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Visual discomfort associated with ceiling luminaires: Observations, trends and challenges 2009 -2018

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VISUAL DISCOMFORT ASSOCIATED WITH CEILING LUMINAIRES: OBSERVATIONS, TRENDS AND CHALLENGES 2009-2018

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Abstract

This is a retrospective analysis of 30 onsite workplace assessments conducted during 2009-2018 where visual discomfort was associated with the apparent brightness of ceiling luminaires. Strategies attempted by individuals to manage their discomfort included wearing tinted spectacles, wearing a hat/visor and using barriers to block the view of luminaires. Half the workplace managers were reluctant to switch off luminaires because of potential aesthetics, safety or task illuminance issues. Relocating individuals to alternative workstations was not always feasible nor advantageous (for example, if other workstations had identical issues). Many workplaces have embraced the trend for activity-based work areas, but there are limited options for addressing visual discomfort if workers do not have assigned workstations. There is a challenge to provide lighting designs which meet the diverse visual needs of workers and which do not rely on high luminance luminaires.

Keywords: Visual discomfort, luminaires, luminance, lighting, open-plan office, activity-based work

1 Introduction

Office work has changed significantly over the past 10 years. In 2009 an office workstation was typically assigned to a single worker, and included a desktop computer, 1-2 computer monitors, and perhaps space for a laptop. By 2018, there was a trend away from assigning an individual their own workstation, to activity-based work whereby an area within the office is allocated to a team of people, and each day individual workers can select any workstation within that area from which to work. Activity-based work design also includes allocating areas within the office for individuals to select a work area (and workstation) according to the task performed, for example, collaborative areas, meeting areas and quiet areas. One of the principle enablers for this shift in office design philosophy is the emergence of mobile technology such as wi-fi, smartphones and other portable computer devices.

Office lighting has also changed over the past 10 years. In 2009 offices were predominantly lit with fluorescent lamps, whereas now there is a trend toward Light Emitting Diode (LED) based lighting systems. Although some offices are still lit with fluorescent lamps, the sales of fluorescent lamps and other traditional light sources are in decline (Anonymous, 2017), and new lighting designs are predominantly LED.

Despite the change in how offices are designed and lit, the lighting requirements for comfortably performing computer-based tasks is unchanged. For example, the lighting should not be a source of direct glare or reflected glare, there should be adequate illuminance to read hardcopy documents at the workstation, there should be adequate ambient illuminance so that large brightness differences are minimised between the computer display and other objects, and the lighting design should be aesthetically pleasing.

Lighting an office workspace is a challenge – not only to meet these requirements, but also to accommodate the range of visual capabilities of the people who use the space. These capabilities, which include tolerance to light, can be influenced by an individuals’ age, their ocular and physical health status, medication use and anatomical differences, for example, amount of pigmentation within the eye. In short, lighting which is comfortable for one person may not be comfortable for another.

This paper presents a retrospective analysis of 30 workplace assessments conducted between 2009 and 2018 where visual discomfort was associated with the luminance of ceiling luminaires. The purpose of this paper is to document some of the reasons for discomfort and how the discomfort was managed by individuals and their managers. This paper also highlights the importance of lighting design which is comfortable for all occupants of an office, particularly activity-based work designs where an individual has less control over their immediate work environment.

1.1 Definitions

Illuminance: The amount of light incident on a surface per unit area. Units of measurement are lumens per square metre, or lux.

Lamp: The light source, for example, fluorescent.

Luminaire: The entire light fitting, that is, the lamp and its housing.

Luminance: The luminous intensity emitted in a given direction by a luminous object per projected area of the object in the given direction (Julian, 1999). The luminous object could be a light source (such as a lamp) which emits light, or a surface which reflects light. Units of measurement are candelas per square metre ($cd.m^{-2}$). Although “brightness” is subjective whereas “luminance” is a physical measurement, an object with high luminance may be perceived by an observer as brighter than an object of the same size with low luminance.

2 Methods

Workplace assessments were included in the analysis if the assessment location was an office, the office worker performed computer-based tasks at their workstation and the worker reported visual discomfort from the brightness of the ceiling luminaires.

There were 30 workplace assessment reports which met this inclusion criteria. Data in this paper is reported in the aggregate so as not to identify specific individuals or workplaces.

3 Observations and findings

3.1 Luminaires

The assessed workstations were all located in open-plan offices. The ceiling luminaires included fluorescent lamps (n=28) either fitted with prism diffusers (n=12) or glare-reducing louvres (n=16), and LED fitted with opal diffusers (n=2).

Examples of the luminaires are shown in figures 1, 2 and 3. NOTE: these images are for illustration only, and do not necessarily represent products assessed during the workplace assessments.

