Experiencing a daylit space – physiological, visual and perceptual dynamics of daylighting

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Abstract

To embed the diversity and variability of human needs as foundational elements of daylighting design and put human occupants back at the core of the building question, we need to reach out to fundamental discoveries from neuroscience, biology and other fields, which will bring new insights and a deeper understanding of how we interact with our environment.

The multiplicity and variability of our needs regarding (day)light exposure have been a topic of investigation for years now in photobiology and psychophysics, though have not yet penetrated the design realm as dynamic models of human response. Humans need to be in an environment conducive to health and have physiological light exposure needs, whose time- and spectrum-dependent non-visual effects we only start to understand. On the other hand, users of a space often need to perform tasks for which comfortable visual conditions are needed, to which we respond with head and gaze dynamics that psychophysics can help us better recognize. Finally, any attentive witness to a space seeks to enjoy its play of light and dark. Perception of daylight is the primary interpreter of the materiality and dynamism of any architectural space. As a result, while daylight as a subjectively perceived visual effect is actually very hard to use as a design factor, it is often what drives decisions.

It is time to bring these exciting new research perspectives back into the design realm in a way it can interactively, dynamically and effectively fuel the creative design process: we have access to the essential ingredients of human-responsive design, now we need to cook.
Keywords: daylighting, climate-based, goal-based performance, non-visual lighting, design decision support

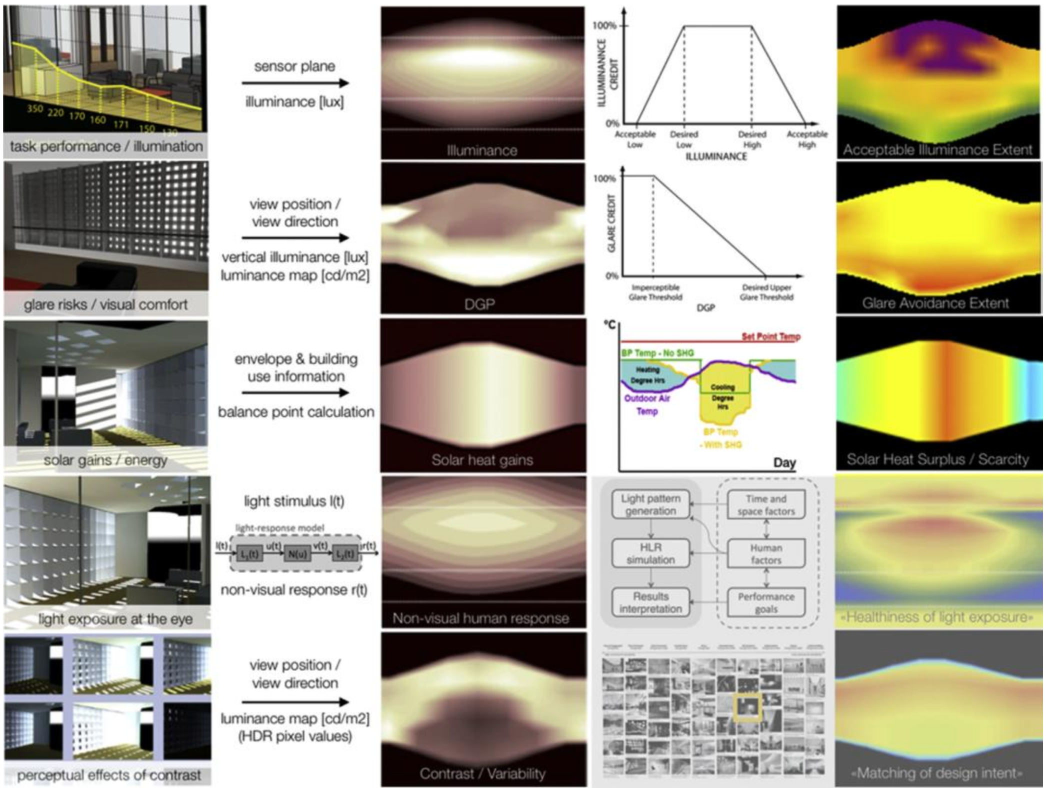

Figure 1. Five interpretations of daylighting performance. From daylighting use (left) to extracting "absolute" quantities (middle) to goal-based metrics (right). Bottom-right (greyed) are work in progress.

