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Research Note: Uncertainty in subjective evaluation of discomfort glare

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Abstract

The magnitude of discomfort glare has often been evaluated using the de Boer rating scale. This note raises doubts about measuring discomfort glare this way. There is a possibility that the presence of discomfort may be a false alarm because this rating scale forces an opinion and/or because the response scale does not include a 'no glare' option. Further, there is a possibility that response variance is increased through uncertainty over the meaning of the magnitude descriptors. Actions that will reduce the likelihood of such distortions occurring are suggested.

1. Observations and recommendations

Discomfort glare is the form of glare that causes discomfort without necessarily impairing the vision of objects; it is not well understood and there is no proven cause.¹ The degree of discomfort experienced is a quantitative subjective assessment. Such assessments are prone to significant bias associated with the stimuli experienced, the procedure for recording the observer's response and the observer's behaviour.²⁻⁶ This bias can lead to disagreement between studies using different stimuli and procedures and may be one factor contributing to slow progress in understanding discomfort glare. Furthermore, some elements of discomfort glare evaluation may lead to discomfort being indicated in situations when it is not present.

According to recent guidance "*the current state-of-the-art for assessing discomfort glare is the use of subjective rating scales, such as the De Boer (1967) scale, commonly used to assess vehicular headlamp glare and glare from outdoor lighting.*"⁷ De Boer rating employs a 9-point response scale that observers use to describe the magnitude of the discomfort according to descriptors attached to the odd-numbered points. One example of the de Boer scale uses the following magnitude descriptors: 1 = Unbearable, 3 = Disturbing, 5 = Just permissible, 7 = Satisfactory, 9 = Just noticeable.^{7,8}

De Boer scales have been used in two studies associated with glare from outdoor lighting,^{8,9} six studies of headlamp glare,¹⁰⁻¹⁵ and one study of glare from a miner's cap lamp.¹⁶ A de Boer-like scale has been used in three studies of interior lighting.¹⁷⁻¹⁹ Other studies have used something other than a 9-point de Boer-like scale: Three have examined glare and display screens using response ranges of 4, 5 or 6 points,²⁰⁻²² two have examined

daylight glare using a 4-point scale,^{23,24} and three have used abstract conditions to examine involuntary physiological responses to glare using a 10-point scale^{25,26} or an analogue scale.²⁷

The de Boer and de Boer-like scales show a number of ambiguities. First, the minimum discomfort that can be recorded is 'Just noticeable': The observer is forced to at least acknowledge the presence of glare and is not given the option of stating that glare is not at all apparent. This is common in many studies.^{8,11,12,14,24} Geerdinck¹⁸ suggests that most rating scales have tended to measure discomfort glare on a scale that ranges from *mild* to *extremely annoying*: 'mild' discomfort may indicate that the discomfort is slight or minor but that is not the same as an absence of discomfort. This situation may unintentionally force respondents to report a stimulus to be uncomfortable when that is not the case. This, in turn, may lead to a datum which forces the magnitude of discomfort with other stimuli to be overestimated. Furthermore, the act of asking for ratings of the level of glare may itself prompt participants to evaluate an item they may otherwise have not chosen to evaluate or considered to be relevant as has been found in studies of perceived safety.^{28,29}

Some studies using a rating scale to measure discomfort do give the option of a no-glare response, e.g. by replacing *just noticeable* with *unnoticeable*.^{9,10,15,17,20,22,23,25,26,27} Point 9 was originally labelled by de Boer in 1967 as *unnoticeable* but it was subsequently changed to *just noticeable* in 1973.³⁰

Point 7 on the de-Boer scale is labelled *satisfactory*: if the stimulus is causing discomfort then what aspect of this is satisfactory? Similarly, how do participants discriminate between *just permissible* glare and *satisfactory* glare? Inconsistencies may arise from individual interpretations of the labels of a rating scale⁶ and thus, these need to be clear and unambiguous.

