LIGHTING QUALITY FOR ALL

Peter Boyce
peter@boycepeter.freeserve.co.uk

Abstract: This paper discusses how good quality lighting might be made available to all. It begins by defining lighting quality as that which meets the objectives and constraints set by the client and the designer. Based on this definition, lighting installations can be classified as of bad, indifferent or good quality. Numerical lighting recommendations provided by authoritative bodies constitute a means to eliminate bad lighting but do little to ensure good lighting, the end result usually being indifferent lighting. The relative merits of four approaches to bridging the gap between indifferent lighting and good lighting are discussed. These are the development of more numerical lighting criteria, more use of daylight, changing the basis of design from the working plane to the whole space and giving occupants individual control of the lighting through the use of plug and play technology. Unless one or other of these approaches is tried, there is a risk that good quality lighting will be confined to those who can afford to hire a talented lighting designer while the rest have to be content with indifferent quality lighting.

Keywords: Lighting quality, criteria, daylight, design

Defining lighting quality

Before considering how good quality lighting might be made available to all it is necessary to define what lighting quality is. Unfortunately, defining lighting quality is not easy. A number of different approaches have been suggested; from single-number photometric indices calibrated by subjective responses [1]; to the results of a holistic design process based on lighting patterns [2]; to the lighting conditions which have desirable impacts on task performance, health and behavior [3]; to lighting which enhances the ability to discriminate detail, colour, form, texture, and surface finishes without discomfort [4]. Despite these attempts, the most universal definition remains the extent to which the installation meets the objectives and the constraints set by the client and the designer. The objectives can include meeting all relevant regulations, enhancing the performance of tasks, ensuring visual comfort, creating specific impressions, generating a desired pattern of behavior and eliminating user complaints as well as minimizing energy consumption and operating cost. The constraints are usually the budget, the time available for completion of the work and, sometimes, restrictions on the design approach that can be used.

To many people, defining lighting quality in this way must be a disappointment. It is both mundane and obvious. It is not expressed in terms of photometric measures, but rather in terms of the impact lighting has on more distant outcomes. There are three arguments in favour of such an outcome-based definition of lighting quality rather than any of the alternatives based directly on lighting measures. The first is that lighting is usually designed and installed as a means to an end, not as an end in itself, so the extent to which the end is achieved becomes the measure of success. The retailer does not care about lighting, *per se*, but only about lighting as a tool for increasing sales. The second is that what is desirable lighting depends very much on the context. Almost all the aspects of lighting that are considered undesirable in one context are attractive in another. The third is that there are many physical and psychological processes that can influence the perception of lighting quality [5,6]. It is this inherent variability that makes a single, universally applicable recipe for good quality lighting based on photometric quantities an unreal expectation.

The role of lighting recommendations

So where do lighting recommendations of the type found in SLL documents [7.8] fit into lighting quality? A simple concept that offers a place for lighting recommendations is that lighting installations can be divided into three classes of quality: The good, the bad, and the indifferent. Bad quality lighting is lighting which does not allow you to see what you need to see, quickly and easily and/or causes visual discomfort. Indifferent quality lighting is lighting which does allow you to see what you need to see quickly and easily and does not cause visual discomfort but does nothing to lift the spirit. Good-quality lighting is lighting that allows you to see what you need to see quickly and easily and does not cause visual discomfort but does raise the human spirit.

This in turn raises another question, what is it that causes lighting to be classified as of good, bad, or indifferent quality? The outcome-based definition of lighting quality implies that bad lighting occurs when it is inappropriate for what the visual system is being asked to do. For example, if a particular task with specific visual size and contrast characteristics has to be performed, then lighting that makes the signal-to-noise ratio between the task and its background low, or the signal-to-noise ratio between irrelevant stimuli and their backgrounds high, will be considered bad lighting; the former making the visibility of the task poor and the latter causing distraction. Among the phenomena which can contribute to such effects are insufficient light, too much light, excessive non-uniformity, veiling reflections, shadows, flicker, and disability and discomfort glare, i.e. all the phenomena which we currently think of as being responsible for visual discomfort. Eliminating these phenomena, remembering always that in some contexts they may be desirable, will generally lead to indifferent lighting. This is not a mean achievement.

