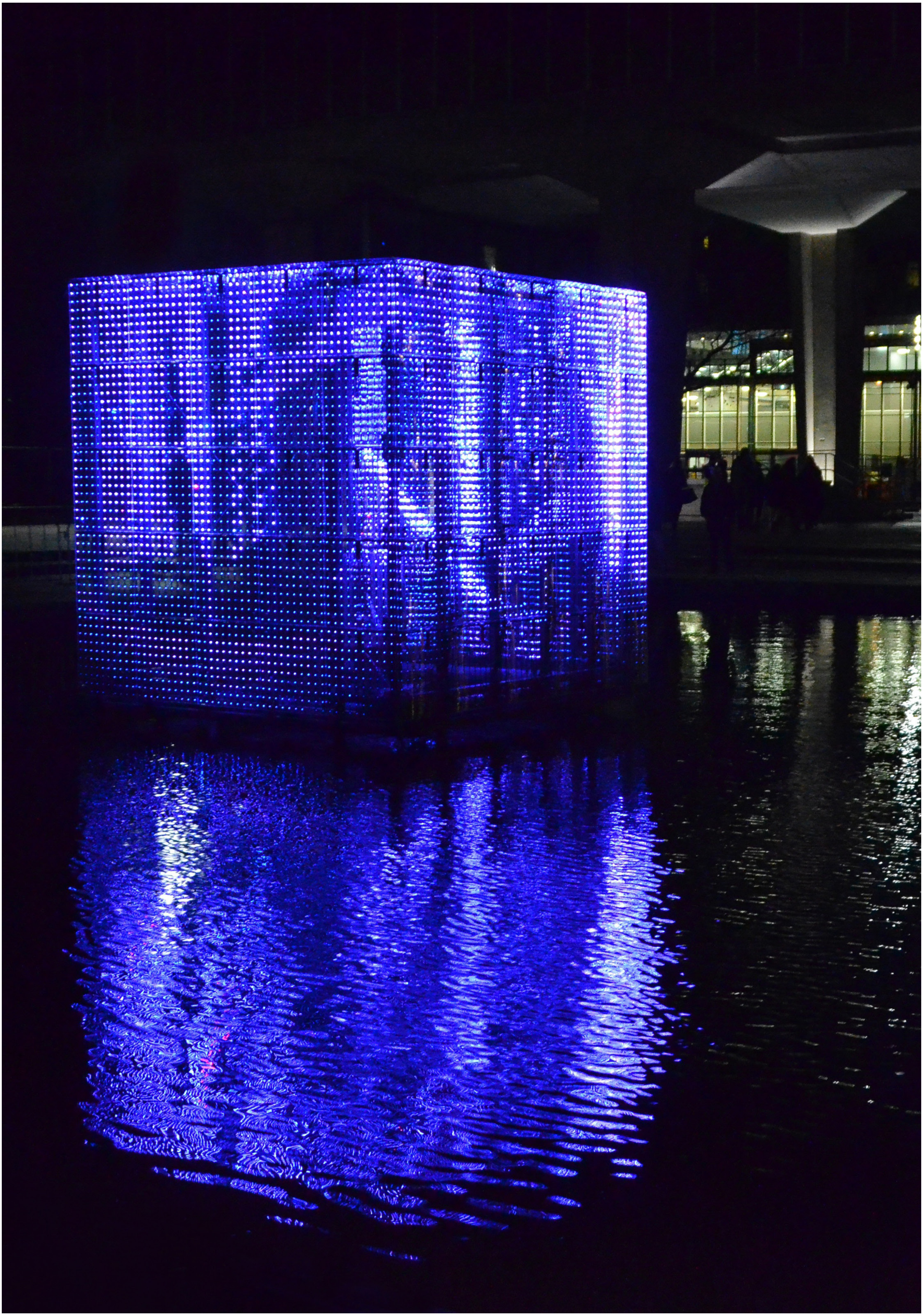
CONCLUSIONS

In this paper we pointed out that psychological constructs such as alertness, arousal and anxiety are prone to mixed use and to being loosely defined. More importantly, they are not considered, at the moment, in pedestrian lighting research and we do not yet understand the psychological mechanisms behind them. In doing so, urban lighting policies are neglecting concepts related to pedestrian's attention and safety. A focus on concepts of alertness, arousal and anxiety may boost understanding of both the attention of pedestrians (i.e., higher traffic safety) as well as their perceptions of personal safety. Findings from our pilot study suggest that this shift of focus might be worth of further research.

ACKNOWLEDFEMENTS
This research was performed within the European Training Network LIGHTCAP (project number 860613) supported by the Marie Skłodowska-Curie actions framework H2020-MSCA-ITN-2019. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

REFERENCES

1. Burtt, H., (1916). The effect of uniform and non-uniform illumination upon attention and reaction-times, with especial reference to street illumination. Journal of Experimental Psychology, 1, 2, 155-182.
2. Mao, Y. ve Fotios, S., (2021). Lighting for pedestrians: Does multi-tasking affect the performance of typical pedestrian tasks? Lighting Research & Technology, 0, 1-28.
3. Fujiyama, T., Childs, C., Boampong, D. ve Tyler, N, (2005). Investigation of lighting levels for pedestrians: some questions about lighting levels of current lighting standards. Walk21-VI, Everyday Walking Culture 6th International Conference of Walking in the 21st Century. 2005.
4. Knight, C, (2010). Field surveys of the effect of lamp spectrum on the perception of safety and comfort at night. Lighting Research & Technology, 42, 3, 313-329.
5. Yang, B. ve Fotios, S., (2015). Lighting and recognition of emotion conveyed by facial expressions. Lighting Research & Technology, 47, 8, 964–975.
6. Matthias, E., Bublak, P., Müller, H., Schneider, W., Krummenacher, J. ve Finke, K., (2010). The influence of alertness on spatial and nonspatial components of visual attention. Journal of Experimental Psychology: Human Perception and Performance, 36, 1, 38-56.
7. Brown, V. ve Bowman, E., (2002). Alertness in: Ramachandran, V., ed. Encyclopedia of the Human Brain, Academic Press, 99–110, University of Michigan.
8. Chandrakumar, D., Keage, H., Gutteridge, D., Dorrian, J., Banks, S. ve Loetscher, T, (2019). Interactions between spatial attention and alertness in healthy adults: a meta-analysis. Cortex, 119, 61–73.
9. Thayer, R., (1978). Toward a psychological theory of multidimensional activation (arousal). Motivation and Emotion, 2, 1, 1–34.
10. Thayer, R., (1986). Activation-deactivation adjective check list: Current overview and structural analysis. Psychological Reports, 58, 2, 607–614.
11. Kastner-Dorn, A., Andreatta, M., Pauli, P., Wieser, M., (2018). Hypervigilance during anxiety and selective attention during fear: Using steady-state visual evoked potentials (ssVEPs) to disentangle attention mechanisms during predictable and unpredictable threat. Cortex, 106, 120–131.
12. Bateson, M., Brilot, B. ve Nettle, D., (2011). Anxiety: an evolutionary approach. The Canadian Journal of Psychiatry, 56, 12, 707–715.
13. Cornwell, B., Mueller, S., Kaplan, R., Grillon, C. ve Ernst, M., (2012). Anxiety, a benefit and detriment to cognition: Behavioral and magnetoencephalographic evidence from a mixed-saccade task. Brain and cognition, 78, 3, 257–267.
14. Eysenck, M., Derakshan, N., Santos, R. ve Calvo, M., (2007). Anxiety and cognitive performance: Attentional control theory. Emotion, 7, 2, 336–353.



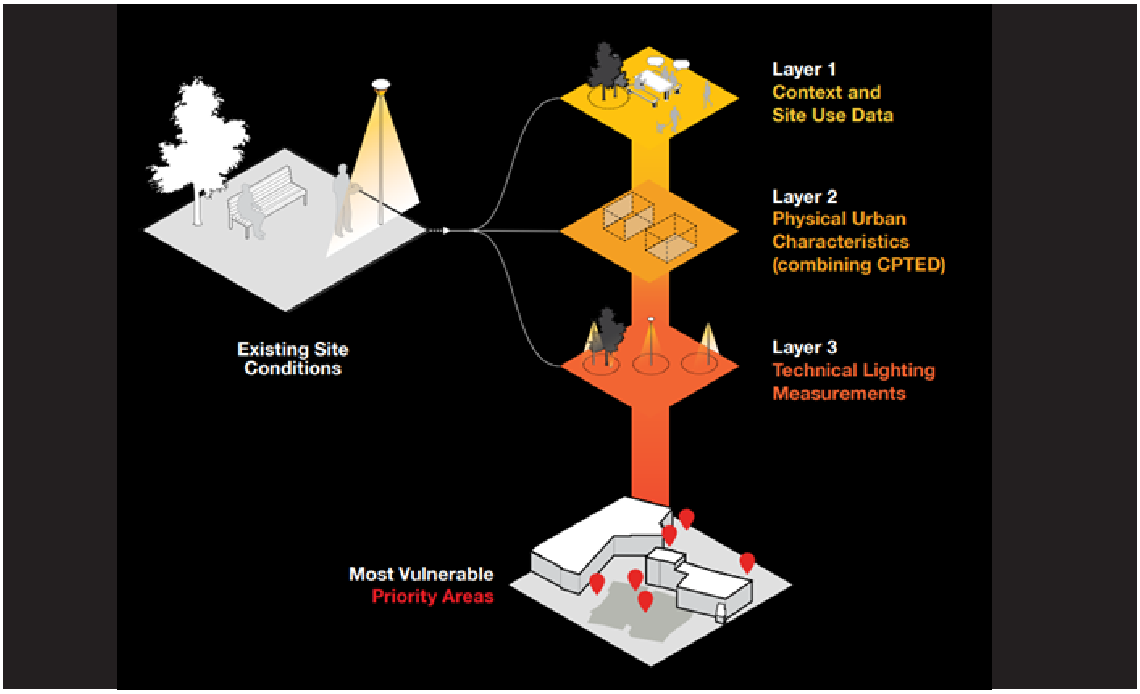
LEVERAGING 'DIGITAL' FOR COMMUNICATION WITH STAKEHOLDERS AND COMMUNITIES TO IMPROVE NIGHT TIME DESIGN FOR SAFETY AND COMFORT – CASE STUDIES FROM ARUP

keywords
lighting design, GIS, geospatial datasets, smart cities

ABSTRACT
Arup has developed a suite of digital tools to harness the power of community engagement to inform better lighting design for nighttime wellbeing in urban environments. These tools harness Geographic information system mapping, geospatial datasets, digital analytics, 3D environmental scanning, to address findings from Arup's research that demonstrate a lack of consideration for holistic and human centric experience-led urban lighting design.