Another ambiguity with the de Boer scale is whether the judgements are made according to comfort or acceptance. Geerdinck¹⁸ used ratings of acceptance and comfort, both rated using 9-point scales ranging from highly uncomfortable (or unacceptable) to highly comfortable (or acceptable). The results indicated a significant difference between comfort and acceptance in those conditions where glare was expected to be more uncomfortable although they did not suggest a difference when glare was of a lower magnitude. One conclusion drawn from this is that preventing glare does not necessarily result in comfortable lighting.

What is needed is an understanding of participants' interpretation of rating scale magnitude descriptors and whether these match the experimenter's intended interpretation. What might be useful is to use language which is less open to misinterpretation than the typical de Boer labels, such as the Vos 9-point rating scale³¹ in which the odd-numbered points are labelled 1 = *bad*, 3 = *inadequate*, 5 = *fair*, 7 = *good*, 9 = *excellent*. Murray *et al*²⁵

labelled the extreme end of their scale as “*could not avoid closing eyes*” which might be a less ambiguous label than *unbearable*.

Clear definitions of the meanings of each descriptor might help reduce confusion but this appears to have been done in only a few studies²⁰⁻²² and these three were associated with glare and display screens. Osterhaus and Bailey²⁰ used a four-point scale with response labels defined as *imperceptible*, *noticeable*, *disturbing* and *intolerable*. They suggested that the borderline between *imperceptible* and *noticeable* was the changeover point where glare discomfort would be first noticed. In their definition, this criterion would be equivalent to a very slight experience of discomfort that could be tolerated for approximately one day when placed at someone else’s workstation. The borderline between noticeable and disturbing glare was defined as discomfort that could be tolerated for 15 to 30 minutes, but that would require a change in lighting conditions for any longer period. The borderline between disturbing and intolerable glare was defined as the turning point where one would no longer be able to tolerate the lighting conditions. Rodriguez and Pattini²² also used duration-related descriptors.

Rating scales for measuring discomfort glare have used variations in the number of points in the response range, including 10-point,^{25,26} the typical 9-point de Boer scale, 5-point,²² 4-point,^{20,23} and 3-point scales.³⁰ There is some evidence that the number of response points in a rating scale can affect the outcome, although this is not conclusive. While Monfared³ found significant differences in ratings of thermal comfort using 4, 5 and 7 point response ranges and Dawes³² found significant differences in price consciousness when using rating scales with 5, 7 and 10 points, in other studies the effect was not found to be significant.^{33,34} Geerdinck¹⁸ did not find a significant difference in ratings of acceptance and comfort when using either a 9-point rating scale or a dichotomous (yes/no) response, but this may be because the small sample size (n=21) was too small to reveal an effect.³⁵ Further data are desirable to determine if response range affects evaluation of glare.

Null condition trials are employed in two-alternative forced-choice tasks to investigate the magnitude of bias - if the two stimuli observed are identical, then the distribution of votes should be identical for both. In a single-interval task such as rating the discomfort experienced with a single visual scene, one form of control is to seek repeated ratings for the same scene to investigate whether the same response persists. This does not appear to be common practice which is unfortunate because the results of studies using rating¹² and adjustment²⁰ procedures indicate there may be a change in response with time, possibly associated with a learning effect¹³ or time of day.³⁶

In summary, the issues discussed here raise doubts about the validity of measuring discomfort glare using a rating scale such as the de Boer scale. There is a possibility that

the presence of discomfort may be a false alarm because this rating scale forces an opinion and/or because the response scale does not include a 'no glare' option. There is also a possibility that response variance is increased through uncertainty over the meaning of magnitude descriptors.

It was pointed out in 1982 that there has been little discussion about the calibration of observers' responses when using rating scales, these having the potential to be influenced by a variety of parameters some of which may be superfluous to the task at hand, and that this can lead to erroneous interpretation of how people perceive a stimulus.⁶ This situation does not appear to have improved: There is still insufficient understanding of discomfort ratings. Some authors state they are aware of the problems but carry on to use de Boer anyway;^{8,16,22} for example "*Despite all of these difficulties, using ratings such as the De Boer scale is recognised presently as the best and most reliable method for measuring discomfort glare.*"⁸ Despite this potential for uncertainty, the findings are used to create complex equations^{17,37}).

