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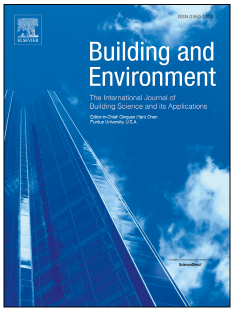

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Iason Konstantzos, Athanasios Tzempelikos

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Daylight glare evaluation with the sun in the field of view through window shades

Iason Konstantzos[1,2], Athanasios Tzempelikos[1,2,*]

[1]Lyles School of Civil Engineering, Purdue University, 550 Stadium Mall Dr., West Lafayette, IN 47907 USA

[2]Center for High Performance Buildings, Ray W. Herrick Laboratories, Purdue University, 140 S. Martin Jischke Dr., West Lafayette, IN 47907, USA

ABSTRACT

This paper provides new insights on daylight glare evaluation for cases with the sun in the field of view through window shades. 41 human subjects (*n*=41) were tested while performing specific office activities, with 14 shade products of different openness factors and visible transmittance values (direct and total light transmission characteristics) installed on the windows. The measured variables and survey results were used to: (i) associate discomfort glare with measured and modeled parameters (ii) evaluate the robustness of existing glare indices for these cases (iii) examine alternate illuminance-based criteria for glare assessment through fabrics, extract discomfort thresholds and suggest a new related index and (iv) propose corrections in the DGP equation coefficients when the sun is visible through the shades. The modified DGP equation resulted in the best fit; the findings show that the general form of the DGP equation is reasonable and can be adjusted to account for different cases, by clustering different sets of coefficients for different environmental conditions or fenestration systems. The new alternate glare discomfort index developed in this study, based on direct and total-to-direct vertical illuminance on the eye, captures the impact of sunlight as well as the interdependence between the fabric color, overall brightness, and the apparent intensity of the visible sun. It can simplify annual simulations, eliminating the need for detailed luminance mapping of the interior, and can be directly associated with fabric optical properties for development of design guidelines and glare-based shading controls.

Keywords: daylight glare; window shades; sunlight; visual comfort.

1. Introduction

Visual comfort is one of the main concerns in human-centered design of interior spaces and is mostly associated with effective control of daylight glare. Several indices have been developed to quantify glare, given its subjective nature and the several factors involved with its evaluation [1-2]. Examples include DGI [3], originally proposed to describe glare from a large source as a window, and UGR [4], originally developed to describe glare from artificial sources. Vertical illuminance on the eye has been found to be the most significant factor in some studies [5-6], sometimes even outperforming more complex metrics, while other studies support luminance-based metrics. The Daylight Glare Probability or DGP [7] is considered a reasonable metric to assess daylight discomfort glare, as it simultaneously considers the overall brightness of the visual field as well as the impact of glare sources and contrast (Eq. 1), extracted from experiments with human subjects:

$$DGP = 5.87\times10^{-5} E_v + 9.18\times10^{-2} \cdot \log_{10}\left(1+\sum_{i=1}^{n}\frac{L_{s,i}^2\,\omega_{s,i}}{E_v^{1.87}\,p_i^2}\right) + 0.16 \tag{1}$$

where E_v is the total vertical illuminance, and L_s, ω_s and P are the luminance, solid angle and position index for each identified glare source respectively. The current knowledge gaps in discomfort glare analysis and remaining challenges summarized by Van Den Wymelenberg [8] show the complexity of the topic.

Shading fabrics are widely used in office spaces to improve visual and thermal comfort, control solar gains and also induce privacy when necessary. They are available in a variety of different colors, materials and weave densities and they can be manually or automatically controlled. The main optical properties that characterize shading fabrics are the openness factor (*OF*) and the visible transmittance (T_v); the first is an indicator of the weave density and the direct light transmission, whereas the latter indicates the portion of the visible light transmitted through the

*Corresponding author. Tel.: +1 765-496-7586.
E-mail address: ttzempel@purdue.edu (A. Tzempelikos)