WORKSHOP ON DISCOMFORT GLARE: FINAL REPORT

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Abstract

Limitations to the predominant models for discomfort glare prediction for electric lighting, the Unified Glare Rating and the Visual Comfort Probability, are well known. There is no single widely-accepted model as yet for discomfort experienced from daylight. Overhead glare from small, bright light sources is a newly-identified problem. This workshop at the CIE Session in Sun City sought to animate a discussion of these issues among the world-wide lighting community there assembled. Five expert panellists presented their perspectives on the issues and there was lively audience participation. The results are expected to lead to new technical committees in the coming quadrennium.

Keywords: discomfort; glare; light sources; daylight; models

1 Introduction

At present, the Visual Comfort Probability (VCP) model (Committee on Recommendations for Quality and Quantity of Illumination (RQQ), 1966) and the Unified Glare Rating (CIE, 1995) are the most commonly used glare prediction models for electric lighting in North America and the rest of the world, respectively. Similar models exist for discomfort from daylight (Nazzal, 2001; Wienold & Christoffersen, 2006). They predict discomfort glare on the basis of size and position of a glare source (luminaire) relative to an observer's position, background luminance (adaptation), and luminance of the glare source. Lengthy debates occurred during the development of these models, and there are still varying opinions with respect to the validity of these models (Mistrick & Choi, 1999). The equations used to predict discomfort glare have limited applicability and display certain mathematical inconsistencies, and daylight glare prediction models are more disputed than those for electric lighting.

Throughout the debates, very little attention has been paid to serious attempts for proposing a causal model which might explain how discomfort glare arises (Veitch, 2001), or to other factors and psychological variables which might impact on the glare experience (Osterhaus & Bailey, 1992). Overhead glare from small, but bright light sources is also seen as an area needing further attention (Ngai & Boyce, 2000).

This workshop was the next step, with a full discussion of the utility of existing models and the needs of industry for new or refined models. Its purpose was to engage in a discussion on current experiences with discomfort glare prediction and assessment methods in lighting design practice and on future directions for advancing research on the topic. Approximately 100 lighting designers and researchers from around the world participated in the workshop, a much smaller group of about 25 people actively engaged in the discussions.

2 Audience Brainstorming

Following an introduction from the moderators, the audience was invited to brainstorm for ten minutes, starting from the following questions:

- How and when are current models used in practice today?
- What do you consider the most serious issues with current glare prediction models?
- What kinds of concerns would new glare prediction models address?

Kevin Houser (Penn State University, US), one of the editors of the 10th edition of the IESNA *Lighting Handbook* (DiLaura, Houser, Mistrick, & Steffy, 2011), mentioned that this handbook now lists both VCP and UGR methods, but provides calculation formulae only for UGR. IESNA sees this as a step towards a world-wide glare calculation standard.

Thomas Lemons (TLA Lighting Consultants, US), an active US lighting designer in the field of sports lighting, reported that glare assessment methods for outdoor sports lighting have been successfully applied in indoor sports venues, but suggested one might adopt the UGR system.

Mathew Cobham (Philips Lighting, The Netherlands) supported the need of a reliable glare prediction method for sports lighting.

Peter Thorns (Thorn Lighting, UK) suggested that there are not too many complaints about glare from electric lighting installations in buildings and that CIE might wish to look at what works and why. Rather than always focusing on problem areas, he wishes to understand those areas which work and learn from this.

Marc Fontoynont (ENTPE, France) saw a need for further publications on UGR and how to apply it in different situations and addressing problems associated with overhead glare from small light sources with high luminance (e.g. LEDs), as the complaints about those are on the increase.

Peter Dehoff (Zumtobel Lighting, Austria) noted that within the EU, UGR was widely used and accepted, but that there was a need for glare assessment methods which could be used in the field, i.e. measurement standards for determining glare.

Stefan Völker (Technical University Berlin, Germany) has researched lighting in relation to car headlights. He suggested that research to predict glare in buildings might also need to look at the impact of light source intensity distribution patterns and spectral characteristics. He also argued that there has to be a better common understanding in both the lighting industry and the building profession about why glare assessment is so important.

Wenli Wang (China) believed that there needs to be better information on glare, as well as more published data from research.

Shuxiao Wang (China) stressed the importance of considering complex, non-uniform glare sources and their effect on determining adaptation levels for glare assessment. Currently existing glare models are predominantly based on research with uniform light sources.

Warren Julian (University of Sydney, Australia) emphasized that there is a need for educating the general public about glare while working out the serious problems associated with current prediction methods. Sometimes the more interesting lighting installations cause glare, while glare-free installations might appear boring. Maintaining visual interest seems important. He also suggested that distraction was perhaps an area to consider when assessing glare. In addition, overhead glare appears to create a downward pressing feeling which is difficult to measure. Gloom was another area possibly closely related to glare, especially overhead glare from bright sources in otherwise rather dark ceilings.