OVERVIEW
Designing urban spaces for people to share and enjoy goes beyond practical considerations. It's about creating memorable night time experiences and attracting people, energising wider city precincts and ultimately cities themselves. The importance of how light interacts with the urban environment to create atmospheres of fear or safety is often an afterthought in masterplans and urban design strategies.
Statistics show us that a perceived lack of safety can lead to marginalised groups such as women using less public transport, participating in the night time economy, or leaving the house after dark at all. Being able to hear and collect community feedback from the most marginalized voices within a safe and accessible forum ensures designs that are evidence based and socially resilient.
Arup's research collaboration with Monash University XYX Lab and PLAN International into how light shapes perceptions of safety for women and girls (presented in Session 2) has shown that at present, we are not considering urban night-time experiences within a holistic or systematic design process.
As specialists in the built environment, Arup has developed a suite of tools to harness the power of community engagement to inform better design for night time experiences:

1.1 The Lighting Vulnerability Assessment (LVA)



Tim Hunt, Hoa Yang, *Arup*

An evidence based methodology enabled through Geographic Information System mapping (GIS), Radiance Luminance processing and advanced digital analysis to measure the social, physical and atmospheric qualities that work together to affect perceptions of safety after dark. The LVA brings together Arup's consulting expertise in criminology, risk and resilience, urban design, architecture, lighting, advanced digital data collection and analysis of existing site conditions. This unique methodology identifies and recommends practical design changes to urban spaces where people are predicted to feel least safe by assessing how people perceive safety in night time spaces at three levels – contextual, social and individual. The assessment weaves the technical component of lighting design, prospect and refuge theory, incident statistics and CPTED with human experience through digital data capture and analysis to improve user perceptions of the night time journey.

1.2 Digital night-time community engagement website
Community consultation often requires hours of investment and is usually conducted during daylight hours. It is difficult to impart the atmospheres of night time and collected contextualized feedback from the community under a daytime environment. Further, the context of in-person forums often means that only the loudest, more dominant voices are heard. The digital night-time community engagement website was created to facilitate night time specific community feedback within an accessible environment, that is easy and convenient to use. The platform allows for controlled crowdsourcing from the community through an immersive night time street view portal achieved through 360 degree environmental scanning and tailors questions to generate more nuanced feedback to embed evidence based technical design solutions to meet community needs.

1.3 Your Brightness Journey
External lighting projects are often implemented without consideration of the lit context surrounding the site. This can lead to harsh differences of light levels that can compromise the comfort and ease in the night time experience in a persons journey to their destination. Harnessing Geographic Information System mapping (GIS), geospatial datasets and aerial imaging, Arup has developed a web based portal that allows for local councils and public transport authorities to predict and assess the brightness journey of a person's night time multi-modal experiences between key transport nodes, public spaces and homes. The platform allows for a more holistic approach to master planning and lighting design for the built environment.

ACKNOWLEDGEMENT
These tools have been developed by Arup, a global firm of designers, advisors and experts working across 140 countries.

REFERENCES

1. Arup (2019). Making Cities Safer for Girls and Women in Arup Research Review 2019. [online] Available at: https://research.arup.io/story/cities-for-girls

SIMULATION OF DAYLIGHT BY RADIANCE IN DENSE URBAN AREAS

keywords
daylighting, radiance, dense urban areas, light wells, low-light

ABSTRACT
This work deals with daylighting simulation in dense urban areas. The availability of daylighting in these areas is very low; therefore, it is necessary to improve the condition of the light wells. Their driving surface is often not fully utilised because of obstructions, and they are often full of installations associated with residential use. In addition, several light wells are dark, damp and unhealthy, not allowing the correct conduction of light into the ground floor dwellings. Consequently the aim of this research is to simulate the daylight inside ground floor dwellings, where there is low daylight level. The case study is the old town of San Sebastian (Spain), in particular the light well bounded by the streets Esterlines, Narrika and Enbeltran, and in the first floor dwelling of Esterlines 3. For this purpose, the accuracy of the simulation is important, so that low light levels can be correctly predicted. For this case, it is considered appropriate to use Ray-Tracing by Radiance, adding the largest sky division as 2305 of Reinhart, and to measure accurately the surface material properties. The Two-Phase Method by rfluxmtx is used to obtain Point-in-Time illuminance level and Daylight Autonomy. The measurements of material properties have been made with a camera and a reflectometer. The results show that a high level of detail for geometries and material properties is mandatory to achieve accurate daylight simulation performance.

INTRODUCTION
This work deals with daylighting simulation in dense urban areas. Many cities have dense urban areas such as the old town. These urban structures correspond to the compact city typology [1]. This type of construction is based on resource optimization. However, the availability of daylighting in these areas is very low to maintain a quality of life over time. This daylight availability, in addition to narrow facades, is obtained by light wells.

Usually, light wells' driving surface is often not fully utilized because of obstructions, and they are often full of installations associated with residential use, as the clotheslines. In addition, several light wells are dark, damp and unhealthy, not allowing the correct conduction of light into the ground floor dwellings, where the light level is lower and it is very little [2].

Consequently the aim of this research, conducted through light wells, is to simulate with precision the daylight inside of theses ground floor dwellings, where there is low-light level. The performance of light-well's materials with different types of reflection will be studied. Daily daylighting performance will be obtained by "dynamic and climate-based analysis", improving the annual assessment of the models [3]. Regarding the discretization of the sky, the most accurate one normally used in Radiance will be used. Point in time real sky and interior material optical properties are measured to show the relevance of these data for more accurate simulations.

MATERIALS AND METHODS
The method used to obtain the daylighting performance of light well and the interior low-light level results are simulation. The used simulation method is ray-tracing by the open source software Radiance. In low-light conditions the accuracy of the simulation is relevant to obtain reliable results; error can be very decisive [4].
In this study, we first try to demonstrate the importance of the real radiance emitted by the sky and its discretization, and as well as, the real reflections of materials. Then, to simulate a standard light-well with two different materials: a material with white diffuse surface; and a material with specular surface (See Figure 1).

Urtza Uriarte, *Department of Architecture, University of the Basque Country UPV/EHU, Plaza Oñati 2, 20018 Donostia-San Sebastián, Spain*

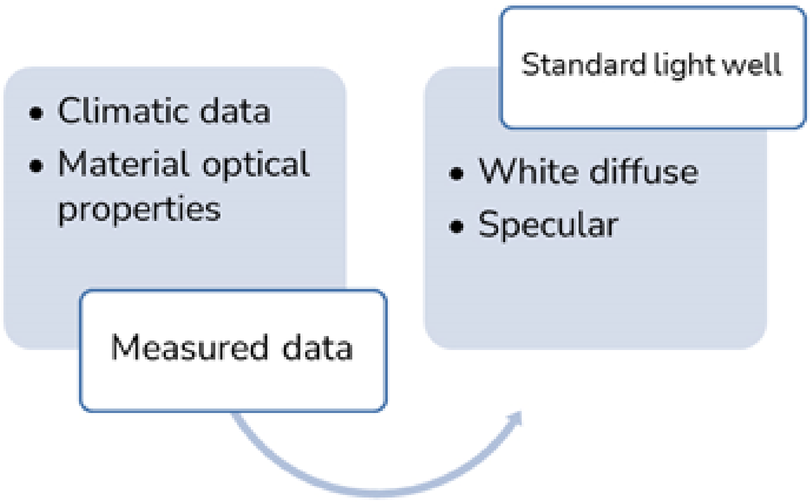


Figure 1. Description of the scheme of methodology used

2.1 Measurement samples
Some measurements are proposed in order to see that the standard values in these conditions should be more precise. For this purpose, the old town of the city of San Sebastian was chosen. A light well with access from street Esterlines number 3 is selected to assess. On the one hand, from the roof, sky measurements are proposed, which are related to climatic data. On the other hand, measurements of material properties are proposed. The measured materials are of the interior of the dwelling.

2.1.1 Climatic data
It is proposed to perform a point in time measurement using the imaging technique. A Canon camera with 5-exposure HDR and a tripod for 360° is used. This results in a 360 ° HDR photograph of the radiance (watts/steradian/m2) of the sky in false color [5, 6]. On the other hand, different sky discretizations are tested to prove the accuracy effect: Tregenza division with 145 patches; and Reinhart division with 2305 divisions. The 2-Phase Method of Radiance is used with “rfluxmtx” command, and the parameters used are: 6 diffuse reflections (-ab); 10000 number of rays (-ad); and 10 maximum numbers of reflections (-lr).

2.1.2 Material optical properties
A reflectometer Mini-Diff v2 is used to test BSDF (sr-1) measurements of different materials. As an example, the materials of the interior of the house, located on the first-floor, are tested. The calibration data are the following ones: AOI calibrated, 40°; Color calibrated G(525nm).

2.2 Standard light well simulations
In addition, the first simulations of a light well are carried out. The proposed light well has a standard design. The most common light wells are rectangular with 4 floors, Well Index (WI)=4 [7]. Therefore, the light well is 3 x 3 m with 12 m of height, and the interior room proposed and enlightened through the light well is about 4 m deep, 3 m width, and 2.75 m high [8]. The 2-Phase

Method of Radiance is used with “rfluxmtx” command, and the parameters used are: 30 diffuse reflections (-ab); 1000000 number of rays (-ad); 30 maximum number of reflections (-lr); and 2305 sky divisions.