In further studies using rating scales to evaluate discomfort I recommend that visual scenes are observed in a random order of presentation, that the magnitude descriptors are defined, that there is a clear option to indicate when there is no sensation of glare, that a null/control condition is included and that a second method is used in parallel, similar to CIE recommendations for evaluation of spatial brightness.² Definition of a standard set of conditions in order to calibrate a person's responses⁶ would allow comparison between studies.

References

- 1 Boyce PR. *Human Factors in Lighting*. 3rd edition. Boca Raton, FL: CRC Press, 2014.
- 2 Commission Internationale De L'Éclairage. CIE Report 212:2014 *Guidance Towards Best Practice In Psychophysical Procedures Used When Measuring Relative Spatial Brightness*. Vienna: CIE, 2014.
- 3 Monfared IG. Importance of scale format, respondent's attitude and temporal effects in post-occupancy evaluation surveys. PhD Thesis. University of Sheffield. 2012.
- 4 Poulton EC. *Bias in Quantifying Judgements*, Hove and London: Lawrence Erlbaum Associates Ltd, 1989.
- 5 Poulton EC. Quantitative subjective assessments are almost always biased, sometimes completely misleading. *British Journal of Psychology*, 1977; 68: 409-425.
- 6 Rea MS. Calibration of subjective scaling responses. *Lighting Research and Technology*, 1982; 14: 121-129.

- 7 Alliance for Solid-State Illumination Systems and Technologies (ASSIST). *A Method for Estimating Discomfort Glare from Exterior Lighting Systems*. Troy, NY: Lighting Research Center, 2011.
- 8 Bullough J, Brons JA, Qi R, Rea MS. Predicting discomfort glare from outdoor lighting installations. *Lighting Research and Technology*, 2008; 40; 225-242.
- 9 Tashiro T, Kawanobe S, Kimura-Minoda T, Kohko S, Ishikawa T, Ayama M. Discomfort glare for white LED light sources with different spatial arrangements. *Lighting Research and Technology* Published online 24 April 2014. doi: 10.1177/1477153514532122.
- 10 Christianson KB, Greenhouse DS, Barton JE, Chow C. *Methods to Address Headlight Glare*. California PATH Research Report UCB-ITS-PRR-2009-20. California Partners For Advanced Transit And Highways. 2009.
- 11 McLaughlin S, Hankey J, Green CA, Larsen M. *Discomfort Glare Ratings of Swivelling HID Headlamps*. SAE International, 2004. 2004-01-2257.
- 12 Reagan IJ, Frischmann T, Brumbelow ML. *Test Track Evaluation of Headlight Glare Associated with Adaptive HID, Fixed HID, and Fixed Halogen Low Beam Headlights*. Insurance Institute for Highway Safety. 2004.
- 13 Schmidt-Clausen HJ, Bindels JTH. Assessment of discomfort glare in motor vehicle lighting. *Lighting Research and Technology*, 1974; 6(2); 79-88.
- 14 Sivak M, Flannagan M, Ensing M, Simmons CJ. *Discomfort Glare is Task Dependent*. UMTRI-89-27. University of Michigan Transportation Research Institute, 1989.
- 15 Theeuwes J, Alferdinck JWAW, Perel M. Relation between glare and driving performance. *Human Factors*, 2002; 44: 95–107.
- 16 Sammarco JJ, Mayton AG, Lutz T, Gallagher S. Discomfort glare comparison for various LED cap lamps. *IEEE Transactions on Industry Applications*, 2011; 47(3):1168-1174.
- 17 Cai H, Chung T. Evaluating discomfort glare from non-uniform electric light sources. *Lighting Research and Technology*, 2013; 45; 267-294
- 18 Geerdinck L. Glare perception in terms of acceptance and comfort. Eindhoven University of Technology. 2012.
- 19 Lin Y, Fotios S, Wei M, Liu Y, Guo W, Sun Y. Eye movement and pupil size constriction under discomfort glare. *Investigative Ophthalmology and Visual Science*. Published online, January 29, 2015, doi:10.1167/iovs.14-15963
- 20 Osterhaus WKE, Bailey IL. *Large area glare sources and their effect on discomfort and visual performance at computer work stations. Proceedings of the 1992 IEEE Industry Applications Society Annual Meeting*, 4-9 October 1992. Houston, Texas.
- 21 Ramasoot T, Fotios SA. Lighting and display screens: Models for predicting luminance limits and disturbance, *Lighting Research and Technology*, 2012; 44(2); 197-223
- 22 Rodriguez RG, Pattini A. Tolerance of discomfort glare from a large area source for work on a visual display. *Lighting Research and Technology*, 2014; 46: 157-170.