Returning now to the original question, what is the purpose of the lighting recommendations given in the SLL Code for Lighting? The answer is to eliminate bad lighting. The recommendations do this by making sure that the amount, spectrum and distribution of light provided is enough for whatever the visual system is likely to be asked to do and ensuring that this light will be provided in such a way that it does not cause visual discomfort. Is this enough to ensure good quality lighting? The answer is yes, but only if all the client and designer have in mind is to provide enough light for a high level of task performance, without discomfort, and thereby avoid complaints from occupants. Unfortunately, this appears to be the limit of ambition of many clients and designers, as is evident to anyone who visits many modern workplaces. However, saying this may be being too hard on the designers of such places. For many workplaces, at the design stage the designer does not know what work is to be done there, where it is to be done, what the furnishings will be like or even what the surface reflectances are to be. In the face of such ignorance, eliminating the bad is about the best that can be expected and applying the SLL recommendations is enough to ensure the bad is banished. The lack of specific information also goes a long way to explain the persistence of the horizontal working plane as a basis of design. Despite the use of task plane rather than working plane in recent recommendations and the fulminating of various eminent personages, the fact is the horizontal working plane is still the plane of choice for simple lighting calculations. This is because in the absence of any other information, applying the illuminance recommendations to a horizontal working plane and assuming high reflectance room surfaces is usually enough to guarantee adequate illumination of most forms of work [9].

But what happens if the client and the designer do have greater ambitions than simply avoiding complaints and are willing to supply additional information about the nature and location of the work and the furnishing and finishes of the space. Then, good quality lighting can be delivered provided attention is paid to context, fashion, and opportunity. Context is important because what would be considered attractive lighting for an office seems unlikely to be so attractive in an intimate restaurant. Fashion is important because we often crave the new to provide interest and variety. There is no reason to suppose that lighting should be any different in this respect than most other aspects of life. As for opportunity, that is partly a matter of technology and partly a matter of being in the right place at the right time. And what is the right place? An eminent lighting designer, J.M. Waldram, once said “If there is nothing worth looking at, there is nothing worth lighting” so the right place is presumably, a place which contains something worth looking at. Also, given that to be really good the lighting has to be matched in some way to the particular environment, each lighting solution would be specific and not generally applicable. This combination of fashion and specificity suggests that the conditions necessary to produce good quality lighting are liable to change over time and space. At the moment, good quality lighting most frequently occurs at the conjunction of a talented architect and a creative lighting designer, neither of whom is given to slavishly following numerical lighting criteria. This should not be taken to mean that numerical lighting criteria are irrelevant. Their purpose is to act as a baseline so that bad lighting is eliminated. The interesting question then becomes how the gap between indifferent and good quality lighting might be bridged.

Bridging the gap

The first and most obvious approach to bridging the gap between indifferent and good quality lighting is to continue along the path that enthusiasts have been following for the last 70 years, develop more lighting criteria. When the Illuminating Engineering Society, as it then was, published its first Code, it was little more than a list of illuminances. Developments since then have been driven by the arrival of new technology. With the arrival of the fluorescent lamps came the colour rendering index and the glare index. With the arrival of the computer monitor came luminaire luminance limits. Now, with the arrival of the LED, the colour rendering index is being revised or replaced and the flicker index has risen from the grave. The characteristic all these metrics have in common is that they seek to avoid visual discomfort, i.e., to prevent indifferent lighting slipping back into bad lighting. With this history, it seems unlikely that simply providing more lighting criteria will bridge the gap from indifferent to good quality lighting.

The second approach to bridge this gap is to make more use of daylight. People love daylight and spaces that make extensive use of it are generally considered attractive. But they do not love it unconditionally [10,11]. Like any other light source, daylight has to be controlled to avoid visual discomfort as well as thermal discomfort. Provided this is done, then daylighting through windows can create a bright and interesting visual environment, these two attributes being the two dimensions on which people assess the quality of a space [12]. The variation of daylight over the day also delivers meaningful information about the passage of time and the view out can provide some useful stimulation. Buildings where daylight is thoughtfully delivered without visual or thermal discomfort are considered better buildings [13]