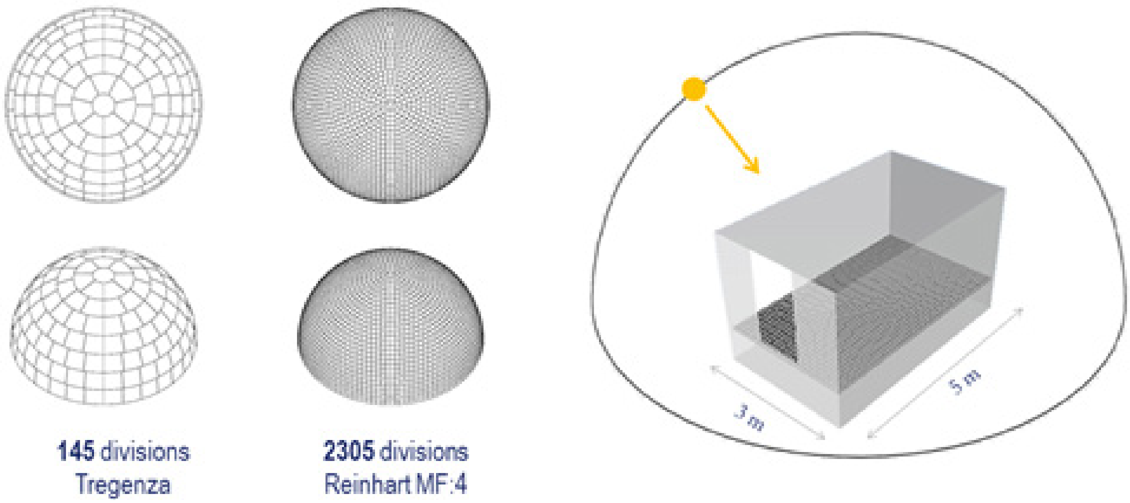


Figure 2. Model for the sky discretization

2.1.2 Material optical properties

A reflectometer Mini-Diff v2 is used to test BSDF (sr-1) measurements of different materials. As an example, the materials of the interior of the house, located on the first-floor, are tested. The calibration data are the following ones: AOI calibrated, 40°; Color calibrated G(525nm).

2.2 Standard light well simulations

In addition, the first simulations of a light well are carried out. The proposed light well has a standard design. The most common light wells are rectangular with 4 floors, Well Index (WI)=4 [7]. Therefore, the light well is 3 x 3 m with 12 m of height, and the interior room proposed and enlightened through the light well is about 4 m deep, 3 m width, and 2.75 m high [8]. The 2-Phase Method of Radiance is used with “rfluxmtx” command, and the parameters used are: 30 diffuse reflections (-ab); 1000000 number of rays (-ad); 30 maximum number of reflections (-lr); and 2305 sky divisions.

Figure 3. Description of the standard light well model

2.2.1 White diffuse material

In this first sample the material used in the standard light well is Lambertian diffuse reflection. The selected reflection is 85 % of grey, the same reflection for RGB wavelengths.

2.2.2 Specular material

In this other simulation sample the material used in the standard light well is specular reflection. The selected specular reflection is 90 % of grey, the same reflection for RGB wavelengths.

MATERIALS AND METHODS

3.1 Point in time measurements results

3.1.1 Sky radiance result

According to the aforementioned imaging technique, in 360° mounted photographs the radiance or luminance distribution is shown. There are 2 photographs, one from the sky, and one from the interior space of the first-floor dwelling. The photographs are in Lambert Projection and Hemisphere Projection (See Figure 4).

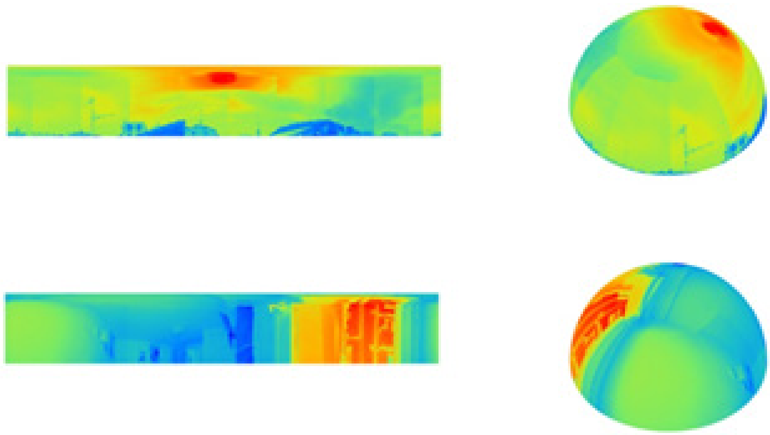


Figure 4. Radiance results of the sky from the 360° photograph:
left, lambert projection; right, hemisphere projection

3.1.2 Different sky discretization results

If the sky discretization is bigger with more divisions the total emitted flux is equal. Therefore, the light level of a working plane for different sky divisions is equal. However, the view factor is different because with higher division the definition of the part of the sky that is seen is greater and the limit of direct radiation is more accurate (See Figure 5). The sky is simulated with “gensky” and “genskyvec” command and the parameters are: gensky 03 21 12 +s -a 41 -o -2 -m -15 | genskyvec -m 1, for 145 divisions; and with –m 4 for 2305 divisions.

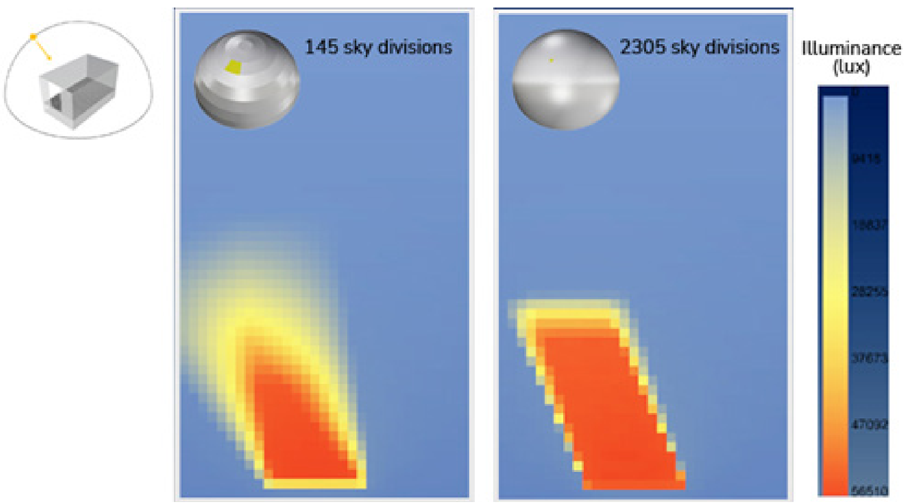


Figure 5. Simulation of direct radiation from a window according to different sky discretizations

3.1.3 Material optical properties results

The measurement of the material optical properties is relevant, because comparing with its material standard reflection coefficient; the measured reflection coefficient is very different. In addition, knowing the specular and diffuse component of the unmeasured BSDF is difficult to obtain (See Figure 6).

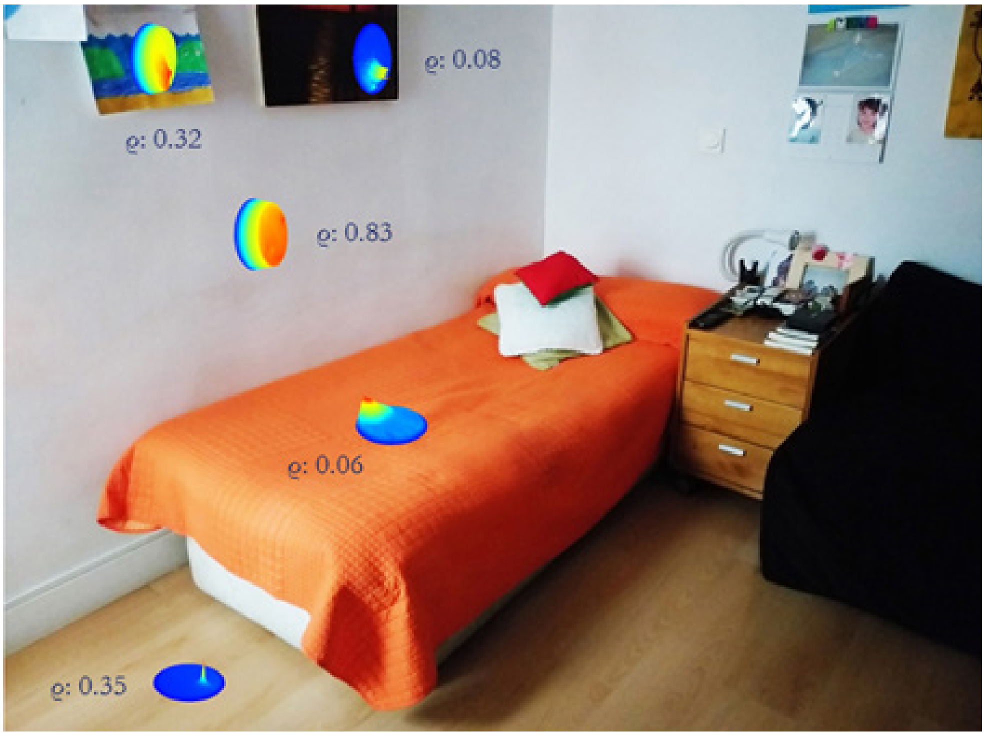


Figure 6. The material optical properties with measured BSDF of interior first-floor dwelling

3.2 Standard light well simulations results

The reflection coefficient is relevant for daylight conduction. Consequently, the material of light well is determinant for low-light conditions. If the refection coefficient of this material is higher, the daylight conduction is considerable higher. Therefore, the specular material conducts approximately 3 times more than white diffuse material (See Figure 7).