The human challenge

Daylighting as a research topic situates itself at the interface between psycho-physiological and environmental factors. It brings together questions relevant to architectural design and building engineering, but also to human physiology and behaviour, which makes it both a challenging and essential aspect of how "performative" a space can be considered.

Decision support for human designers

Can we better integrate the complexity of human needs in buildings into effective design and decision-making support for daylit spaces? How well a given space is daylit is by essence a multifaceted question. It is a key factor in how well any visual task will be performed and a main driver of occupant satisfaction regarding visual and thermal comfort (and hence energy consumption resulting from trying to meet comfort requirements). It has a strong impact on human health and well-being, a close association with (subjective) emotional delight and perceived quality of a space, and is highly dynamic and variable in nature resulting from a combination of predictable (sun course) and stochastic (weather) patterns. There is, as a result, a multiplicity of perspectives from which daylighting performance can – and should – be evaluated in building design. Through very different perspectives ranging from task-driven illumination or comfort to human-driven health and perception, the architect is hence faced with multiple, highly variable, bounded criteria that can conflict but need to be brought together to lead to a satisfying solution.

What the numerous existing tools and approaches have in common is the aim of trying to either define or meet broadly acceptable (yet sometimes population or condition-specific) target values so as to guide design towards objectively 'better' performance. Yet daylighting is known to be a field where no strictly defined numerical boundaries are enforced. There is a vast range of parameters and values that contribute to 'good' daylighting design and make absolute performance targets of questionable relevance. The question of "how good is good?" is indeed far from trivial with the multifaceted, highly variable nature of daylighting performance, about which people – occupants as much as designers – have highly diverging opinions.

Architectural design cannot be replicated by a well-defined computational process because optimization does not respond well to the non-deterministic, ill-defined and unpredictable nature of the design process. Therefore, computer technology and its efficiency in comparing and testing options should be used to help designers fulfil their primary role, which is: to know what to look for.

Decision support for human occupants

The 'human' challenge at hand is two-fold. It comes from the human nature of the designer, which remains the main driver of a design process: the ultimate balance between multiple, often-conflicting criteria cannot solely be based on measurable parameters, thus the design process must remain non-deterministic. And it comes from the human nature of the occupants, which encompasses individual diversity and temporal variability: as we know, to feel comfortable in a daylit space can result in very different constraints depending on the time of day, the season and the location of the building. Furthermore, human factors will induce diverging preferences for comfort from individual to another. The necessary flexibility and dynamic response of design goals also applies to our cyclic physiological needs or to the ever-changing ambiance of a space that contributes so intimately to its uniqueness.

To more deeply embed the diversity and variability of human needs as foundational elements of daylighting design and put human occupants back at the core of the question, we need to reach out to other research fields, so as to bring new insights and a deeper understanding of how we interact with our environment. This presentation will discuss ongoing research regarding the assessment of daylighting performance by considering different interpretations of "well-being" in a space:

- as human inhabitants of a living space who need to be in an environment conducive to health, and have physiological light exposure needs whose time- and spectrum-dependent non-visual effects we only start to understand thanks to recent findings in circadian photoreception research [1],
- as users of a (work)space who perform a task for which comfortable visual conditions are needed, and behave dynamically in a space in which lighting must be well controlled as a key factor of workplace satisfaction and ergonomics [2],
- as witnesses of a delightful space who want to enjoy it and seek to experience its choreography of geometry and light dynamics [3],

that should complement our more fundamental daylighting needs regarding illumination (e.g. based on workplane illuminance) while keeping energy implications under control (overheating risks).

