Light hygiene in the built environment

Marilyne Andersen*, Victoria E. Soto Magán, Forrest Webler, Clotilde Pierson

Laboratory of Integrated Performance in Design (LIPID), School of Architecture, Civil and Environmental Engineering (ENAC), Ecole polytechnique fédérale de Lausanne (EPFL), Switzerland

*main presenter, contact info below

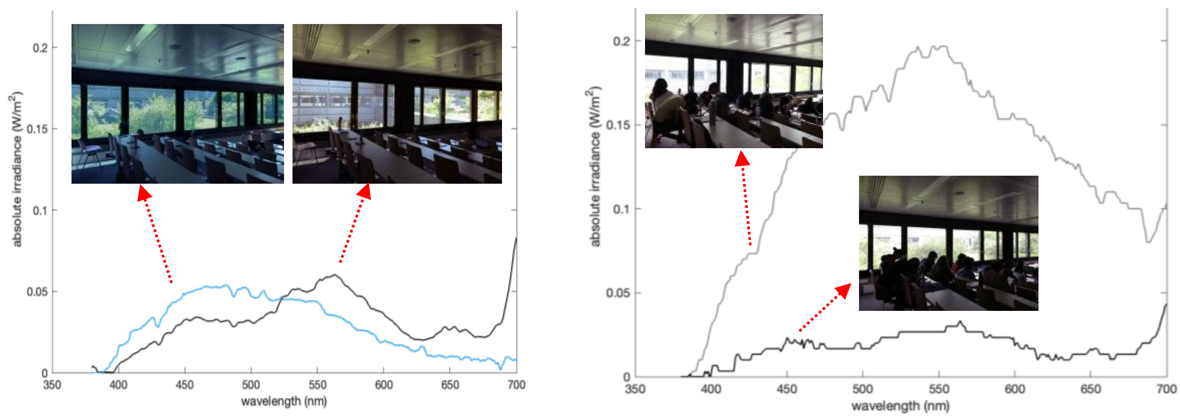
Abstract

Since the discovery of ipRGCs in the human eye [1-3], the field of circadian photoreception has led to fundamental discoveries on the effects of ocular light exposure on non-visual responses such as alertness, sleep, health and other neurobehavioral processes.

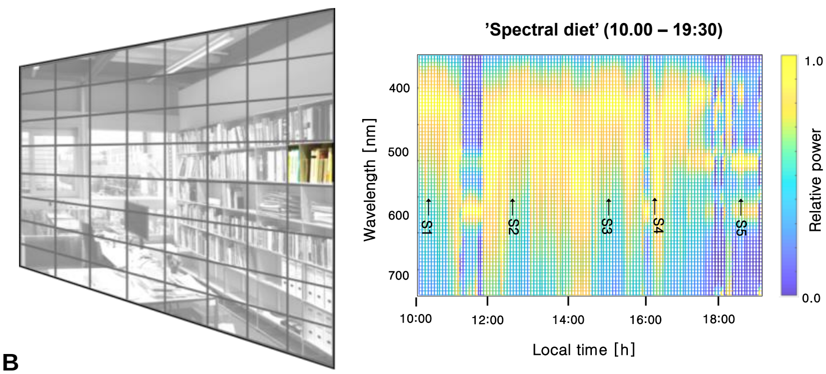
They have come from a variety of laboratory studies (often conducted at night to use melatonin levels as an indicator of circadian phase [4-6]), in which participants are usually exposed to rather extreme and well-controlled conditions [7]. Their applicability to real-life, daytime conditions, are thus difficult to assess, and to what extent these findings matter for architectural design still remains ambiguous.

The role of daylight in this context has so far not been clearly identified either. Abundant and inherently renewable, this source of light is usually considered necessary for regularly occupied working or living environments to be acceptable [8]. Yet it is rarely included in research studies due to its somewhat unpredictable nature. To address this knowledge gap, and considering that we spend the vast majority of our time indoors, it is becoming urgent to get a better understanding of our 'light hygiene' within the built environment, and determine whether and to what extent certain key properties of (day)light – its spectral distribution and its intensity over time – may impact our well-being or the adequacy of the places in which we work, learn or are being cared for [9-11] to fulfill our needs.

Ongoing research efforts at LIPID aim to tackle this question from three perspectives, whose main outcomes and concepts are provided in figures **A**, **B** and **C** below. Semi-controlled, multiple-day studies focusing on daytime alertness in classrooms with distinct conditions in intensity and spectrum [12-13] were conducted in 2018 and repeated in 2019 (**A**). During these studies, a total of 68 subjects were asked to complete hourly routines that included subjective behavioral self-reports and attentional tasks, while monitoring their autonomic nervous activity through electrocardiogram recordings.



A



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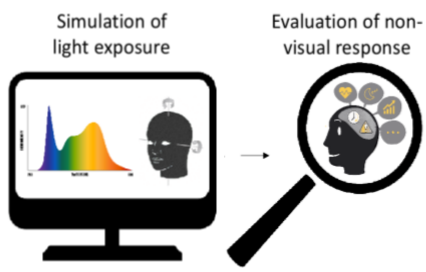

C

A: Effects of intensity and spectrum on non-visual effects of light indoors – **B**: Measuring and analyzing spectral properties of light exposure – **C**: Simulation workflows to anticipate non-visual effects in design

Outcomes showed that participants felt overall more alert, had higher attention spans and decreased heart rate decreased while in bluer rather than neutral dim environments, and while exposed to brighter rather than dimmer neutral daylight conditions. The next step is thus to anticipate the implications of design decisions or lifestyle choices affecting access to daylight by resorting to broader data collection and to simulation models.