A third approach is to develop a new procedure for designing lighting, one that widens attention to the appearance of the space rather than fixating on the lighting of a horizontal working plane. In recent years the prime advocate for this approach has been Cuttle. He starts by attempting to undermine the fundamental purpose claimed as the basis for illuminance recommendations, to ensure adequate visibility. Cuttle [14] argues that, over the last 30 years many visually difficult tasks, e.g. reading a fifth carbon copy, have disappeared and, where they do occur, technology often provides a better way of either doing the task or making it more visible than simply increasing the illuminance. Further, more and more information is being viewed on self-luminous devices such as smart phones and computer screens which higher illuminances make more difficult to see. He concludes that current lighting recommendations based on providing enough light to ensure task visibility on a horizontal working plane are difficult to justify. There is a lot of truth in this. As a replacement he suggests the basis of lighting recommendations should be changed to providing something he calls “Perceived adequacy of illumination”. This rather begs the question of adequate for what? My answer would be “for anything that I would expect to do in that space” which basically means that after identifying what the space is for I am judging what brightness is appropriate for such a space. The metric he associates with this criterion is mean room surface exitance as measured from the position of the observer’s eyes. This metric ignores direct light from the luminaires and considers only light reflected from the room surfaces. Adopting mean room surface exitance as a basis for lighting recommendations would have some interesting implications because light distributions that illuminate the walls and ceiling then become much more energy efficient than those that concentrate their output onto the horizontal working plane. Cuttle [15] has recently gone further by suggesting an additional criterion called target / ambient illumination ratio and a design procedure for first lighting the space and then any significant objects in it. This procedure is all-encompassing in that it allows both art galleries and speculative office space to be designed by the same process, although the former will result in very different lighting than the latter. Interestingly, this procedure can still lead to an installation producing uniform illumination of a horizontal working plane but now it will be the result of a considered opinion rather than unthinking obedience to a schedule of illuminance recommendations. This approach has potential, for four reasons. First, it directs attention away from the horizontal working plane to the whole space, a consideration that often lies behind what is assessed as good lighting. Second, it identifies new lighting criteria designed to ensure an appropriate brightness and a hierarchy to the scene. Third, the proposed design method could readily be implemented through software, which is how all lighting design is done today. Such software would make the design approach accessible to many outside the select few. Fourth, the same design approach can be used with or without detailed information on task type and location. The first step along this approach will be the development of suitable software. It will be interesting to see who has the courage to make that first step.

The fourth approach is, in principle, even more revolutionary. This approach is driven by technology and involves giving individuals control of their own lighting. Technology is already moving in this direction. LED luminaires are already easily dimmed and can be made to change light spectrum and light distribution on demand. Further, developments in wireless communication and computer optimization are making it possible for a regular array of luminaires to be adjusted to provide individual preferred illuminances at minimum electricity consumption without moving luminaires when the workstations are moved [16]. All these developments suggest that plug and play lighting cannot be far away.

And there is already evidence that giving individuals control improves the perception of lighting quality. There are large individual differences in preferred illuminance [17-20]. This means that for any given fixed illuminance, a minority of occupants will experience their preferred condition. Giving individuals control over their lighting can generate positive affect when it enables them to attain their preferred lighting conditions. Having lighting similar to one's personal preference results in improved mood and improved judgments of lighting quality and environmental satisfaction [18,21]. Further, improvements in mood, lighting satisfaction, and discomfort achieved by giving people individual control of their lighting are proportional to the difference between the fixed illuminance and the preferred illuminance, the greater the difference, the larger the improvement [22]. An extensive field study [23, 24] has also shown that direct / indirect lighting suspended over each workstation and providing individual control is considered better than uniform lighting with simple switching and it saves energy. No doubt the very idea of handing over control of lighting in a space to the individuals who occupy the space will be resisted by those who at present hold power over such decisions in the belief that chaos will be the outcome. However, if you believe that lighting quality should be based on meeting desirable outcomes, such as occupant satisfaction, giving individual control has a lot to offer.

All these four approaches are based on the effects of lighting on visibility and visual perception. Lurking on the horizon is the possibility that exposure to light will be shown to have a systematic effect on human health. If this were to occur, then the whole basis of what constitutes good quality lighting would have to be expanded beyond vision to encompass health. This might call for minimum irradiances weighted by the spectral sensitivity of the intrinsically-photosensitive retinal ganglion cell to be delivered to the eye at certain times. Such a development would seem to support the greater use of daylight and Cuttle's design method for electric lighting but it would oppose the idea of giving people individual control of their lighting. Which, if any, of these approaches will be adopted remains to be seen but if one or other is not tried, there is a risk that good quality lighting will be confined to those who can afford to hire a talented lighting designer while the rest have to be content with indifferent quality lighting.