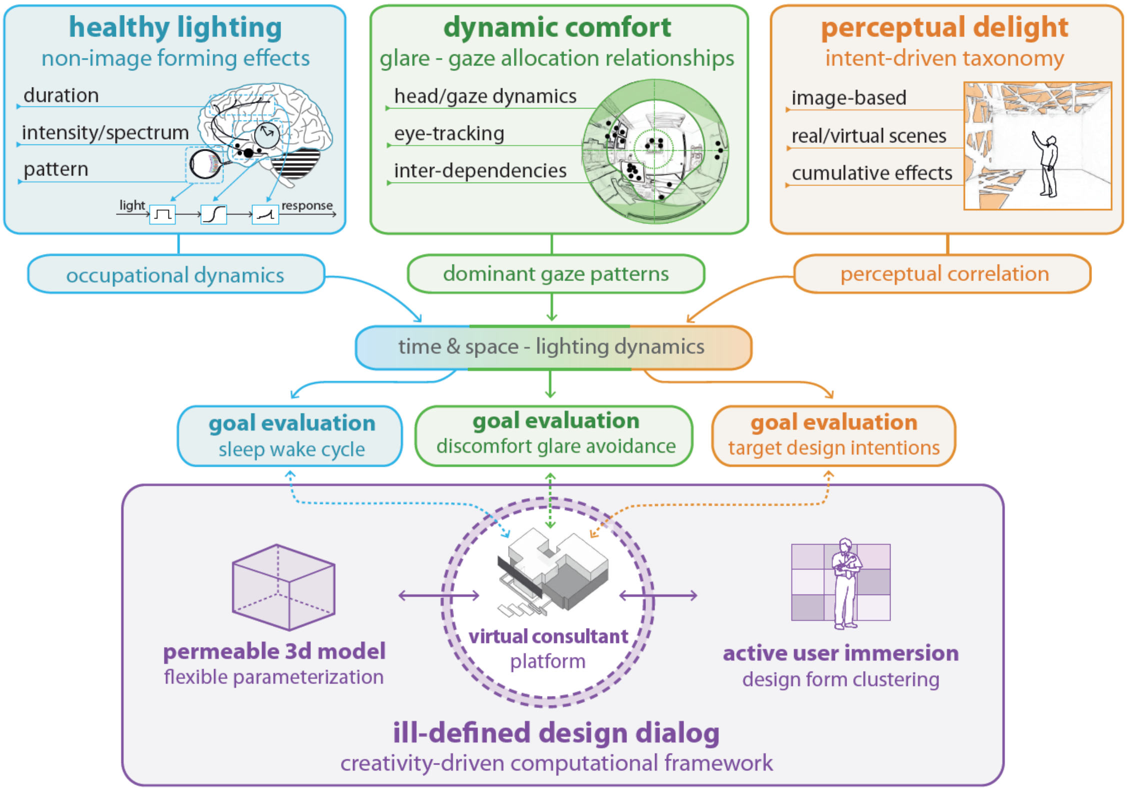

Figure 2. Human-responsive (day)lighting design. Inter-related aspects reaching out to other research fields.

Outlook

What we must identify is how a building should respond to two inputs: on the one hand to what we have, i.e. analysing the resources available to work with (i.e. the building's environment whether natural and/or built, its localisation, climate etc); on the other hand to what we need, to determine whether and how the needs of the building's occupants can be met. The ultimate objective is to provide building designers with the means necessary to assess critical parameters in a successful design and efficiently combine qualitative and quantitative criteria in the solution search process.

Acknowledgements

I would like to thank my PhD students for their contributions to the underlying concepts and models presented in this talk, and especially Dr. Mandana Sarey Khanie, Maria Lovisa Amundadottir and Siobhan Rockcastle, whose just completed and ongoing thesis works form the basis of many of the discussed research developments.

References

1. This text appears in the DETAIL – Daylight & Architecture magazine issue that was concurrently published with the 6th VELUX Daylight Symposium. A more comprehensive and extended version has been published in the Fifty Year Anniversary Golden Issue for Building and Environment in 2015 [4].
2. M.L. Ámundadóttir, S.W. Lockley, M. Andersen, A unified framework for evaluating non-visual spectral effectiveness of ocular light exposure: key concepts, Proc. of 28th CIE conference, Manchester, UK, 2015.
3. M. Sarey Khanie, J. Stoll, W. Einhäuser, J. Wienold, M. Andersen, Development of a gaze-driven methodology for estimating luminance values in the field of view, Lighting Research and Technology, in press.
4. S. Rockcastle, M. Andersen, Measuring the dynamics of contrast & daylight variability in architecture: a proof of concept methodology. Building and Environment 81: pp. 320-333, 2014.
5. M. Andersen, Unweaving the human response in daylighting design, Building and Environment 91: pp. 101-117, 2015 (http://dx.doi.org/10.1016/j.buildenv.2015.03.014).