A quest for new metrics to curb the increase in glare from LED lighting

*Peter Veto, Ph.D., Kent Chamberlin, Ph.D.,
Noah Sabatier, & Mark Baker

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*Correspondence: peter@peterveto.me

In parallel to the appearance of solid-state illumination, reports of excessive glare from roadway and automotive lamps have increased dramatically. A segment of the population have developed debilitating symptoms of aversion to these latest light sources. Commonly used methods in lighting metrology do not account for the increase in perceived glare. In this paper, we briefly outline how LED sources lead to high luminance, the main driver of discomfort glare. We also show that current measurement practices do not appropriately capture maximum luminance. Finally, we suggest the implementation of new measurement standards to quantify the glare-inducing properties of modern light sources.

1 Introduction

Evidence of public perception shows that outdoor LED lighting causes significant discomfort to many, relative to other technologies [1]. Expert analyses, however, generally conclude that solid-state lamps are equivalent to their older counterparts. Our analysis finds that the reason behind this discrepancy is that the measurement tools used to quantify lighting were established before the appearance of LEDs [2] and they are not well suited to pick up the unique traits of solid-state light sources. Most important of these traits when it comes to discomfort glare is the high maximum luminance that is characteristic of LED sources.

2 Luminance

Luminance (perceived as brightness) is the key driver of discomfort glare [3]. All else being equal, smaller light sources have higher luminance. LEDs produce a beam of light with high intensity in the center-line of the beam, as opposed to other light sources, which emit light in all directions [4]. Such an LED light beam is not diffused in most outdoor applications, resulting in a small apparent luminous surface size with high maximum luminance in its center [5].

2.1 Maximum luminance: the "averaging problem" in space

While current regulations and measurement protocols generally ignore luminance differences below a defined upper limit in glare source size [6, 7], such limits are about two orders of magnitude above what the human eye can resolve and the literature is inconclusive about their applicability [8]. This, together with the countless reports of LEDs appearing more glaring than other light sources, suggest that the tiny apparent size and high luminance of LED lamps play an important role in the generation of aversion responses [9].

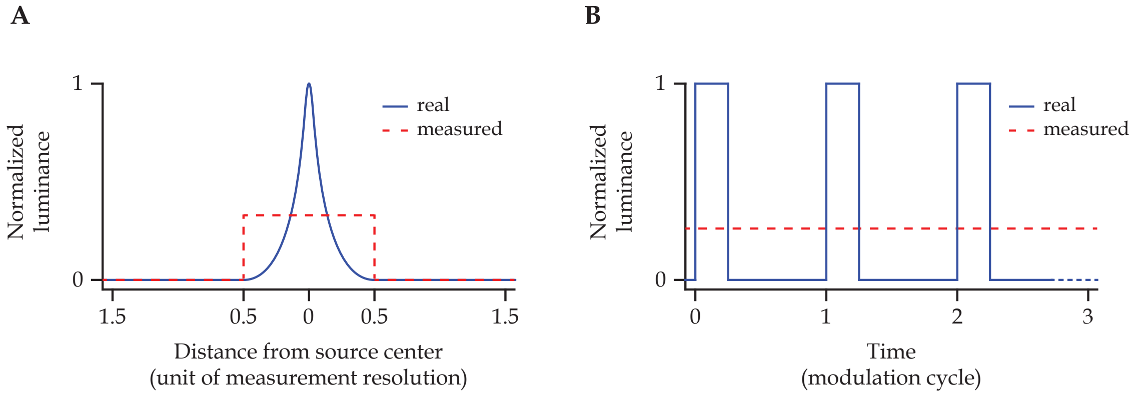

Figure 1: Resolution of measurement. Both in the spatial (A) and temporal (B) domain, low resolution of measurement results in grave underestimation of maximum luminance.

2.2 Flicker: the "averaging problem" in time

Similarly, current luminance measurements take an average across a time period. This is problematic, because LED sources are commonly controlled by pulse-width modulation: the light output is modulated between an *off* state and maximum output at a high frequency. Here, at a duty cycle of e.g. 25%, measured luminance will be 25% of the actual luminance of the source at its *on* state [Figure 1]. Aside from perceptual implications [2, 10], the nervous system may react also when the flickering does not appear in the conscious percept [11]; therefore, the "averaging out" of maximum luminance across time in current measurement methods takes away a meaningful piece of information.

3 Conclusion

Since luminance is the main driver of discomfort glare, capturing it accurately is essential for reliable prediction of aversion responses. Current methods for measurement are lacking both spatial and temporal resolution to register high maximum luminance with LED sources. Regulations up to now, depending on the field of application, either disregard the problem of luminance altogether (only considering levels of illumination) or rely on data from inadequate measurement methods, thereby failing to grasp the increase in glare potential with solid-state light sources (see e.g. [12, 13]). Over the past decade, this has become more and more apparent through a divergence between public reactions and expert assessment. We urge regulators to solve these problems by publishing adequate regulation of maximum luminance, based on high-resolution measurements in both the spatial and temporal domains.

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