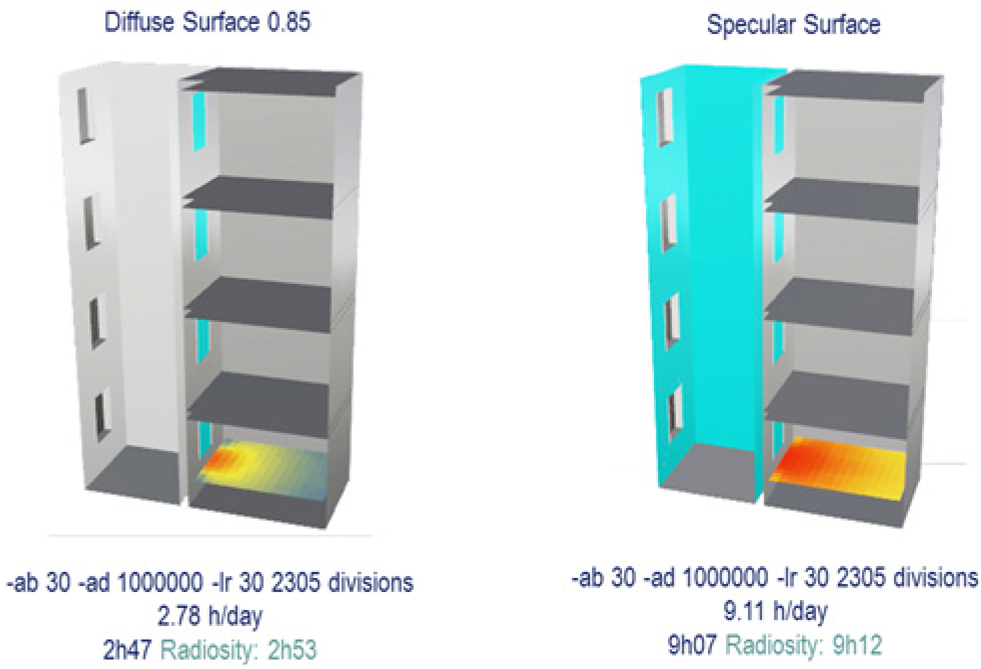


Figure 7. The relevant of light well material for daylight conduction

CONCLUSION

In low-light conditions the simulation accuracy is determinant. On the one hand, the radiance measured of the sky at the same roof of the light well is different comparing with standard climate data of the city. Moreover, the sky discretization is basic for the direct radiation access from a window. Furthermore, knowing the material optical properties with BSDF data is essential to ensure the correct simulation of daylight driving simulation.

On the other hand, the material chosen for light well is critical, because a specular material can appropriately increase driving by a factor of 3, being a considerable contribution in interior low-light conditions.

More measurements should be made in the future of different real sky conditions, more material optical properties and insert in the simulation. In addition, more tests could be done with higher sky discretization.

ACKNOWLEDGEMENT

The author is grateful to Basque Government, because this research has been supported by it postdoctoral training program. In addition, Thanks are given to Urban Physics laboratory of Université de Pau et des Pays de l'Adour (UPPA) and CAVIAR research group of University of the Basque Country (UPV/EHU).

REFERENCES

1. Jacobs, J. (1961). The death and life of great American cities. (N. Y. R. House, Ed.).
2. Beckers, B. (2013). Solar Energy at Urban Scale. https://doi.org/10.1002/9781118562062
3. Reinhart, C. F., & Walkenhorst, O. (2001). Validation of dynamic RADIANCE-based daylight simulations for a test office with external blinds. Energy and Buildings, 33(7), 683–697.
4. Ward, G., & Shakespeare, R. (1998). Rendering with Radiance: the art and science of lighting visualization.
5. Beckers, B., & Beckers, P. (2014). Reconciliation of Geometry and Perception in Radiation Physics.
6. y Miño, J. A. P., Lawrence, C., & Beckers, B. (2020). Visual metering of the urban radiative environment through 4π imagery. Infrared Physics & Technology, 110, 103463.
7. Aizlewood, M. E. (1995). The daylighting of atria: a critical review.
8. Bugeat, A., Beckers, B., & Fernández, E. (2020). Improving the daylighting performance of residential light wells by reflecting and redirecting approaches. Solar Energy, 207, 1434–1444. https://doi.org/https://doi.org/10.1016/j.solener.2020.07.099

A REMOTE SENSING APPROACH TO ESTIMATE PARTICULATE MATTER CONCENTRATION: A LISBON, PORTUGAL CASE STUDY

keywords
air pollution, particulate matters, ANN, AOD, MODIS

ABSTRACT

Particulate Matter (PM) pollution is one of the most significant air quality concerns in Europe.
In most of the countries, residents are facing consequences of air pollution caused by microscopic suspended particles, primarily in urbanized areas and its fringes.
Traditional approach involves setting up the monitor station across the boundaries to monitor concentration of PM, but later after remote sensing technology evolves mapping and modelling of near-surface atmospheric PM becomes a research niche.
After the holistic review of all the data sources available and methodologies adopted, Artificial Neural Network (ANN) based retrieval of PM_{10} and $PM_{2.5}$ from the Aerosol Optical Depth (AOD) using atmospheric and in-situ PM measurements was more reliable when compared with traditional approaches and multiple linear regression model.
In this process of estimation, insitu PM measurements (up to 80% available) is used to train the neural network with respect to the AOD and other metrological based atmospheric parameters.
In this study, we integrate ground-based measurements and satellite data to map temporal PM concentrations for the city of Lisbon, Portugal.
We used MODIS Terra data and developed ANN models to map the ground level PM concentrations.
The modelled PM maps were validated by comparing ground-based PM concentration to test the efficacy of the model.

INTRODUCTION

Suspended particulate matter or aerosol or particulate matter (PM) which can be natural or anthropogenic by origin, and it is a microscopic solid particle suspended in air [1].
PM may be categorized into certain types-based diameter like PM_{10} and $PM_{2.5}$ [2].
When the aerodynamic diameter of PM is less than are equal to 10μm is called as PM10 or respirable particulate matter and originates from construction sites, landfills, agriculture, mining and related sources [2]. When aerodynamic diameter doesn't exceed over 2.5μm is said to be $PM_{2.5}$ or fine particulate matter which emerges mainly from combustion from vehicles and burning of agricultural wastes, coal and related substances [3].
There is evidence, that PM cause severe health ailments primarily respiratory problems and in certain cases it may cause neurological disorders, cardio-vascular problems and even cancer [4].
Accordingly, to United Nations, polluted is responsible for 7 million deaths every year.
Moreover, one third of deaths from stroke, lung cancer and heart disease comes from air pollution.
The developing and certain developed countries are more prone to such effects due to industrialization and rapid urbanization in past two decades [5].
These countries lack infrastructures for monitoring and forecasting PM, due to which several industries use as an opportunity to exhaust their effluents without proper channelling and treatments [6].
These substances scatter the incident solar energy thereby enhancing the albedo and results in reduction of solar radiation reaching the earth surface, called as direct radiative effect of atmospheric particles [7].
Some suspended particles may cause indirect radiative effect which affects the lifecycle of clouds by forming cloud condensation nuclei resulting in the alteration of climatic pattern of the locality [8].
Many studies also reveals that formation of hazy atmosphere which reduces the visibility near the ground, causing disruption to transportation (airways and roadways) [3,9,10].

Rajchandar Padmanaban, Paulo Morgado, *Centre of Geographical Studies, Institute of Geography and Spatial Planning of the University of Lisbon*

Due to adverse health effects, transport disruption and changes in climatic pattern, monitoring of PM concentration is mandatory for every government and administrators in order to mitigate the effects [11].
The most common and straight forward decision of monitoring PM is by erecting necessary instruments like Optical Particle Counter (OPC) in air quality monitoring stations distributed over the administrative boundaries, with these setup discontinuous PM measurements with high accuracy and frequency can be acquired [12].
The point measurements from the monitoring station are not sufficient to study the PM concentration in assessing regional concentration variability [13].
After evolution of modern remote sensing sensors, Aerosol Optical Depth (AOD) or Aerosol Optical Thickness (AOT) can be retrieved for variable spatial scale from those sensors, which can be modelled to derive the continuous PM values over any desired administrative boundaries [3]. The AOD derived from MODIS is accurate and usage of data from geostationary satellite is highly recommendable for preparing PM map with short temporal scale [6].

The main objective of the study is to derive the PM concentration map for Lisbon, Portugal using the satellite and datasets from monitoring stations, and overcome the stationary ground-based observation stations issues Finally, PM concentration map obtained is validated with ground-based dataset in certain region.

MATERIALS AND METHODS

2.1 Data used

MODIS datasets (MOD04/MYD04, MOD07/MYD07) is used to retrieve the Aerosol Optical Depth (AOD) information at the resolution of 10km from seven bands (0.47µm, 0.55µm, 0.65µm, 0.86µm, 1.24µm, 1.64µm and 2.13µm).
We consider the cloud free pixels within the distance of 25km from the ground-based observation station. For estimating and modelling the PM, we can integrate the satellite data with the ground observation data's as it has different spatial and temporal characteristics.
Ground-based observation data are collected from Portuguese environment institute air quality network, this network consists of several monitoring stations situated in Portugal provide hourly measurements of particulate matter suspended in atmosphere.
The ground observations are made in such a way that observations coincide with the satellite overpass, for validating and increasing the accuracy of satellite measurements.

METHODOLOGY

The methodology for estimating the particulate matter (PM) in any particular area is illustrated in figure 1. PM is estimated by integrating the ground measurements with the satellite measurement (MODIS) using Artificial Neural Network (ANN).

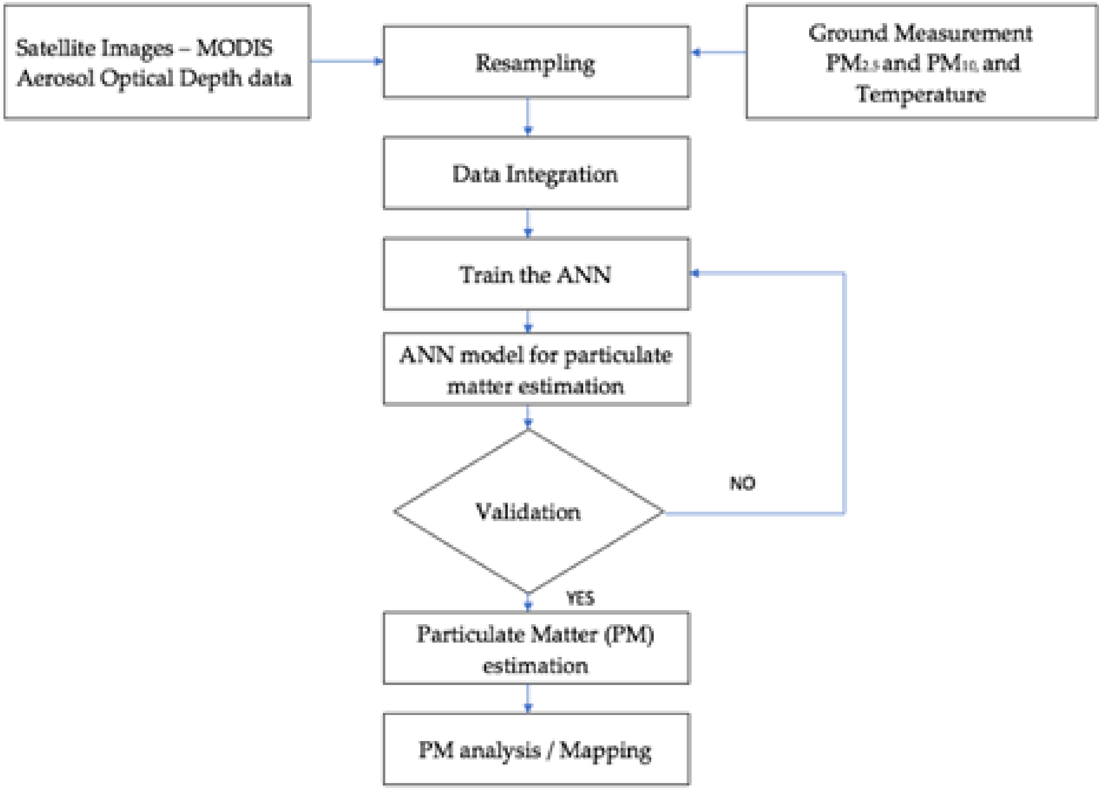


Figure 1. Methodology to estimate PM concentration in Lisbon using Satellite datasets and in-situ measurement

RESULTS

The generated $PM_{2.5}$ and PM_{10} map were illustrated below.

