Advancing Quantification Methods for Personal Light Exposure Patterns

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QUANTIFYING LIGHT EXPOSURE

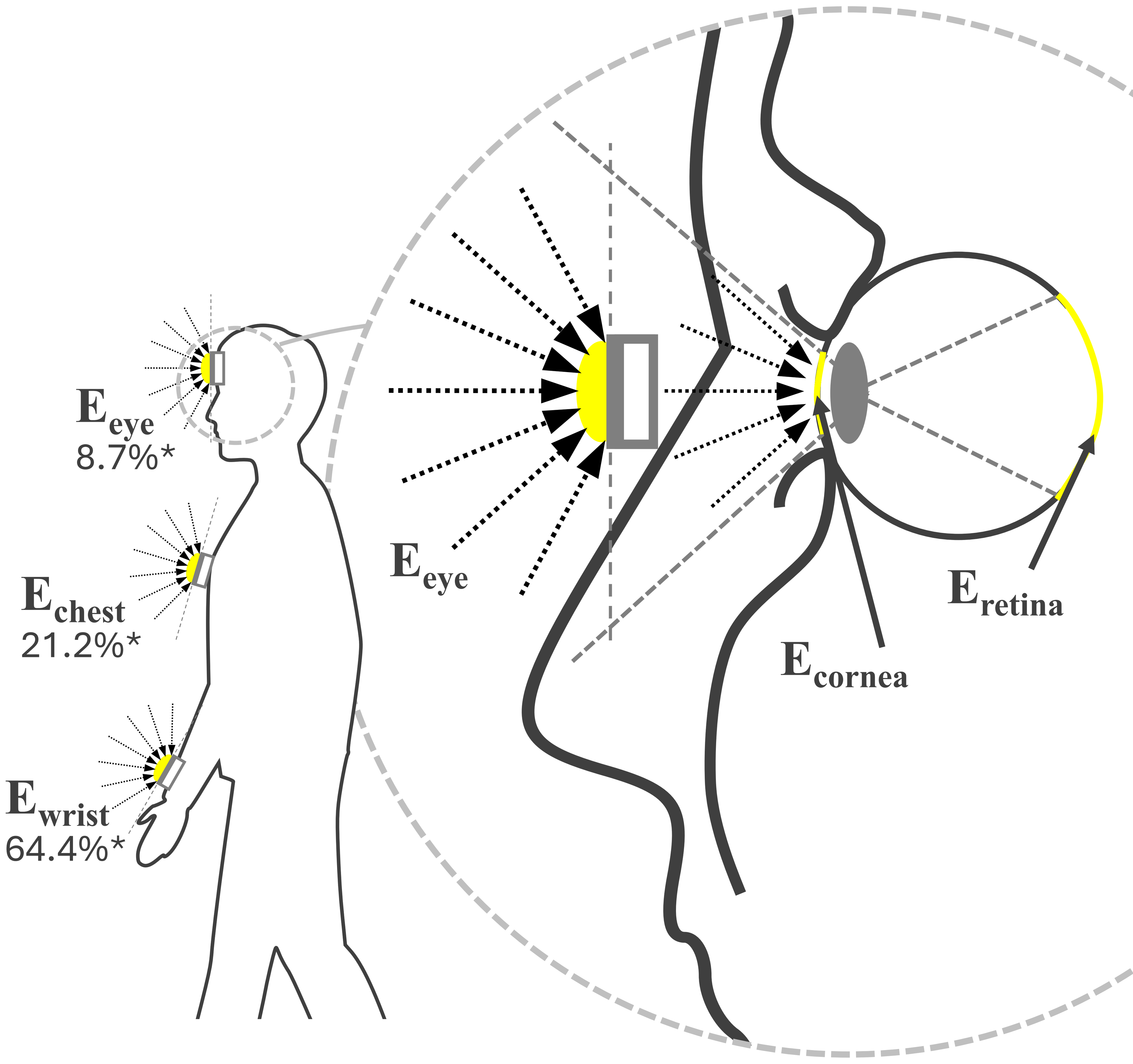
Personal light exposure patterns (i.e. the light an individual gets exposed to over time) are valuable for research and practice. In research, these patterns can help identify the (causal) relationship between light exposure at eye level and non-image-forming (NIF) effects. In practice, these patterns can be used to evaluate the actual (personal) lighting conditions in buildings and predict the occurrence of NIF effects, as input for intelligent lighting systems. Current quantification methods include light dosimetry, lighting simulations, self-reported scales, and environmental measurements, each with its assumptions and associated inaccuracies. **This project aims to advance the accuracy and practicality of these four methods, focusing primarily on light dosimetry.** The other quantification methods will be explored to see if they can complement or replace light dosimetry.

