MODELING DYNAMIC ASPECTS OF HUMAN NONVISUAL RESPONSES TO LIGHT

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Purpose: Since 2002, when the first reports on the discovery of a novel type of mammalian ocular photoreceptor were published, a new field of study at the intersection of photobiology and architecture started to emerge. These novel non-rod, non-cone photoreceptors in the retinal ganglion cell layer are the primary mediators of nonvisual responses to light in humans, including synchronizing circadian rhythms and directly alerting the brain. This study aims to understand how these nonvisual responses evolve over time with respect to changes in the intensity, spectral composition and exposure duration of light stimuli. The ultimate goal is to incorporate these effects of light into building design.

Methods: Recent studies in the field of photobiology provide us with information about the human nonvisual responses to light. Researchers have identified intensity, spectrum, duration, history and timing of light exposure as important parameters that influence the responsiveness of the nonvisual system. Experimental research quickly reaches its limitations, because it is infeasible to carry out a complete experiment with respect to all parameter combinations. Mathematical models are the method of choice to enable such analysis. A block-structured model is proposed that combines linear filters, a nonlinear term and a feedback mechanism. The linear filters reflect the temporal processing between the light stimulus and the output response. The nonlinear term is the sigmoid-shaped intensity-response curve that receives input from the feedback mechanism to regulate the system's response with changes in prior light history and timing of circadian phase. Moreover, the spectral sensitivity of the nonvisual system is modeled as a time-varying function.

Results: Based on this model, which takes the intensity, spectrum and duration of light exposure into account, it is possible to compare the nonvisual efficiency of different spectra as a function of duration. Results demonstrate that duration is an important parameter in addition to spectral sensitivity when comparing nonvisual effects of different light sources at low light intensities.

Conclusions: This model provides a framework that can inform designers about the effects of lighting on human health and wellbeing in real-life settings. The ultimate goal of this work is not to reveal the underlying functionality of the retina, but rather to predict human nonvisual responses to light using mathematical models and test the predictions experimentally. Modeling dynamic aspects of nonvisual responses to light is important to understand the dynamic relationship between light and human nonvisual responses that occurs in real-world settings.