

Abstract: Validation and Universalization of Daylight Glare Probability Index

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Introduction

In the present climatic and energetic context, the design of buildings taking advantage of natural daylight is of crucial importance. However, some annoyances due to poor designs could cancel out all the benefits linked to daylight penetration in buildings. One of these annoyances is glare. Glare may likely drive the occupants to the use of electrical lighting, which is easier to control.

It is thus of major importance, when designing or renovating a building, to be able to evaluate the glare risks linked to daylight penetration in the building.

The Daylight Glare Probability (Eq. (1)) is at the moment the only daylight glare index developed under real daylighting conditions. The DGP evaluates the probability that a person is disturbed by daylight glare [1]. Whereas most of the glare index formulas are based on the contrast between the luminance of the glare source and the luminance of the background, the DGP is mainly influenced by the vertical illuminance at eye level. The probability is computed as:

$$DGP = 5,87 \cdot 10^{-5} E_V + 9,18 \cdot 10^{-2} \log(1 + \sum_i \frac{L_{s,i}^2 \omega_{s,i}}{E_V^{1,87} P_i^2}) + 0,16 \quad (1)$$

where E_V is the vertical illuminance at eye level; L_S is the luminance of the glare source; ω_s is the solid angle subtended by the glare source; and P is the Guth's position index.

During Wienold's experiment, the DGP showed promising results for glare assessment, making it the most widely used index to date. However, recent studies indicate that the DGP could misevaluate glare perception in some situations such as under direct sun-facing conditions [2, 3], under low luminance levels [4], or in open plan spaces [5].

Research objectives

In order to clarify these issues and to validate the DGP for a wider range of situations, this research focuses on three main objectives.

The first one is the validation of the DGP as is. This implies to assess the proper relevance of the DGP when it is used in a real office environment, with similar characteristics to Wienold's adjacent cells [1].

The second objective of the research project is the extension of the DGP scope. In addition to the validation of the index in an individual south-oriented office, there is a need to assess the proper functioning of the DGP when used under other conditions, e.g. with various shading devices,

different daylighting levels, multiple space arrangements, etc.

Finally, the third objective of this research project is the evaluation of the adaptive nature of glare perception according to usual climatic conditions. Indeed, the literature shows that humans perceive glare at varying intensity depending on different parameters, such as age [6], seasons [7], time of day [8], current task [9], or even information from the outside view [10]. Moreover, Cauwerts suggested that a cultural adaptability might exist regarding tolerance to glare [11]: in her experiments, same scenes were perceived as less glaring by the French sample of participants than by the Belgian one.

Method

To develop the DGP, Wienold worked on a comparison basis, between subjective and objective assessments of glare. Two identical office-like room cells adjacent to each other (Fig. 1) were used; in the test room, the subject was asked to answer a questionnaire while in the reference room, measurements were taken simultaneously [12]. The coefficients of the DGP formula were chosen with the help of an algorithm optimizing the correlation between the statistical analysis of the questionnaires and the measured physical data.

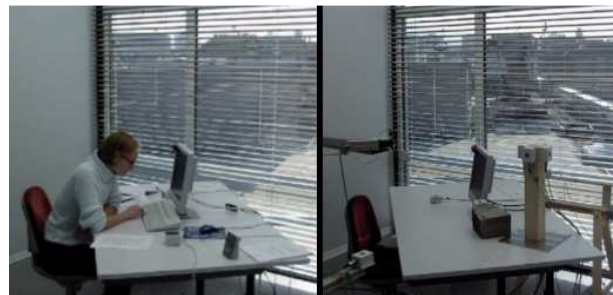


Fig. 1. Wienold's test room (left) and reference room (right)

The method chosen in the here-presented research project is similar to Wienold's one but will be performed in real office situations. This means that the experiment must be carried out in a single room, as it is impossible to find two adjacent offices with identical features (inside organisation and outside view) in the real world. Therefore, the objective and subjective assessments of glare will have to be done at the same spot, successively. Similar methods have already been reported in the literature: Hirning et al. [13] evaluated discomfort glare experienced by employees

at their desk through a survey consisting in a quick questionnaire followed by HDR (high dynamic range) measurements.

Furthermore, Painter et al. [4] monitored visual comfort in a daylit building during a 12 month field study. Objective assessments of glare were collected every 30 minutes with an on-screen, user-friendly questionnaire. HDR pictures were taken right afterwards using an automated networked system. The digital SLR camera was positioned as close as possible to the subject's head. The two main challenges mentioned by the authors are the bias that can occur due to a too invasive survey and the rapid changes in lighting conditions under low light levels.