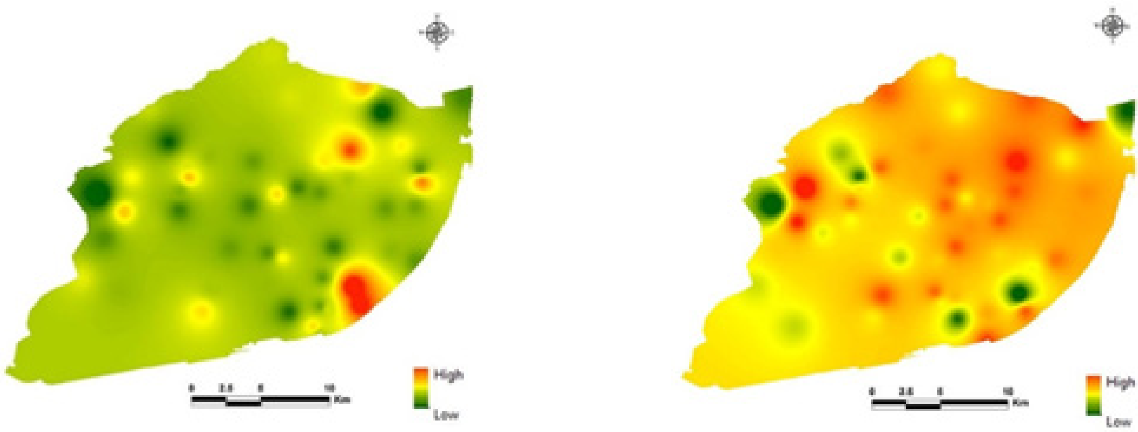


Figure 2. $PM_{2.5}$ map (Left) and PM_{10} (Right) for 2020.

REFERENCES

1. Nguyen, T. T. N.; Bui, H. Q.; Pham, H. V.; Luu, H. V.; Man, C. D.; Pham, H. N.; Le, H. T.; Nguyen, T. T. Particulate matter concentration mapping from MODIS satellite data: A Vietnamese case study. Environ. Res. Lett. 2015, 10.
2. Imani, M. Particulate matter (PM2.5 and PM10) generation map using MODIS Level-1 satellite images and deep neural network. J. Environ. Manage. 2021, 281.
3. Tsai, T. C.; Jeng, Y. J.; Chu, D. A.; Chen, J. P.; Chang, S. C. Analysis of the relationship between MODIS aerosol optical depth and particulate matter from 2006 to 2008. Atmos. Environ. 2011, 45, 4777–4788.
4. Chu, Y. H.; Kao, S. W.; Tantoh, D. M.; Ko, P. C.; Lan, S. J.; Liaw, Y. P. Association between fine particulate matter and oral cancer among Taiwanese men. J. Investig. Med. 2019, 67, 34–38.
5. Onyango, S.; Anguma, S. K.; Andima, G.; Parks, B. Validation of the atmospheric boundary layer height estimated from the MODIS atmospheric profile data at an equatorial site. Atmosphere (Basel). 2020, 11.
6. Schwartz, C. S.; Liu, Z.; Lin, H. C.; McKeen, S. A. Simultaneous three-dimensional variational assimilation of surface fine particulate matter and MODIS aerosol optical depth. J. Geophys. Res. Atmos. 2012, 117.
7. Schaaf, C. B.; Wang, Z. H. MCD43A3 MODIS/Terra+Aqua BRDF/Albedo Daily L3 Global - 500m V006 [Data set] 2015.
8. Camiolo, M. D.; Cozzolino, E.; Dogliotti, A. I.; Simionato, C. G.; Lasta, C. A. An empirical remote sensing algorithm for retrieving total suspended matter in a large estuarine region. Sci. Mar. 2019, 83, 53–60.
9. Park, J.; Chang, S. A particulate matter concentration prediction model based on long short-term memory and an artificial neural network. Int. J. Environ. Res. Public Health 2021, 18.
10. De Mattos Neto, P. S. G.; Firmino, P. R. A.; Siqueira, H.; De Souza Tadano, Y.; Alves, T. A.; De Oliveira, J. F. L.; Da Nobrega Marinho, M. H.; Madeiro, F. Neural-Based Ensembles for Particulate Matter Forecasting. IEEE Access 2021, 9, 14470–14490.
11. Li, Y. G.; Gao, X. Epidemiologic studies of particulate matter and lung cancer. Chin. J. Cancer 2014, 33, 376–380.
12. Escribano, J.; Gallardo, L.; Rondanelli, R.; Choi, Y. S. Satellite retrievals of aerosol optical depth over a subtropical urban area: The role of stratification and surface reflectance. Aerosol Air Qual. Res. 2014, 14, 596–607.
13. Xu, J.; Jiang, H.; Xiao, Z.; Wang, B.; Wu, J.; Lv, X. Estimating air particulate matter using modis data and analyzing its spatial and temporal pattern over the Yangtze Delta region. Sustain. 2016, 8.

ETHICAL LEGAL AND SOCIAL ASPECTS (ELSA) OF URBAN LIGHTING AND RELATED HEALTH STUDIES

Chair: **Deborah Mascalzoni**

Urban Lighting interventions poses ethical challenges for the impact on communities and the environment. This is particularly true when we consider the ethical implications posed by electric lighting to human health. In this session we wish to map out and analyze broadly some of the ethical concerns and values at stake. We will also unravel another aspect of research on health and urban lighting which is the tension between the benefits of open data and approaches that comply with high standards for data protection and GDPR compliance in the collection, handling and sharing of health data.

RESEARCH ON HEALTH AND URBAN LIGHTING BETWEEN OPEN DATA AND DATA PROTECTION

keywords
lighting, research, open data, FAIR, data protection, data governance

ABSTRACT
While wide data sharing is key to promote research and increasingly required by funders, the protection of participants' fundamental rights, including the right to data protection, is not only mandated by the law but is also critical to ensure the participants' trust in the research. This also applies to the emerging research trends concerning the impact of urban lighting, which may involve 'sensitive' data, such as health-related data. The objective of this paper is to outline approaches that reconcile open data and high standards for data protection and GDPR compliance in the sharing of health data. To this end, the most relevant open data approaches (particularly, the FAIR principles) are considered and put in relation with key data protection law principles (such as lawfulness, purpose limitation, data minimization, transparency, and accountability). This is to assess if and to what extent data FAIRisation approach is feasible without infringing data protection law nor participants' trust. This paper finds that an effective data governance structure should be set up with transparent access policies and effective lines of accountability, and this should be reflected in projects' data management plans.

INTRODUCTION
Data sharing is key to promote research and increasingly required by funders in terms of open access or open data policies [1]. At the same time, EU regulations require an effective protection of research participants' fundamental rights, including the right to data protection under the GDPR. In particular, sharing 'sensitive' data obtained in research activities may expose research participants to forms of discrimination and stigma both on an individual and a collective level [2].
Against this backdrop, a comprehensive protection of research participants' fundamental rights is also critical to ensure the participants' trust and continued participation in the research [3].
These concerns are not alien to the emerging research trends concerning the impact of urban lighting, which also involves 'sensitive' data, such as health-related data.
This overarching tension between data sharing and data protection is widely studied in the literature. In particular, most scholarly works on this topic focus generally on the extent to which the GDPR allows for the sharing of data for research purposes [4]. However, the relationship between specific open data approaches and data protection has attracted much less attention.
In an attempt to fill this gap, the objective of this paper is to outline approaches that reconcile open data approaches and high standards for data protection and GDPR compliance in the sharing of health data.

MATERIALS AND METHODS
To pursue the stated objective, the most important open data approaches will be outlined.
Focusing on the FAIR principles (Findability, Accessibility, Interoperability, and Reuse [5]), each of them will be reviewed and put in relation with key data protection law principles established by the GDPR (such as lawfulness, purpose limitation, data minimization, transparency, and accountability).
This is to assess the potential, concrete scope available to research partners for reconciling data FAIRisation and data protection rules and principles.

Andrea Parziale, *EURAC Research*

RESULTS AND DISCUSSION

Data protection law provides for a series of constraints that inevitably impact and shape open data solutions, especially when it comes to sharing 'sensitive' data, such as health-related data.
In this respect, the concept of data stewardship (or long-term care [6]) seems to offer a point of contact between open data and data protection. This requires to specify, among other things: whether the data produced and/or used in the project is useable by third parties, in particular after the end of the project; which data will be made openly available, the rationale for keeping some data closed; how the data will be made available; how access will be provided in case there are any restrictions; whether there is a need for a data access committee; what are conditions for access; how the identity of the person accessing the data will be assessed. In sum, an effective data governance system is needed based on objective and transparent access policies to enable access to data by researchers and the exercise of the participants' rights regarding their data.

CONCLUSION

To strike an appropriate balance between open data and data protection, an effective data governance structure should be set up. This should outline transparent access policies as well as clear and effective lines of accountability. This should be adequately reflected in any project's data management plans.

ACKNOWLEDGEMENT

This research falls within the ENLIGHTENme project (EU Horizon 2020 GA No 945238).