- 23 Christoffersen J, Wienold J. *Monitoring Procedure for Assessment of User Reaction to Glare*, Report ECCO-DBUR-0303-01. Energy, Environment and Sustainable Development Programme (1998-2002): European Community. 2004.
- 24 Fisekis K, Davies M, Kolokotroni M, Langford P. Prediction of discomfort glare from windows. *Lighting Research and Technology*, 2003; 35(4); 360-371.
- 25 Murray I, Plainis S, Carden D. The ocular stress monitor: A new device for measuring discomfort glare. *Lighting Research and Technology*, 2002; 34: 231-239.
- 26 Stringham JM, Garcia PV, Smith PA, McLin LN, Foutch BK. Macular pigment and visual performance in glare: Benefits for photostress recovery, disability glare, and visual discomfort. *Investigative Ophthalmology and Visual Science*, 2011; 52: 7406-7415.
- 27 Berman S, Bullimore M, Jacobs R, Bailey I, Gandhi N. An objective measure of discomfort glare. *Journal of the Illuminating Engineering Society*, 1994; 23: 40-49.
- 28 Acuña-Rivera M, Uzzell D, Brown J. Perceptions of disorder, risk and safety: The method and framing effects. *Fundación Infancia y Aprendizaje Psicología: Revista Bilingüe de Psicología Ambiental - Bilingual Journal of Environmental Psychology*, 2011; 2 (2); 167-177.
- 29 Ramsay M, Newton R. *The Effect of Better Street Lighting on Crime and Fear: A Review*. Crime Prevention Unit paper No. 29. London: The Home Office. 1991.
- 30 Gellatly AW, Weintraub DJ. User Reconfigurations of the de Boer Rating Scale for Discomfort Glare. Report No. UMTRI-90-20. University of Michigan Transportation Research Institute. 1990.
- 31 Vos JJ. Reflections on glare. *Lighting Research and Technology*, 2003; 35(2): 163-176.
- 32 Dawes J, Do data characteristics change according to the number of scale points used? An experiment using 5-point, 7-point and 10-point scales. *International Journal of Market Research*, 2008; 50: 61–77.
- 33 Parducci A, Perrett LF, Category rating scales: Effects of relative spacing and frequency of stimulus values. *Journal of Experimental Psychology*, 1971; 89: 427-452.
- 34 Atli D, Fotios S. Rating spatial brightness: Does the number of response categories matter? *Ingineria Iluminatului*, 2011; 13(1): 15-28
- 35 Field A. *Discovering Statistics Using SPSS*. 2nd edition. London: Sage Publications. 2005. p34.
- 36 Kent MG, Altomonte S, Tregenza PR, Wilson R. Discomfort glare and time of day. *Lighting Research and Technology*, 2014. Published online 21 August 2014. doi: 10.1177/1477153514547291.
- 37 Clear RD. Discomfort glare: What do we actually know? *Lighting Research and Technology*, 2013; 45: 141–158.