3 Expert Presentations

To further spark discussions, five short expert presentations had been invited, each addressing a different aspect of glare prediction. The presentations are available for download on the CIE Division 3 web site (http://div3.cie.co.at/).

- Toshie Iwata (Tokai University, Japan) with Werner Osterhaus: "Mathematical Inconsistencies, Range Limits and Application of Current Glare Predication Methods" — The authors presented preliminary results of comparisons they have conducted between UGR, developed for large-area electric lighting sources, and PGSV, DGP, as well as luminance differences based on luminance histogram analysis (ratio of mean to median luminance value), developed for daylight. They noted that additivity is an issue, in that one large glare source does not give the same result as the same glare source split into an array of smaller sources. Furthermore, the experimental conditions leading to the articulation of the various indices covered different ranges of solid angles and luminances for the glare sources and the surrounding visual fields, suggesting that the application ranges and conditions of the indices should be carefully considered.
- Daisuke Ito (Institute of Technologists, Japan) with Kensuke Nagayoshi and Toshie Iwata "Optical Properties and Control of Blinds for Daylight Glare Prevention" — These authors presented the development of an algorithm for automated venetian blind control based on the PGSV model.

- Etsuko Mochizuki (Chiba Institute of Technology, Japan): "Practical Problems with Glare from LED Sources" — The author pointed out that LED sources will primarily be in arrays of points, making them very non-uniform. Preliminary evidence suggests that this might be perceived as causing more discomfort than UGR would predict.

  In a comment to Etsuko's presentation, Naoya Hara (Kansai University, Japan) reported that she had looked at luminance distributions across LED luminaires. With equivalent (presumably average) luminance of the source, the same level of discomfort glare was experienced for different non-uniform distributions. Glare from sources with non-uniform distributions, however, was higher than from a source with uniform distribution, especially for elderly subjects.

- Martine Knoop: "Discomfort Glare from LED Sources" — The author agreed with the previous presentation, and also pointed out, based on the work under way in TC 3-50, that there are also suggestions that there is a higher risk of overhead glare from LED luminaires and issues related to their very high maximum luminance and position.

- John Mardaljevic (De Montfort University, UK): "Discomfort Glare from Daylight in the IESD Visual Comfort Study" — This presentation described a methodology using high-dynamic-range images and online software to record the real-time conditions associated with discomfort votes in an office setting.

4 Open Discussion

The presentations provided further food for thought for a 40-minute open discussion on the following questions:

- Are the limitations identified in current glare prediction methods really serious enough to warrant new research for establishing better methods?
- Do new technologies (e.g. LEDs) create additional problems with glare? If so, are there suggestions for addressing this?
- Can we prioritize the most important tasks for new work on glare prediction methods?
- Could there be one glare prediction model for all types of light and glare sources?
- Would lighting or architectural practice be improved by having one integrated glare model for electric lighting and daylighting?
- Which terms of reference could be articulated for a new technical committee addressing these issues?

The open discussion addressed the questions in random order.

Thomas Lemons suggested that it would be impossible to design an interior space without knowing who the occupants will be and where they will be placed in the room. Only then would it be possible to design the lighting system in such a way that glare can be avoided by placing potential glare sources away from the critical zones.

Yandan Lin (Fudan University, China) proposed that any new glare model should include functions for the movement of an observer to account for changing adaptation levels and thus changing glare experiences.

Larry Leetzow (Magnaray International and Rensselaer Polytechnic Institute, US) responded to Yandan Lin that this would be difficult to apply in practice.

Miyoshi Ayama (Utsunomiya University, Japan) suggested that in experiments with LEDs in a matrix arrangement with a) diffuser, b) lens and c) homogeneous field, the overall luminance seemed to be the most reliable glare predictor.

Peter Thorns proposed to get back to basics and not to get hung up on details as we rarely had the knowledge of details during the design process. We needed to look at two types of glare: one which affects the person (presumably discomfort glare), and one which affects the task (presumably disability glare).

Udo Krüger (TechnoTeam, Germany) stated that the technology was available to measure solid angles, luminance values and luminance distributions via luminance mapping cameras. To evaluate UGR, DGP and other glare metrics directly (presumably as the luminance image is taken), more input was needed, especially for defining what needs to be considered a glare source. A luminance threshold seemed insufficient. Further data on angular relationships between glare sources and observer would perhaps be needed.

Marc Fontoynont warned that one should not limit the discussion of glare problems with new lighting technology to LEDs, as metal halide sources might present similar problems. A more general investigation of matrix arrangements of small, bright light sources could be a way forward. Perhaps, one could also show totally unacceptable glare situations which the outside world would understand in order to illustrate the problem.

Werner Osterhaus reiterated the urgent need for guidance on what and how to measure with respect to glare. CIE could provide much help in this respect to the ‘outside world’, especially architects, engineers and lighting designers (see also remark by Peter Dehoff above).

Warren Julian saw a number of issues: For light sources of very small solid angle, one might need to look at intensity, rather than luminance. Luminaires for which one could see the individual small light sources would be especially problematic. Spatial frequency would be another important topic to consider as some people might experience nausea or seizures. He mentioned disturbing glare problems with LED arrays from several pavilions at the Shanghai Expo when viewing them from a distance.

