How to Reduce Glare for Comfortable Lighting Levels.

Glare and the human physiology

Glare affects everyone. It is a visual sensation, which is best described as an an excessively bright light spill, which is exposed to the line of sight of an individual, causing discomfort and/or disability to the person experiencing it. As stated by Rea (2000), "Disability glare is the reduction in visibility caused by intense light sources in the field of view, while discomfort glare is the sensation of annoyance or even pain induced by overly bright sources". Glare can be associated with impaired vision, decreased safety to the individual, visual and bodily discomfort, injury to the visual organs and overall detriment to the health of the individual (Holladay et al. 1925, p.221)

The main detrimental effect of glare from a human factors perspective is the task related temporary impairment of sight as well as veiling or reduction in visual contrast, secondarily the long term impact of glare on the psycho-physiological state of people. As identified by IESNA (2009, p.2) 'As we age, even healthy eyes become more sensitive to glare — they require higher contrasts to see than they did when we were younger, as well as higher illumination levels'.

Glare in detail

Glare is a by-product of luminaires which have excessive light spill*, and is considered to be visual pollution due to its detrimental effect on people as well as the omnipresent irradiation effect. Guidelines and regulations exists in order to inform light manufacturers and lighting designers to control the amplitude of glare emitted by lights (IESNA and AS1680 within the Australian standards for interior lighting).

It is important to note that glare occurs solely when the eye is exposed to the luminous element of a luminaire, and when such an instance occurs: the amplitude of the glare can range from barely noticeable to extremely discomforting and can be quantified by the Unified Glare Rating (UGR).

*excessive light which exits the luminous element at angles greater than 80° from nadin (light central axis)

brightgreen

Glare in detail (cont.)

$$UGR = 8\log_{10}\left[\frac{0.25}{L_b}\sum\frac{L^2\varpi}{p^2}\right]$$

The variables for the UGR are: background illuminance (Lb), the sum of light luminance (L), the sum of the solid angle with the viewer's line of sight (ω) and the Guth index/ position index (p). The UGR formula and its structure demonstrate that the higher the variables Lb and p, which are located at the denominator, the lower the UGR value. In a sense, brighter interior backgrounds and greater light fixture distance to users contribute to lower the glare potential. UGR levels range from UGR= 10 (minute glare) to UGR= 30 (excruciating glare).

According to the Australian standards (AS/NZS 1680.1:2006, p.44), discomfort glare occurs at UGR ≥19. It is recommended that all residential space remain below UGR 19. Having said that, many projects aim to achieve UGRs of 10.

UGR is best evaluated as part of a lighting design software, since the calculation depends on very intricate factors such as precise total luminance levels, illuminance levels (greatly dependant on reflectivity of room surfaces) and the ability to strategically position calculation sensor surfaces.

For validation of the UGR in regards to LED lighting, the following is a simulation of the Brightgreen D700+ LED downlight versus the Inlite LL-9035-W LED downlight. Both lights are in the same wattage class, with the sole difference being their optical configuration.

Product: LED downlight	Product: LED downlight
Brand: Inlite	Brand: Brightgreen
Model: LL-9035-W	Model: D700+ CR 55 3K
Power: 10W	Power: 13W

Glare in detail (cont.)

The simulation setup (p.3) , replicates a person standing 1.5 m away from the nadin (the centre axis of the luminous distribution curve) with the sensor plane located at 1.6m above the ground (eye level). The hard angle between the line of sight and the luminous surface is approximately 40°.