Towards this end, wearable technology is being developed in combination with novel mathematical models to build more knowledge about the 'spectral diet' [14] we are actually experiencing in our urban lifestyle (**B**) and better anticipate its potential impact on health and well-being. Specifically, the objective is to map the current topography in 'light hygiene' by collecting ambient light information from multiple individuals to assess the prevalence of different spectral diets. We are then interested to evaluate the long-term potential health impact posed by the more common diet profiles in order to assess the global risk associated with poor light hygiene, which requires to resort to simulation.

New simulation workflows are thus needed that rely on models able to link given properties of light [15] with neurophysiological responses (**C**). The idea is to determine to which degree spectral simulation can be used to predict building occupants' exposure to light (considering both the spectral distribution and intensity over time), accounting for probable changes in view direction and position over time.

The ultimate objective pursued here is to help inform design with a better understanding of what we should be most attentive to with regards to our light exposure when designing working, learning or healing places [16].

References

1 Brainard GC, Hanifin JP, Greeson JM, et al. Action Spectrum for Melatonin Regulation in Humans: Evidence for a Novel Circadian Photoreceptor. *The Journal of Neuroscience* 2001; 21: 6405–6412.

2 Berson DM, Dunn FA, Takao M. Phototransduction by Retinal Ganglion Cells That Set the Circadian Clock. *Science* 2002; 295: 1070–1073.

3 Hattar S, Liao HW, Takao M, et al. Melanopsin-containing retinal ganglion cells: architecture, projections, and intrinsic photosensitivity. *Science* 2002; 295: 1065–1070.

4 S.L. Chellappa, R. Steiner, P. Blattner, P. Oelhafen, T. Götz, C. Cajochen, Nonvisual effects of light on melatonin, alertness and cognitive performance: can blue-enriched light keep us alert? PLoS One 6 (2011) e16429, http://dx.doi.org/10.1371/journal.pone.0016429.

5 S.W. Lockley, E.E. Evans, F. Scheer, G.C. Brainard, C.A. Czeisler, D. Aeschbach, Short-wavelength sensitivity for the direct effects of light on alertness, vigilance, and the waking electroencephalogram in humans, Sleep 29 (2006) 161–168.

6 Phipps-Nelson J, Redman JR, Schlangen LJM, et al. Blue Light Exposure Reduces Objective Measures of Sleepiness during Prolonged Nighttime Performance Testing. *Chronobiology Int* 2009; 26: 891–912.

7 Smolders KCHJ, de Kort YAW, Cluitmans PJM. A higher illuminance induces alertness even during office hours: Findings on subjective measures, task performance and heart rate measures. *Physiology & Behavior* 2012; 107: 7–16.

8 European Standard 2018, Daylight in buildings, EN 17037:2018, CEN, Belgium.

9 Pechacek CS, Andersen M, Lockley SW, Preliminary Method for Prospective Analysis of the Circadian Efficacy of (Day)Light with Applications to Healthcare Architecture, LEUKOS 2008; 5(1): 1-26.

10 Konis K, Schneider EL. The importance of daylight in dementia care communities: a call to action. *Sr Hous Care J* 2018; 28–37.

11 Konis K, Mack WJ, Schneider EL. Pilot study to examine the effects of indoor daylight exposure on depression and other neuropsychiatric symptoms in people living with dementia in long-term care communities. *Clin Interv Aging* 2018; 13: 1071–1077.

12 Soto Magán VE, Webler FS, Andersen M. Perceived and yet not seen: non-visual effects in daylit spaces. In: *ANFA 2018 'Shared behavioral outcomes'*. Salk Institute, La Jolla, CA, 2018.

13 Soto Magán VE, Andersen M. How to assess alerting effects of daylight at the workplace? Learnings from semi-controlled studies. In: *Proceedings of the 29th Quadrennial Session of the CIE*. Washington DC, USA: International Commission on Illumination, CIE, pp. 227–240.

14 Webler, Forrest S., et al. "What is the 'spectral diet' of humans?." *Current opinion in behavioral sciences* 30 (2019): 80-86.

15 Amundadottir ML, Lockley SW, Andersen M. Unified framework to evaluate non-visual spectral effectiveness of light for human health. Light Res Technol 2017; 49: 673–696.

16 Amundadottir ML, Rockcastle S, Sarey Khanie M, et al. A human-centric approach to assess daylight in buildings for non-visual health potential, visual interest and gaze behavior. *Build Environ* 2017; 113: 5–21.

Authors

Marilyne Andersen is Full Professor at EPFL and Head of the LIPID Laboratory. Her research lies at the interface between science, engineering and architecture with a dedicated emphasis on the impact of daylight on building occupants. Focused on questions of comfort, perception and health, these research efforts aim towards a deeper integration of the design process with daylighting performance and indoor comfort, by reaching out to various fields of science, from chronobiology and neuroscience to psychophysics and computer graphics.
Contact: Prof. Marilyne Andersen, Email : marilyne.andersen@epfl.ch, Profile: https://people.epfl.ch/marilyne.andersen

Victoria E. Soto Magán is a PhD Candidate at LIPID, EPFL. Her background is in architecture and sustainable environmental design, and her PhD thesis focuses on the non-visual effects of (day)light at the workplace.

Forrest Webler is a PhD Candidate at LIPID, EPFL jointly supervised by Dr. Manuel Spitschan at the University of Oxford. With a background in physics and biomedical engineering, his PhD thesis focuses on characterizing the spectral light exposure profiles of individuals on the city scale.

Clotilde Pierson is a PostDoc fellow at LIPID, EPFL jointly advised by Mariëlle Aarts, from TU Eindhoven. Building upon a background in architectural engineering and a PhD on discomfort glare perception from daylight, her current research focuses on new simulation workflows enabling to anticipate non-visual effects of light in working environments.