Jennifer Veitch reported that an IEEE working group on health effects from LED lighting investigates spatial frequency problems associated with arrays of small light sources (IEEE PAR1789 “Recommending practices for modulating current in High Brightness LEDs for mitigating health risks to viewers”). One aspect was flicker, another one the effect of stripes on the retina.

Larry Leetzow suggested that new glare research should perhaps start with street lighting.

Gideon Naudé (South Africa) asked about threshold increments as measures for determining glare and whether this was something to take into consideration.

Yandan Lin suggested that glare evaluation might also depend on light source colour.

Peter Thorns proposed to use limits intended for standard arrays of fixtures for LEDs, but that questions existed about whether this was appropriate in more complex situations and how the limit numbers would need to be interpreted. A better understanding was required.

Stefan Völker saw a strong need for a definition of average luminance of a glare source so that various research and assessment results could be compared on a consistent basis.

As the last contributor, Tom Lemons expressed concern about Stefan’s statement. The intensity along the axis of the direct light beam in sports lighting, for example, was very high and the source very small. In LED arrays, the specific directional intensities of individual LEDs were perhaps much more critical than the average luminance across the entire LED array.

5 Conclusions

The moderators attempted to summarize the issues.

Glare criteria and levels used in previous studies have typically mixed issues of comfort and acceptability. These should be clearly separated as the experience of discomfort is independent of whether or not someone accepts the discomfort experienced. One might, for example, accept a certain level of discomfort from daylight when there is a mitigating factor, such as a great view out across a wonderful landscape or the ocean. It might thus be useful to describe situations under which glare might be tolerated. This could also help in the design process.

When lighting technology (especially light sources and the respective luminaire) changes, the impact of that change on discomfort glare needs to be carefully studied. LEDs clearly pose a challenge, as their small size and high luminance present conditions very different from those studied while current metrics were developed. These mostly relied on larger areas of lower luminous intensity.

To study glare phenomena in real-world situations, better measurement protocols are needed so that the measurements from various studies can be compared and carefully assessed. Currently, different researchers or assessors appear to measure different things. Further development of measurement equipment seems also an important consideration.

Of special importance might be the transient adaptation, i.e. the changes in adaptation luminance a person experiences when moving around in a space or changing view directions. Current discomfort prediction models assume a fixed position and viewing direction to which an observer is adapted.

There is a great need to get a better handle on the fundamental mechanisms underlying the experience of discomfort. This should include work on physiological pathways between eye and brain. The current discomfort glare models may be too simple. Once more complex models can be understood, there might be a chance to simplify them again on a different basis, leading to better prediction models.

The workshop closed with thanks to all the participants. Further discussion of these issues is expected among members of Division 3, leading to the possible development of new technical committees following the completion of ongoing work in TCs 3-39 (Discomfort Glare from Daylight in Buildings) and 3-50 (Lighting Quality Measures for Interior Lighting with LED Lighting Systems), whose work also will benefit from the open discussion in Sun City.

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References

Commission Internationale de l'Eclairage (CIE). (1995). *Discomfort glare in interior lighting*. (CIE 117-1995). Vienna, Austria: CIE.

Committee on Recommendations for Quality and Quantity of Illumination (RQQ). (1966). Outline of a standard procedure for computing visual comfort ratings for interior lighting - Report No. 2. *Illuminating Engineering, 61*, 643-666.

DiLaura, D. L., Houser, K. W., Mistrick, R. G., & Steffy, G. R. (2011). *The Lighting Handbook* (10th ed.). New York: Illuminating Engineering Society of North America.

Mistrick, R. G., & Choi, A.-S. (1999). A comparison of the Visual Comfort Probability and Unified Glare Rating systems. *Journal of the Illuminating Engineering Society, 28*(2), 94-101.

Nazzal, A. A. (2001). New daylight glare evaluation method. Introduction of the monitoring protocol and calculation method. *Energy and Buildings, 33*(3), 257-265.

Ngai, P., & Boyce, P. R. (2000). The effect of overhead glare on visual discomfort. *Journal of the Illuminating Engineering Society, 29*(2), 29-38.

Osterhaus, W. K. E., & Bailey, I. L. (1992). Large area glare sources and their effect on visual discomfort and visual performance at computer workstations *Proceedings of the 1992 IEEE Industrial Applications Society Meeting, Houston, TX, October 4-9, 1992* (Vol. Vol. 2, pp. 1825-1829). Piscataway, NJ: Institute of Electrical and Electronics Engineers.

Veitch, J. A. (2001). Psychological processes influencing lighting quality. *Journal of the Illuminating Engineering Society, 30*(1), 124-140.

Wienold, J., & Christoffersen, J. (2006). Evaluation methods and development of a new glare prediction model for daylight environments with the use of CCD cameras. *Energy and Buildings, 38*(7), 743-757.