Simulation 1

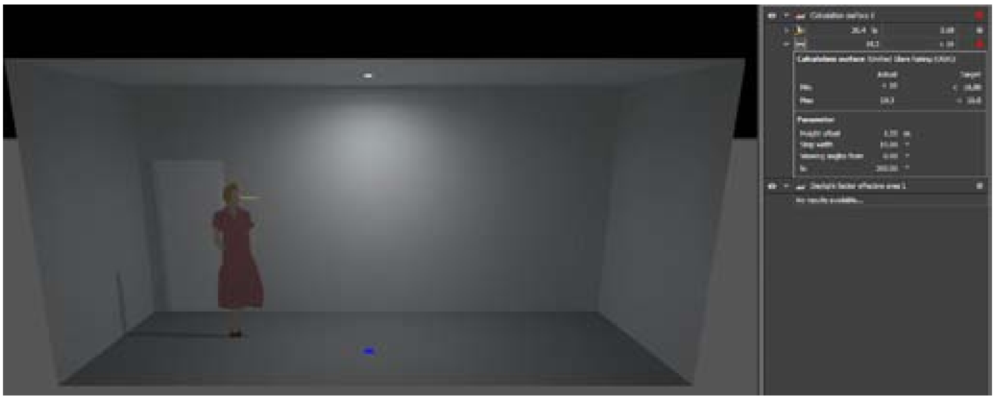

Fig.2 UGR simulation of the inlite LL-9035-W

Simulation 2

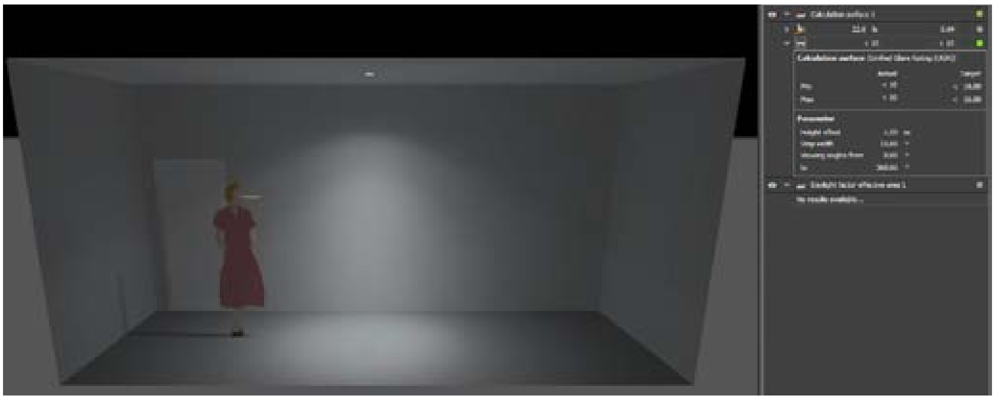

Fig.3 UGR simulation of the brightgreen D700+ CR 55 3K

Simulation 1	Simulation 2
Inlite LL-9035-W LED downlight	Brightgreen D700+ CR 55 3K LED downlight
Max UGR: 19.3	Max UGR <10

Glare in detail (cont.)

Brightgreen's D700+ CR 55 3K achieved an outstanding UGR of <10 (Fig.3), demonstrating a negligible glare scenario. On the other hand, the Inlite LL-9035-W resulted in discomfort glare with a UGR of 19.3(Fig.2).

Glare Control

The most effective way to account for glare when designing a light, is to implement light shielding into the geometry of the luminaire fixture also known as light cutoff. This will redirect light spill exiting the luminous element to follow the intended/efficace lighting distribution, often perpendicular to the light emitting surface, and away from the line of sight. As shown in Fig.4 ,this can be achieved by either using a reflector, lens, or by recessing the luminaire.

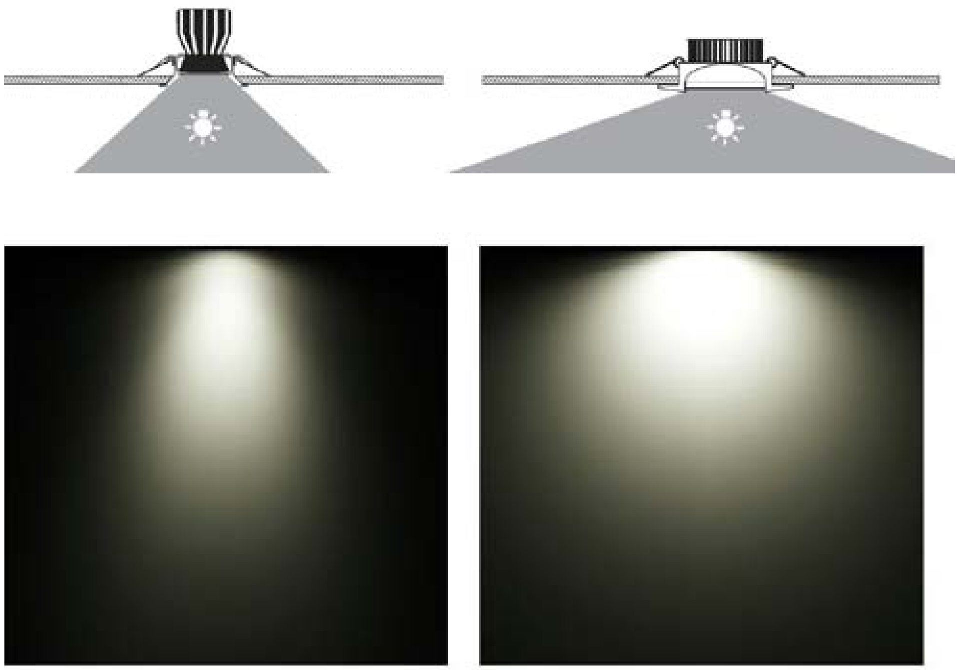

Fig.4 brightgreen D700+ (left), inlite LL-9035-W (right)

brightgreen

Glare control (cont.)

Luckiesh et al. (1949, p.650) identified the main factors contributing to glare and the quality of the visual environment:

- brightness of the source or luminous area
- visual size of the source
- brightness of the surrounding field
- position of the source in the visual field
- number of sources in the visual field
- configuration of the sources

While some of the above factors are functional and essential to an environment, such as: bright surrounding field and multiple light sources, several other factors are subject to design emphasis, such as: visual size of the source, position of the source in the visual field and configuration of the source.