References

1. Bean, A.R., Bell, R.I. "The CSP Index: A practical measure of office lighting quality", *Lighting Research and Technology*, 1992, Vol 24, pp215-225.
2. Loe, D.L., Rowlands, E. "The art and science of lighting: A strategy for lighting design", *Lighting Research and Technology*, 1996, Vol 28, pp153-164.
3. Veitch, J.A., Newsham, G.R. "Determinants of lighting quality 1: State of the science", *Journal of the Illuminating Engineering Society*, 1998, Vol 27, pp92-106.
4. Cuttle, C. *Lighting by Design*, 2nd edition, Oxford, Architectural Press, 2008.
5. Veitch, J.A. "Lighting quality considerations from biophysical processes", *Journal of the Illuminating Engineering Society* 2001, Vol 30, pp3-16.
6. Veitch, J.A. "Psychological processes influencing lighting quality", *Journal of the Illuminating Engineering Society*, 2001, Vol 30, pp124-140.
7. Society of Light and Lighting *The SLL Lighting Handbook*, London: SLL, 2009.
8. Society of Light and Lighting *The SLL Code for Lighting*, London: SLL, 2012.
9. Jay, P.A. "Inter-relationship of the design criteria for lighting installations", *Transactions of the Illuminating Engineering Society (London),* 1968, Vol 32, pp47-71.
10. Veitch, J.A., Newsham, G.R. "Preferred luminous conditions in open-plan offices: Research and practice recommendations", *Lighting Research and Technology*, 2000, Vol 32, pp199-212.
11. Al Marwaee, M., Carter, D.J. "A field study of tubular daylight guidance installations", *Lighting Research and Technology*, 2006, Vol 38, pp241-258.
12. Boyce, P.R. *Human Factors in Lighting*, London: Taylor and Francis, 2003.

13. Veitch, J.A., Galasiu, A.D. "Occupant preferences and satisfaction with the luminous environment and control systems in daylit offices: a literature review" *Energy and Buildings* 2006, Vol 38, pp728-742.
14. Cuttle, C. "Towards the third stage of the lighting profession", *Lighting Research and Technology* 2010; Vol 42, pp73-93.
15. Cuttle, C., "A new direction for general lighting practice", *Lighting Research and Technology* 2013, Vol 45, in press.
16. Wen, Y-J., Agogino, A.M. "Control of wireless-networked lighting in open-plan offices", *Lighting Research and Technology* 2011, Vol 43, pp235-248.
17. Maniccia, D., Rutledge, B., Rea, M.S., Morrow, W. "Occupant use of manual lighting controls in private offices", *Journal of the Illuminating Engineering Society* 1999, Vol 28, pp42-56.
18. Newsham, G., Veitch, J. "Lighting quality recommendations for VDT offices: A new method of derivation", *Lighting Research and Technology*, 2001, Vol 33, pp97-116.
19. Moore, T., Carter, D.J., Slater A.I. "Long-term patterns of use of occupant controlled office lighting", *Lighting Research and Technology* 2003, Vol 34, pp207-219.
20. Boyce, P.R., Veitch, J.A., Newsham, G.R., Jones, C.C., Heerwagen, J., Myer, M., Hunter, C.M., "Occupant use of switching and dimming controls in offices", *Lighting Research and Technology* 2006, Vol 38, pp358-378.
21. Boyce, P.R., Veitch, J.A., Newsham, G.R., Jones, C.C., Heerwagen, J., Myer, M., Hunter, C.M., "Lighting quality and office work: two field simulation experiments", *Lighting Research and Technology* 2006, Vol 38, pp191-223.
22. Newsham, G. R., Veitch, J. A., Arsenault, C., Duval, C. "Effect of dimming control on office worker satisfaction and performance" *Proceedings of the IESNA Annual Conference, Tampa, FL*. New York: IESNA, 2004.
23. Galasiu, A.D., Newsham, G.R., Suvagau, C., Sander, D.M. "Energy saving lighting control systems for open-plan offices: a field study", *Leukos*, 2007, Vol 4, pp7-29.
24. Veitch, J.A., Donnelly, C.L., Galasiu, A.D., Newsham, G.R., Sander, D.M., Arsenault C.D. "*IRC Research Report 299 Office Occupants' Evaluations of an Individually-Controllable Lighting System"*, Ottowa: National Research Council Canada, Institute for Research in Construction, 2010.