REFERENCES

1. Popkin, G. (2019). Data sharing and how it can benefit your scientific career, Nature, 569, 445-447.
2. Staunton, C., Slokenberga, S., Mascalzoni, D. (2019). The GDPR and the research exemption: considerations on the necessary safeguards for research biobanks, Eur J Hum Genet, 27, 8, 1159-1167.
3. Kaye, J., Curren, L., Anderson, N. et al (2012). From patients to partners: participant-centric initiatives in biomedical research, Nat Rev Genet, 13, 371-376.
4. Vlahou, A., Hallinan, D., Apweiler, R. et al (2021). Data Sharing Under the General Data Protection Regulation, Hypertension, 77, 1029-1035.
5. Wilkinson, M., Dumontier, M., Aalbersberg, I. et al (2016). The FAIR Guiding Principles for scientific data management and stewardship, Sci Data, 3, 160018.
6. Boeckhout, M., Zielhuis, G.A., Bredenoord, A.L. (2018). The FAIR guiding principles for data stewardship: fair enough?, Eur J Hum Genet, 26, 931-936.

CONTROLLER-PROCESSOR OR JOINT-CONTROLLERS? RIGHTS AND RESPONSIBILITIES IN RESEARCH CONSORTIA

keywords
data sharing, GDPR, controller, processor, data rights, privacy

ABSTRACT
Research is increasingly reliant on access to large quantities of data, often obtained through data sharing arrangements. This sharing of data raises considerable legal and ethical complexities, including privacy concerns.
The General Data Protection Regulation (GDPR) has impacted this sharing of data. In addition to the conditions that must be met in the processing of personal data, the GDPR sets out lines of responsibilities, notably in relation to the data controller, the data processor, and joint controllers. It is the data controller who will decide the means and processing of personal data and the data processor who processes data on behalf of the data controller. The responsibilities of both parties differ; therefore, it is essential that prior to the sharing of data, the relationship on which the samples and data are shared (i.e., controller-processor or joint controllership) is established.
There has been a fragmented application of the GDPR at a national level, challenging the identification of the appropriate data sharing relationship. In this paper we discuss these relationships and unpack the data sharing relationship in two contexts: collaborations between institutions and research consortia.

INTRODUCTION
Research is increasingly reliant on access to large quantities of data, often obtained through data sharing arrangements. This sharing of data raises considerable legal and ethical complexities, including privacy concerns, and the introduction of the General Data Protection Regulation (GDPR) has impacted this sharing of data [1]. In any data processing arrangement, the GDPR requires that these roles and responsibilities between the different parties processing data are identified. The data controller has considerable responsibilities under the GDPR, but in the context of research, the data controller can also invoke derogations and exemptions for research. This leaves the data controller with the power to limit data subject rights, but in doing so, they also have the responsibility to ensure that there are appropriate safeguards in place. It is thus particularly important that roles and responsibilities are clearly outlined in scientific
collaborations. An added complexity in this domain is the fragmented application of the GDPR in the context of research at a national level. In multi-site and multi-jurisdictional research collaborations that require the sharing of personal data, the rules that apply to the data may therefore differ, making the delineating of roles and responsibilities challenging. Although the GDPR and EDPB provide guidance on controllers and processors, identification of such roles can be challenging considering the various circumstances in which data is shared for research. In this paper we analyse the respective roles of data controllers, data processors and data controllers and apply this discussion to data sharing relationships in a research consortium

DATA CONTROLLERS, DATA PROCESSORS, AND JOINT CONTROLLERS

2.1 Data sharing in a controller-processor relationship
It is the data controller "determines the purposes and means of the processing of personal data" (Article 4(7)). The data controller has considerable responsibilities: they are accountable for compliance and demonstrating compliance with the GDPR (Article 5); they must implement appropriate technical and organisational measures to demonstrate that the processing is in accordance with the GDPR (Article 24); they have responsibility for ensuring data protection by design and default (Article 25); they have responsibilities to be met when appointing data processors (Article 28); and that any transfers to third countries comply with the provisions set out in Chapter V.

Ciara Staunton, Andrea Parizale, *Institute for Biomedicine, Eurac Research, Bolzano*
Deborah Mascalzoni, *Centre for Research Ethics and Bioethics*

In the context of research, the data controller also potentially has considerable powers as the GDPR provides for derogations and exemptions to many of the strict processing requirements for research, either through invoking the GDPR directly or through Member State of EU law [2]. This means that the data controller can potentially decide to limit some data subject rights, retain personal data for longer than is necessary if it is for research, and use the data for a purpose not specified or anticipated at the time of data collection. Thus, provided the processing meets the principles of the GDPR, including an authorisation to process sensitive data, and the research is line with any applicable research ethics requirements, it is the data controller who will decide on the secondary use of data. The GDPR does state that such derogations are not legitimate unless subject to "appropriate safeguards" as per Article 89. In the absence of guidance, it is for the data controller to make this determination.

The processor on the other hand "processes personal data on behalf of the controller" (Article 4(8)). Article 29 makes it clear that the processor must process personal information following the controller's instructions, unless they are required to process it by EU or Member State law. A data processor is an external partner to the data controller, and will not be an employee of the data controller. Although the GDPR does put considerable responsibility for the data processor in the hands of the data controller, the data processor has certain responsibilities under the GDPR. First there are general responsibilities under the GDPR: it must maintain a record of all categories of data processing (Article 30(2)), it must meet the security requirements as set out in the GDPR, the obligation to appoint a data protection officer (DPO) in certain circumstances also applies to processors (Article 37), as do the strict rules on data transfers to third countries. Second, it has some duties to the data controller: it must assist the data controller in demonstrating compliance where necessary, and it must notify without undue delay to the data controller any data breach (Article 33(2)). Third, it has some responsibilities shared with the data controller: it has equal responsibility to ensure that its relationship with the data controller is bound by a legal act or a contract and it can also be fined by a supervisory authority in the event of non-compliance with the GDPR.

The processing activities of the data controller and the data processor are intertwined and there is a sharing of some responsibilities, but there are significant differences. In the processing of personal information generally, it is the data controller who has responsibility for demonstrating compliance (albeit assisted, if necessary, by the data processor), and who must notify the supervisory authority in the event of a data breach. In the context of research, the data controller has additional powers and responsibilities. It is the data controller who can invoke derogations and exceptions for research that limit the rights of the data subjects, but they equally have a responsibility to identify appropriate safeguards in such circumstances. It is the data controller who must document the justifications for invoking any derogations and demonstrate that the safeguards are appropriate.

2.2 Data sharing in a joint controllership

Health research is increasingly collaborative that involves two or more parties that are developing and partaking in the research, and therefore deciding on the means and the processing of personal data. The GDPR makes provision for this through joint controllership in Article 26 and this occurs when two or more parties "jointly determine the purpose and means of processing". Key to a joint controllership is that the parties "jointly" decide the means and purpose of processing and the EDPB has stated that this may arise in two situations [3]. First, through a common decision when two or more parties together decide the means and the purpose of processing. Second, through a converging decision when the decisions on the purpose and means of the processing by the parties complement each other and have a tangible impact on the purposes and means of the processing. Joint controllership therefore exists when the entities are involved in the same processing purposes for a jointly defined purpose. This can be a common purpose or a closely linked or complementary purpose. It could also arise when two or more entities jointly determine the means of the processing, but this does not require all entities to be involved in all decisions at all stages of processing [3].

In research that involves more than one party, it is essential that it is established whether they are in a controller-processor relationship or one of joint controllership. If it is a joint controllership, the parties need to establish their respective compliance responsibilities in advance of the research. The EDPB has stated that the party responsible for exercising data subjects' rights, implementing the principles of data protection, identification of the lawful basis of processing, data protection impact assessments, and the party to notify the relevant supervisory authority must be established. Irrespective of how a joint controllership is arranged, a data subject can exercise their rights against each of the controllers [3].
In the context of research that can involve multi-site and multi-jurisdictional parties, the delineating of responsibilities can be complex and compounded by the fragmented national implementation of the GDPR for research [4]. The lawful basis on which to process personal data for research is not uniform across Member States, and the rules on secondary use of data can also differ. Following this, although the EDPB has stated that one supervisory authority can be appointed responsibility for breach notifications in a joint controllership, in a fragmented landscape, it does not make sense, nor indeed uphold data subject rights, to only notify one supervisory authority, where differing rules apply.

DATA SHARING RELATIONSHIP IN A RESEARCH CONSORTIUM

Increasingly, research funding is awarded to research consortia with partners in differing jurisdictions across Europe. As a way of maximizing the investment, the European Commission requires the making available of data collected and generated as part of a consortium, where possible. Projects funded by the European Commission are required to develop a data management plan (DMP) that must describe, amongst other issues, the purpose for which the data is to be processed, the type of data to be collected, where it is collected, and how the data may be accessed. As part of these discussions on data management, partners will need the respective responsibilities, and this is not always clear. The consortium will together have agreed upon the aim and objectives of the research and how they should be achieved. The question that arises is whether each partner is responsible for all the data that has been collected to answer this research question. If all parties are involved in data collection and share the data as part of the research, they are in a joint controllership. Together they have decided on the means and purpose of processing. The consortium will therefore need to together identify the respective responsibilities to ensure that there is compliance with the GDPR. This, however, must be done in a way that enables each partner to adhere to the differing rules that are likely to apply across each jurisdiction, therefore making the delineating of rules and responsibilities complex.

CONCLUSION

The sharing of data for research is important in research consortia, but it must be done in a manner that safeguards research participants rights. A necessary first step in this is the establishment of the data sharing relationship. The fragmented application of the GDPR makes this challenging, but it is an essential step in the compliance with the GDPR.