> "The ultimate goal of lighting practice is to provide brightness in the entire visual environment which produce the most satisfactory seeing conditions"
>
> (Luckiesh et al. 1949, p.650).

Holladay et al. (1925, p.237) identified that dazzle glare ceases when the light source is more than 30 degrees above the line of vision.

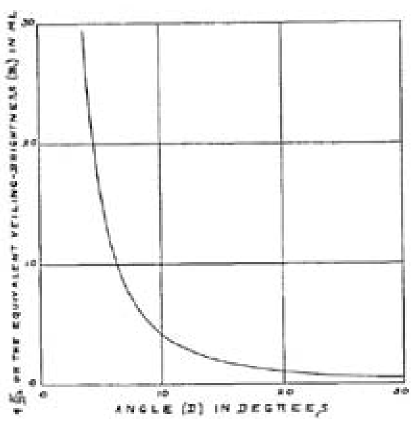

Fig.5 Veiling brightness as a factor of light source angle in regards to the line of sight (Holladay et al. 1925, p.245)

brightgreen

Glare control (cont.)

Following the finding in Fig.5, it is important to satisfy a minimum of 30 degrees between the visible luminous openings and the line of sight when engineering lights as well as a lighting design. Adequate user centric scenarios have to be accounted for within potential indoor spaces, ultimately factoring in worst case scenarios and catering for them by having the right amountof luminaire shielding for prospective ceiling heights as a function of a user positions in space.

Additionally, glare can be greatly reduced by having a well lit environment, with indirect lighting. as identified by Holladay et al. (1925, p.244) pupillary dilatation is a factor of the surrounding brightness, and the larger the pupil diameter the higher the glare dazzling, hence a brighter background will cause pupil constriction and lower glare perception.

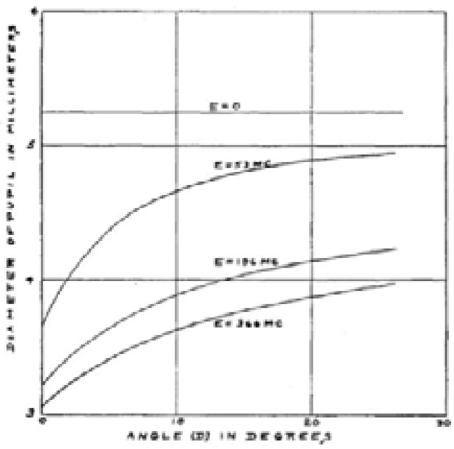

Fig.6 Pupil diameter as a function of the line of sight angle and the resultant dazzleglare (Holladay et al. 1925, p.245)

Following the fact above, it is safe to recommend adequate background lighting in environments which are prone to glare with a high UGR. This can be achieved by having indirect illumination from ceilings (skyglow) and walls (backlight), most commonly achieved by lights that can provide diffused light to ceilings as well as wall washing.

Fig.7 provides testing results on glare amplitude as a function of background illuminance. As demonstrated, for illuminance levels at the eyes between 6 lx and 8 lx the glare amplitude can be reduced from disturbing to acceptable (3 to 6 de Boer rating).

Glare control (cont.)

As identified by Sweater Hickcox et al. (2012, vol.8484, p.5), the perception of discomfort glare from an LED array can be decreased with the addition of a luminous surround, with white or yellow backgrounds substantially lowering glare perception intensity (Fig7).

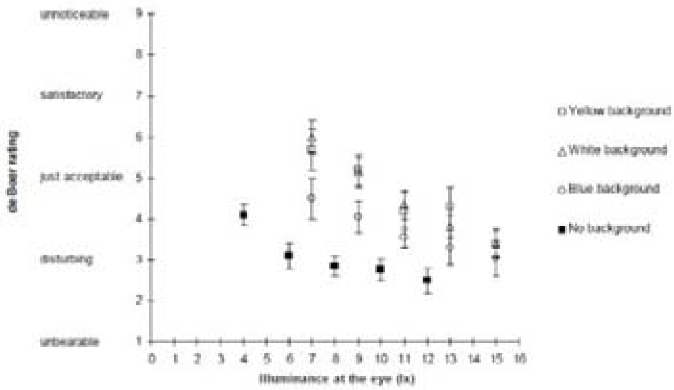

Fig.7 Glare amplitude as a function of background illumination (Sweater Hickcox et al. 2012, vol.8484, p.4)

Conclusion

Despite glare being a truly detrimental visual pollutant, with many deleterious effects on people, there are several ways to reduce or even neutralize it, through better luminaire/fixture design as well as lighting design of spaces. In the instance of luminaire/fixture design, using the IESNA guideline for luminaire shielding, it is possible to dramatically reduce the UGR of spaces. Additionally, through good lighting design it is possible to greatly reduce the UGR via specifying better lights, background lighting, skyglow lighting, and sound distribution of light sources in spaces.

Fig.8 Example of glare control via the usage of backlighting and luminaire shielding (Johnson, 2014)

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