In light dosimetry, wearable sensors (dosimeters) measure light levels on the body. Currently, research efforts are focused on improving the intrinsic photometric accuracy of such sensors [1]. However, questions remain regarding the sensors' in-situ performance, which may alter their photometric properties from those determined in the laboratory, causing variability in the recorded light patterns. Moreover, while wearable sensors placed at the eye level are most accurate, they are also obtrusive, leading to non-wear and data loss [2]. Two research objectives are set:

1. Identify and evaluate in-situ variability of light sensor measurements to allow improved quantifications of personal light exposure patterns.
2. Investigate if light levels measured (anywhere) on the body can be transformed using prediction models to resemble light at the eye more closely. Prediction models might include (real-time) personal and environmental data and machine learning algorithms.

Position	Neglects	Limitations
E_{retina}	-	• Impossible to measure with a dosimeter
E_{cornea}	+ Pupil gaze direction, pupil size, lens properties, eyelid closure (squinting)	• Difficult to measure
E_{eye}	+ Shading by facial features	• Obtrusive
E_{chest}	+ Head movement	• Somewhat obtrusive • Possible shaded by body/clothing
E_{wrist}	+ Posture	• Possibly deviating from prime view direction • Possibly shaded by body/clothing

Table 1: Limitations of measurements positions used to approximate retinal light levels.



*Percentage of 104 light dosimetry studies reviewed by Hartmeyer et al. [3].
Image based on Hoof et al. (2012).

IN-SITU PERFORMANCE OF LIGHT SENSORS

In field studies, light sensors are worn at various positions [3], while light at the retina is of primary interest. There may be considerable differences between light levels recorded on the body and the retina (Table 1). Five studies [4-8] have compared light levels measured by dosimeters at various positions on the body. These studies provide some data on the general relationships between sensor measurements at different body positions, along with exploratory data on the impact of context. However, most studies used relatively short measurement durations, except [6], and involved small participant samples. Additionally, all studies relied on actual dosimeter measurements, which introduces potential variability due to differences between devices. To overcome these limitations, we are developing a hybrid method, i.e. combining measurement and lighting simulations, to identify generalizable and population-specific relations between light levels measured on the body and at the retina.

References

[1] M. Spitschan, J. Zauner, M. Nilsson Tengelin, C.A. Bouroussis, P. Caspar, F. Eloi. Illuminating the future of wearable light metrology: Overview of the Melidos project. Measurement, **235** (2024).
[2] J. van Duijnhoven, M. Aarts, M. Aries, M. Böhmer, A.L.P. Rosemann. Recommendations for measuring non-image-forming effects of light: A practical method to apply on cognitive impaired and unaffected participants. Technology and health care, **25** (2017) 2.
[3] S.L. Hartmeyer, F.S. Webler, and M Andersen. Towards a framework for light-dosimetry studies: Methodological considerations. Lighting Research & Technology, **55** (2023) 4-5.
[4] N. Okudaira, D.F. Kripke, J.B. Webster. Naturalistic studies of human light exposure. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology, **245** (1983) 4.
[5] A.C.N. Jardim, M.D.M. Pawley, J.F. Cheeseman, M.J. Guesgen, C.T. Steele, G.R. Warman. Validating the use of wrist-level light monitoring for in-hospital circadian studies. Chronobiology International, **28** (2011) 9.
[6] M.G. Figueiro, R. Hamner, A. Bierman, M.S. Rea. Comparisons of three practical field devices used to measure personal light exposures and activity levels. Lighting Research & Technology, **45** (2013) 4.
[7] M.P.J. Aarts, J. van Duijnhoven, M.B.C. Aries, A.L.P. Rosemann. Performance of personally worn dosimeters to study non-image forming effects of light: Assessment methods. Building and Environment, **117** (2017).
[8] K.R. Bhandari, H. Mirhajianmoghadam, L.A. Ostrin. Wearable sensors for measurement of viewing behavior, light exposure, and sleep. Sensors, **21** (2021) 21.

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