REFERENCES

1. Staunton, C., Slokenberga, S., Mascalzoni, D. (2019). The GDPR and the research exemption: considerations on the necessary safeguards for research biobanks, Eur J Hum Genet, 27, 8, 1159-1167.
2. Staunton, C., Slokenberga, S. Parziale, A. & Mascalzoni, D. Appropriate safeguards & Article 89 of the GDPR: considerations for biobank, databank and genetic research. Forthcoming in Frontiers in genetics.
3. EDPB. (2021). Guidelines 07/2020 on the concepts of controller and processor in the GDPR. https:// edpb.europa.eu/system/files/2021-07/eppb_guidelines_202007_controllerprocessor_final_en.pdf.
4. Solkenerga, S., Tzortzatou, O., Reichel, J. (2021) GDPR and Biobanking. Springer

URBAN LIGHTING AND RELATED HEALTH STUDIES: HOW CAN RESEARCH INTEGRITY SAFEGUARD AND ENHANCE QUALITY OF RESEARCH?

keywords
research integrity, health studies, fundamental rights, reliability, quality of research

ABSTRACT

Rules of Research Integrity serve the research community as a framework for regulation and self-regulation across all scientific fields. The link between high-quality standards of research and research integrity is gaining growing attention at the European level, especially for all EU-funded project. This is particularly important in research projects including health studies.
Research Integrity always concerns two different but interconnected dimensions of research regulation: "internal" and "external" to the research community.
The former concerns the relationships among researchers, and includes sharing of research results and dissemination, among many other contexts. The latter is aimed at protecting participants and society, or other public interests, such as preventing adverse impact on the environment, waste of resources, etc.
Starting from the key principles and sources of Research Integrity at the European level, the presentation will first analyse the combination of the two mentioned dimensions of Research Integrity in the ENLIGHTENme project and second it will focus on the protection of participants in the qualitative analysis and especially in the biomedical and clinical research. The presentation will thus show how this combination proves to be crucial in addressing the challenges of the project and in enhancing its objectives and benefits.

INTRODUCTION

The link between high-quality standards of research and research integrity (RI) is gaining growing attention at the European level. Research ethics and the connection between RI and fundamental rights are considered for all EU funded projects in all scientific fields to ensure research projects are within the legal and ethical framework, and to enhance and promote the quality of research. This is particularly important in research projects including health studies.
Although several concepts and definitions of "Research Integrity" coexist, RI is usually meant as the body of legal principles, ethical values, and professional standards that form the basis of correct and reliable conduct of researchers, as well as of entities funding, evaluating and promoting scientific research. Rules of RI thus serve the research community as a framework for regulation and self-regulation. Similarly to other fields of professional regulations [2], the framework for RI always concerns two different but interconnected dimensions: "internal" and "external" to the research community. The former concerns the relationships among researchers, and includes sharing of research results and dissemination, among many other contexts. The latter is aimed at protecting participants and society, or other public interests, such as preventing adverse impact on the environment, waste of resources, etc.
An adequate balance between research interests and fundamental rights, as well as between autonomy and responsibility is one of the major challenges for RI.
Urban lighting interventions are an interesting perspective from which to analyse both the combination of the mentioned dimensions and the interplay of principles and sources of law protecting participants, with particular reference to health studies.

MATERIALS AND METHODS

The key principles and sources of Research Integrity at the European level will be outlined.
For instance, according to the European Code of Conduct for Research Integrity published by All European Academies the fundamental principles of good research that guide researchers "in their work as well as in their engagement with the practical, ethical and intellectual challenges inherent in research" are: "reliability in ensuring the quality of research, reflected in the design, the

Elisabetta Pulice, *Eurac Research – Institute for Biomedicine*

methodology, the analysis and the use of resources; honesty in developing, undertaking, reviewing, reporting and communicating research in a transparent, fair, full and unbiased way; respect for colleagues, research participants, society, ecosystems, cultural heritage and the environment; accountability for the research from idea to publication, for its management and organisation, for training, supervision and mentoring, and for its wider impacts"[1].

At both the European and national level these principles contain or correlate with other legal principles and ethical values. The presentation will therefore consider how the framework for RI is based on a variety of regulatory sources (legal rules, codes of conduct, guidelines, good practices, professional standards, rules of professional ethics, etc), as well as on the multilevel protection of ethical and legal principles (international and EU principles, national regulations, specific regulations and needs for different research fields).

Moreover, since RI lies at the intersection between different disciplines (science, ethics, and law), a truly interdisciplinary approach is needed.

RESULTS AND DISCUSSION

The ENLIGHTENme project permits a focused analysis on the abovementioned issues.

The following elements will be discussed to show the combination of the "internal" and "external" dimensions of RI in the ENLIGHTENme Project:

- The sharing of research results and dissemination (e.g., the Open Atlas).
- The protection of participants.

Specific attention will focus on the latter, with particular reference to health studies.

This combination is analysed with reference to the challenges, objectives and benefits of the ENLIGHTENme project.

CONCLUSION

Compliance with RI principles safeguards and promotes quality of research and public confidence in researchers. It prevents adverse impact on participants and society, waste of resources, thus enhancing scientific, social and economic advancement while at the same time protecting the public image of science, researchers and research institutions. From this perspective, RI contributes to the advancements and progress of science in society.

The combination of the "internal" and "external" dimensions of RI proves therefore to be crucial in addressing the challenges of the project and in enhancing its objectives and benefits.

REFERENCES

1. ALLEA (2017), The European Code of Conduct for Research Integrity.
2. Pulice E (2021), Professional Medical Ethics, in Busatta L, Casonato C, eds, Axiological Pluralism. Jurisdiction, Law-Making and Pluralisms, Springer, 2021.
3. Forsberg, EM., Anthun, F.O., Bailey, S. et al. (2018). Working with Research Integrity—Guidance for Research Performing Organisations: The Bonn PRINTEGER Statement. Sci Eng Ethics 24, 1023–1034.
4. Penders B., Shaw D., Lutz P (2018). ENERI Manual: Research Integrity and Ethics, Maastricht University.
5. Science Europe Working Group on Research Integrity (2015). Seven Reasons to Care about Integrity in Research

LIGHT POLLUTION AND JUSTICE

keywords
night time lighting, light pollution, ethics, environmental justice, one health

ABSTRACT
Artificial lighting has been essentially conceived negatively by the few philosophers and ethicists who have written about it. The notion of 'light pollution' has become a common way to conceive concerns over excessive or obtrusive artificial light. As all frameworks, also this one tends to set the limits within which the topic is discussed, essentially as an environmental issue. The aim of this study was two folded: firstly, to provide a synopsis of the ethical issues in the literature of lighting and, secondly, to contribute to the further understanding of the notion of light pollution through an analytical discussion hinged on the principle of environmental justice. To pursue this aim was performed a review of the academic ethics literature and then an analysis of the main concepts involved. The ethical reflection mainly focused on five clusters of concern: loss of darkness, energy waste, ecology, animal harm and human health. The present study has suggested the utility for a deeper understanding of, and solution to, the problem of light pollution to consider it through the lens of a broader environmental justice principle inspired to a One Health approach.

INTRODUCTION
Nights are not dark anymore. The ideal of turning nights into days or of lengthening the days has been long sought after and can now be considered almost ubiquitously achieved. It has been estimated that more than 80% of the world's population lives under a skyglow dome — an effect of artificial lights raising night sky luminance — with a peak in North America and Europe, where a completely natural night sky can be experienced by only the 1% of the population [1]. Urban night-time lighting can be held as the major cause of this and the notion of 'light pollution' has become a common way to conceive concerns over it. As noted by Stone [2], while this notion can be useful to provide a frame of reference to assess the condition under which, and the parameters to measure when, there is too much light, it also sets limits to the discussion of the problem. Probably due to its emergence in the seventies, when astronomers adopted anti-waste communication and conceptual tools to fight excessive artificial night-time brightness [3], light pollution is primarily conceived as an environmental problem. Light pollution usually refers to negative or undesired consequences of night-time lighting, which can be categorized as skyglow, glare, light trespass, and clutter. Thus, negative aspects intrinsic to night-time lighting, which affect human vision. Besides these, a more nuanced understanding of light pollution entails that night-time lighting is also instrumental to public health, environmental, and aesthetic concerns [2]. These undesired effects of light pollution are the main focus of the present study.
Light pollution it is a public health concern in that inappropriate exposure to light at night affects people's health and wellbeing. Light impacts circadian rhythm, and with that, people's health and wellbeing, with negative effects on epigenetics, metabolism, and an increased risk for a number of diseases and conditions, including cancer and psychiatric illness [4]. In urban settings, lighting health-related problems are particularly worrisome for elderly citizens. A different set of concerns relate to energy usage and ecology. Light pollution wastes energy and money. Energy usage keep increasing in spite of the technological improvements in lighting devices, which suggests that a simple conversion to efficient lighting technologies is not sufficient to solve the problem [5]. The environmental dimension is not limited to the issues of efficiency and sustainability. Light pollution is also a huge ecological issue and a source of animal harm [6]. The aesthetic dimension is mainly represented by the loss of night sky and the connected value of the darkness, whose experience is virtually precluded to younger people, who can consider 'normal' present night-time levels of light [7].

Mirko Ancillotti, *Centre for Research Ethics and Bioethics, Department of Public Health and Caring Sciences, Uppsala University, Sweden*
Deborah Mascalzoni, *Institute for Biomedicine, Eurac Research, Italy; Centre for Research Ethics and Bioethics, Department of Public Health and Caring Sciences, Uppsala University, Sweden*

The aim of this study is two folded: firstly, to provide a synopsis of the ethical issues in the literature of lighting and, secondly, to contribute to the further understanding of the notion of light pollution through an analytical discussion hinged on the principle of environmental justice. The second aim is a consequence of the first in that mapping the field highlighted the need to examine in further depth the concept of light pollution.

MATERIALS AND METHODS

A review of the academic literature in English language about the ethics of lighting-connected issues was performed into five databases: Web of Science, Scopus, PhilPapers, PubMed, JSTOR. The search was performed for titles, abstracts, and keywords in the period 1971-2021. The search terms and Boolean operators used were the following: ("moral" OR "ethic*) AND ("night-time light*" OR "urban light*" OR "outdoor light*" OR "indoor light*" OR "domestic light*" OR "light pollution" OR "artificial light*" OR "lighting quality" OR "lighting behav*" OR "light hygiene" OR "lighting poverty" OR "lighting policy" OR "smart lighting"). The search produced 44 results, which after eliminating duplicates and non-pertinent documents, were reduced to 14. The documents were read and relevant contents were organized by topic order, i.e. by main topics or issues.
Furthermore, this abstract adopts conceptual and normative analysis to address the notion of light pollution through the lens of environmental justice.