The process of the experiment will therefore consist in asking the subject to fill in a quick questionnaire when a glare situation is experienced, and taking a HDR picture with illuminance measures at the occupant's eye position right afterwards. A sample of at least thirty glare assessments will be collected for each situation: first, individual offices with similar characteristics to Wienold's cells, then other office typologies with various environmental conditions.

The subjective data collected will be studied by a statistical analysis whereas the HDR images will be processed in Evalglare. If the correlation between the probability that a person is disturbed by glare and the calculated DGP is not as high as in Wienold's experiment, the coefficients or even the whole DGP formula could be adapted to better assess glare in daylit spaces.

Conclusion

The first objectives of this four year research project are the validation and the extension of the scope of the Daylight Glare Probability index. This will be achieved through a large field survey on discomfort glare perception. The other objective of this project is the evaluation of the adaptive nature of glare perception according to climatic conditions. The method to achieve the latter still offers food for thought. A considered solution would be to reproduce the above experiment in a region with a drastically sunnier climate and observe if the correlation between objective and subjective glare assessments is still as high as for the Belgian maritime temperate climate.

Anyway, the question of the DGP validation under low light levels still remains unanswered. The main issue is the quick changes of the lighting environment under overcast sky, making the process of successive measures no longer relevant. Moreover, the DGP has not been defined for values outside the 0.2 to 0.8 range, and for illuminance at eye level lower than 380 lux. These are the reasons why most experiments evaluating discomfort glare are executed with south-oriented rooms under clear skies.

Last but not least, the method proposed here is relatively invasive, which could lead to bias in the experiment results. Indeed, since the subjects will be asked to answer questions focused on glare perception, their judgement could be

influenced. Each of these questions will be reviewed and decisions will be taken to prevent the results to be biased.

References

- [1] J. Wienold, "Daylight Glare in Offices", Universität Karlsruhe (TH), Freiburg, 2009.
- [2] I. Konstantzos, A. Tzempelikos, and Y.-C. Chan, "Experimental and simulation analysis of daylight glare probability in offices with dynamic window shades", *Building and Environment*, vol. 87, pp. 244–254, 2015.
- [3] J. A. Yamin Garretón, R. G. Rodriguez, A. Ruiz, and A. E. Pattini, "Degree of eye opening: A new discomfort glare indicator", *Building and Environment*, vol. 88, pp. 142-150, 2014.
- [4] B. Painter, D. Fan, and J. Mardaljevic, "Evidence-based daylight research: development of a new visual comfort monitoring method", presented at the Lux Europa, 11th International Lighting Conference, Istanbul, Turkey, 2009.
- [5] M. B. Hirming, G. L. Isoardi, and I. Cowling, "Discomfort glare in open plan green buildings", *Energy and Buildings*, vol. 70, pp. 427-440, 2013.
- [6] T. Kuhn, J. Wienold, and C. Moosmann, "Daylight glare. Age effects and their impact on glare evaluation.", presented at the Energy Forum, Bressanone, Italy, 2013.
- [7] J. Christoffersen, K. Johnsen, E. Petersen, and S. Hygge, "Post-occupancy evaluation of danish office buildings", presented at the 24th Session of the CIE, Warsaw, Poland, 1999.
- [8] M. Kent, S. Altomonte, P. Tregenza, and R. Wilson, "Time of day, temporal variables and personal factors in the subjective evaluation of glare sensation", presented at the PLEA2015, Bologna, Italy, 2015.
- [9] M. Sivak, M. J. Flannagan, M. Ensing, and C. J. Simmons, "Discomfort glare is task dependent", University of Michigan, Ann Arbor, Transportation Research Institute 1989.
- [10] N. Tuaycharoen and P. R. Tregenza, "Discomfort glare from interesting images", *Lighting Research & Technology*, vol. 37, pp. 329-338, 2005.
- [11] C. Cauwerts, "Influence of presentation modes on visual perceptions of daylit spaces", Université catholique de Louvain (UCL), Louvain-la-Neuve, Belgium, 2013.
- [12] J. Wienold and J. Christoffersen, "Evaluation methods and development of a new glare prediction model for daylight environments with the use of CCD cameras", *Energy and Buildings*, vol. 38, pp. 743-757, 2006.
- [13] M. B. Hirming, G. L. Isoardi, S. Coyne, V. R. Garcia Hansen, and I. Cowling, "Post occupancy evaluations relating to discomfort glare: A study of green buildings in Brisbane", *Building and Environment*, vol. 59, pp. 349-357, 2013.