RESULTS AND DISCUSSION

3.1 Synopsis of the field

The first consideration to make is that very little has been written about the ethics of lighting. The second is that often the ethical aspects of lighting-related issues were not the focus of the studies but secondary or ancillary issues. Nigh-time lighting has been essentially conceived negatively because excessive and, indeed, often connected to the notion of light pollution.
The authors mainly focused on five clusters of ethical concern: loss of darkness, energy waste, ecology, and, in a limited manner, animal harm, and human health.
In order to deeper understand the issue of the loss of darkness, one needs to loosen the boundaries set by the light pollution framework and focus on the value of darkness, i.e. bring out of focus the negative sides of lighting at night and concentrate instead on what is good about darkness at night [7].
Dark nights are valuable because they hold transformative power in terms of their important intellectual, cultural, aesthetic, and (psycho-physiologically) restorative effects [8].
In typical ecosophy terms, it can be argued that the experience of dark nights is part of individuals' development of ecological consciousness [9].
Energy waste entails an unjustified overproduction of energy for lighting purposes with consequent detrimental effects on the environment and on the allocation of public economic resources. The threshold between proper use and waste of energy changes according to the criteria used in the evaluation. However, as this dimension of the problem does not exist in isolation, it is unlikely that a technological innovation could solve it — for instance LEDs reduce energy consumption but potentially increase skyglow [2].
Ecological concerns encompass both the issue of the harm provoked to fauna and flora by the intrinsic negative effects of night-time lighting but also the environmental issues connected to pollution caused by the energy required for night-time lighting.
While there is a constellation of different positions within the field of environmental ethics,

theories can be fundamentally categorised as forms of extensionism — moral standing is extended to include more entities — and ecological theories — the environment becomes the center [10]. Beyond theoretical differences and in spite of the relative different grounds for action, it can be agreed that there is a value, or at least a common interest, to conserve biodiversity. In Dill's words: "...we therefore have at least one, indirect reason to conserve dark nights: natural darkness is, after all, integral to the health and reproductive success of biodiverse ecosystems and their constituents." [8].

Animal harm is another dimension of light pollution that is extremely dependent on the ethical theory under consideration. Usually, this issue is encapsulated in the broader dimension of ecological concerns. However, this holds true only insofar the value of animals is recognized according to a holistic view — what matters are not the individuals but the ecosystems, the species that include the individuals, which are valuable as a part of something greater than the sum of its parts. The reflection on the ethics of light pollution affecting animals' wellbeing is minimal [11].

Although the threat that light pollution poses to human health is so compelling that night shift work has been classified as a carcinogen [12], the ethical reflection on the issue is limited also in this case. At best, as for animal harm, there are mentions to the problem, often in connection to the already mentioned restorative effects of darkness, thus with reference to the intrinsic negative effects of light pollution.

However, taking into due consideration the undesirable effects to which light pollution is instrumental, it is clear that this is detrimental to human health not only because light impacts circadian rhythm but because it also contributes to the environmental crisis.

3.2 Environmental justice and One Health

As said, artificial light at night is essentially framed as an environmental problem, i.e. light pollution. The core of environmental problems, at least within the more anthropocentric tradition, is that they cause inequalities between people (living and future).

According to Bullard's influential definition [13], 'environmental justice' is the principle according which "all people and communities are entitled to equal protection of environmental and public health laws and regulations."

The principle is the theoretical foundation at the basis of decades of claims that exposure to pollution and other environmental risks is unequally distributed by race and class [14]. As such it can be used to analyse light pollution as a public health problem including inequalities connected to lighting poverty.

However, the principle could be extended to all living entities such that the circle of entities whose interests should be taken into account when planning lighting policies would include also animals, species, plants and ecosystems.

The environmental justice principle should not be extended to other entities only to acknowledge their moral standing and, through this typical extensionist move, grant them more protection on the basis of an assessment of their value (either based on individual characteristics or based on holistic value). Instead, it should be inspired by a One Health approach to global problems, thus recognizing that optimal human health is achievable recognizing the interconnection between people, animals, plants, and their shared environment [15].

CONCLUSION

Light pollution has received little attention from philosophers and ethicists, who mainly focused on five clusters of ethical concern: loss of darkness, energy waste, ecology, animal harm and human health. The present study has suggested the utility for a deeper understanding of, and solution to, the problem of light pollution of considering it through the lens of a broad environmental justice principle inspired by a One Health approach.

ACKNOWLEDGEMENT

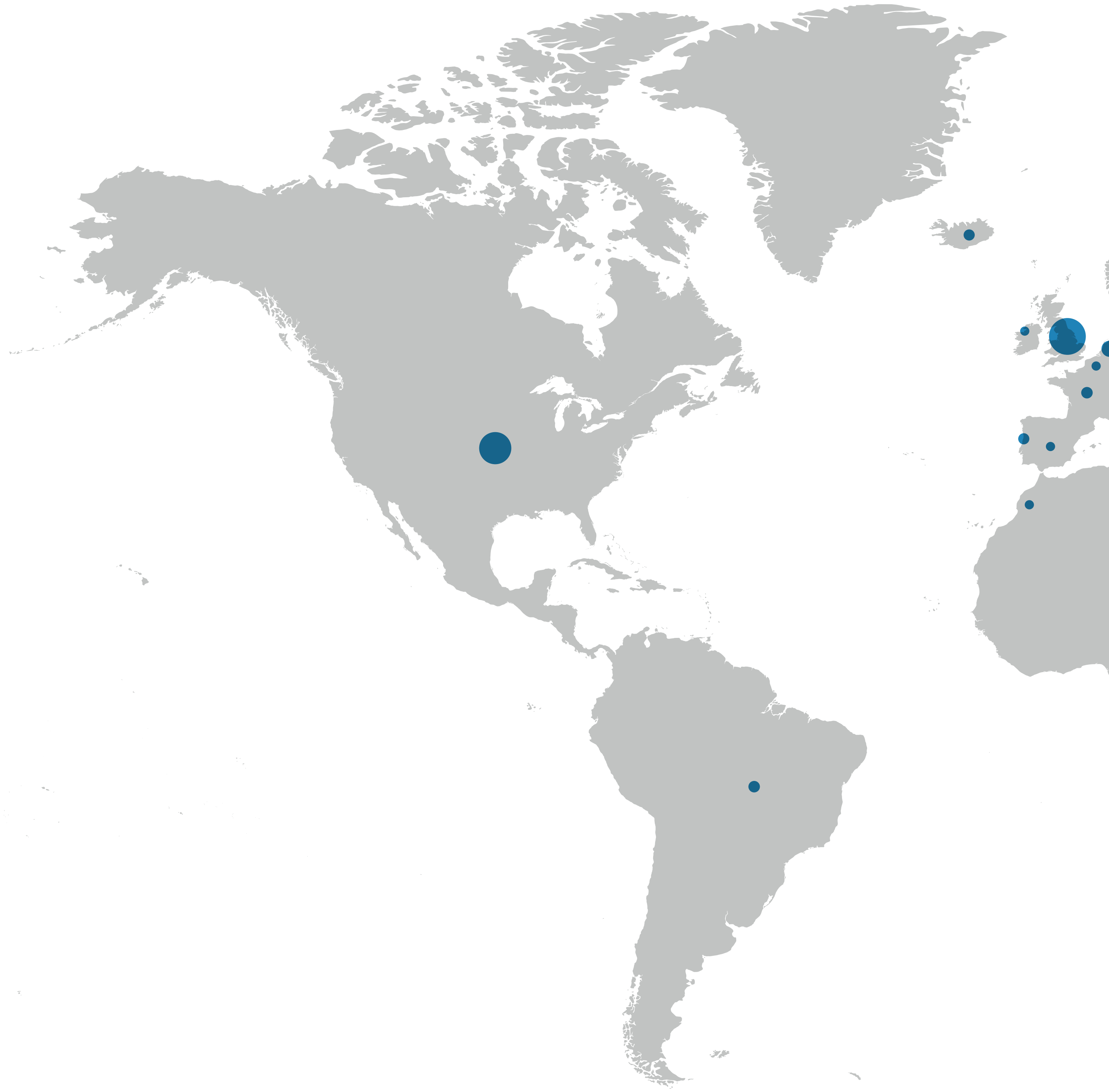
This research falls within the ENLIGHTENme project (EU Horizon 2020 GA No 945238).

REFERENCES

1. Falchi, F., et al., The new world atlas of artificial night sky brightness. Science advances, 2016. 2(6): p. e1600377-e1600377.
2. Stone, T., Light Pollution: A Case Study in Framing an Environmental Problem. ETHICS POLICY & ENVIRONMENT, 2017. 20(3): p. 279-293.
3. Sperling, N. The Disappearance of Darkness. 1991.
4. Stevens, R.G. and Y. Zhu, Electric light, particularly at night, disrupts human circadian rhythmicity: is that a problem? Philosophical Transactions of the Royal Society B: Biological Sciences, 2015. 370(1667): p. 20140120.
5. Kyba, C.C.M., A. Hänel, and F. Hölker, Redefining efficiency for outdoor lighting. Energy & Environmental Science, 2014. 7(6): p. 1806-1809.
6. Gaston, K.J., et al., REVIEW: Reducing the ecological consequences of night-time light pollution: options and developments. Journal of Applied Ecology, 2012. 49(6): p. 1256-1266.
7. Stone, T., The Value of Darkness: A Moral Framework for Urban Nighttime Lighting. Science and engineering ethics, 2018. 24(2): p. 607-628.
8. Dill, K.M., In Defense of Wild Night. ETHICS POLICY & ENVIRONMENT.
9. Naess, A., Ecology, Community and Lifestyle: Outline of an Ecosophy. 1989, Cambridge: Cambridge University Press.
10. Cochrane, A., Environmental ethics, in The internet encyclopedia of philosophy, J. Fieser and B. Dowden, Editors. 2006.
11. Hampton, J.O., et al., Animal Harms and Food Production: Informing Ethical Choices. ANIMALS, 2021. 11(5).
12. Stevens, R.G., et al., Considerations of circadian impact for defining 'shift work' in cancer studies: IARC Working Group Report. Occupational and Environmental Medicine, 2011. 68(2): p. 154.
13. Bullard, R.D., Environmental Justice: It's More Than Waste Facility Siting. Social Science Quarterly, 1996. 77(3): p. 493-499.
14. Mohai, P., D. Pellow, and J.T. Roberts, Environmental Justice. Annual Review of Environment and Resources, 2009. 34(1): p. 405-430.
15. AVMA, One health: A new professional imperative. One Health Initiative Task Force Final Report. 2008, American Veterinary Medical Association: Schaumburg, IL.

Participant impact map

The international conference for the topics covered and the network of partners that make up the consortium has generated a strong interest from over 150 participants, including professors, researchers and industry professionals from around the world.



Project Coordinator
Simona Tondelli - enlightenme@unibo.it

Project Partners

The ENLIGHTENme project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 945238.