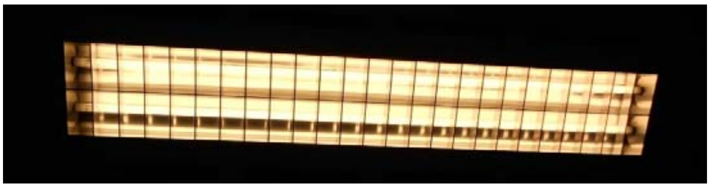

Figure 1 – Fluorescent lamp fitted behind glare-reducing louvres

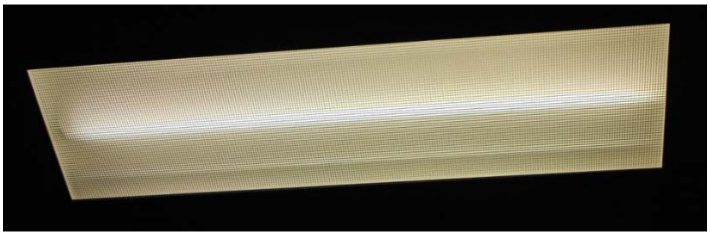

Figure 2 – Fluorescent lamp fitted behind a prism diffuser

Figure 3 – LED fitted behind an opal diffuser

3.2 Basis for discomfort

The basis for discomfort reported by the workers was neurological (for example, migraine) (n=10), physical (for example, ocular disease, ocular disfigurement) (n=7) or non-specific (for example, general discomfort and headaches) (n=13).

The luminaires which contributed to discomfort were identified with the “visor test” (Department of Employment and Industrial Relations Working Environment Branch, 1984), whereby a piece of card was held above the worker’s eyes (like a visor) to systematically block the view of individual luminaires. If the worker reported visual relief when the card obscured a particular luminaire, then this luminaire was noted as a potential cause of discomfort.

There was a general relationship between reports of discomfort, the type of luminaire and its location relative to the workstation:

- Luminaires fitted with glare reducing louvres had lamps which were directly visible from some positions of gaze. These luminaires were reported uncomfortable for workers when they could see the lamp, for example, if their workstation was located underneath the luminaire.
- Luminaires fitted with prism diffusers or opal diffusers were reported as uncomfortable when the luminaire was located to the front or to the side of the workstation. In these cases, workers could see the luminaire in their peripheral vision while working at their workstation.

The luminaires which were reported as uncomfortable also appeared significantly brighter than other objects in the work area. The luminance of these luminaires (when viewed from the workstations of affected workers) ranged between 1 895 cd.m^{-2} and 19 500 cd.m^{-2}, whereas the ceiling luminance was generally less than 50 cd.m^{-2}.

3.3 Description of strategies to mitigate discomfort

Strategies attempted by workers to manage their discomfort included wearing tinted spectacles (n=9), wearing a hat/visor (n=8) and using barriers to block the view of luminaires (n=6).

- In general, tinted spectacles (such as sunglasses) were reported ineffective for improving comfort and made it more difficult for workers to complete their work tasks. Subsequently, workers who had tried this strategy did not wear their sunglasses in the office.
- While some workers had discovered that wearing a hat/visor improved their comfort and were prepared to do so while seated at their workstation, others refused to wear a hat and insisted that the lighting “should be fixed”.
- Imaginative ways workers (and sometimes their managers) implemented to shield uncomfortable luminaires from view included manoeuvring furniture (such as bookcases)

within the office, placing pot plants on furniture and installing higher barriers around the workstation. Despite the effectiveness of these strategies, installing barriers sometimes placed a strain on workplace relationships, especially if the barrier prevented the worker from being seen by other workers in the open-plan office.

The managers of 15 workplaces had already switched off the overhead luminaire which the worker had identified as a source of discomfort, or were intending to do so if the workplace assessment report indicated that it was a suitable strategy. The managers of the remaining 15 workplaces were reluctant to switch off luminaires because of potential aesthetics, safety or task illuminance issues. For example, there was concern that switching off a luminaire would make the office unevenly illuminated and that this may pose a difficulty for other workers navigating the office or being able to see their work.

Relocating individuals to alternative workstations was not always a feasible option. For example, the worker would not be seated near their fellow team members (n=9) or alternative workstations in the office had identical issues (n=8).

3.4 Views about the office lighting

A common sentiment expressed by both managers and workers was that fluorescent lamps are "bad lighting". During the earlier year assessments (before about 2014) it was common to hear managers and workers say that if the lighting took another form (for example, incandescent or halogen) then the discomfort would not occur. When LED started to gain popularity as an office lighting option (after about 2014) many managers and workers anticipated that this would be a solution to visual discomfort.

This has not proved to be true. The two discomfort cases reported in this retrospective analysis which involved LED fitted behind opal diffusers were similar to the reports of discomfort associated with fluorescent lamps fitted behind prism diffuser panels.

4 Discussion

This paper reports the aggregate findings of 30 visual ergonomics workplace assessments in open-plan offices where visual discomfort was associated with high luminance ceiling luminaires. While it is true that there were many hundreds of people working within these offices who did not report discomfort with the ceiling luminaires, more than half the workers referred to in this paper had underlying neurological or physical conditions which increased their light sensitivity, while the remainder had non-specific (or more general) discomfort. Irrespective of the underlying reason, the discomfort experienced by these individuals was significant enough for the individual to report the problem to their manager and for the workplace manager to seek external advice for a solution to the problem.

Visual discomfort associated with high luminance ceiling luminaires has previously been documented in the scientific literature. For example, Ngai and Boyce estimate that 50% of people will experience discomfort if an overhead luminaire has luminance which exceeds 9 000 $cd.m^{-2}$, even if the luminaire is 85 degrees above the horizontal line of sight, i.e. above a person's head (Ngai and Boyce, 2000), and Escuyer and Fontoynont describe how some people in an open-plan office reported glare when a luminaire (luminance of 10 000 $cd.m^{-2}$ at 45 degrees) was within their field of view (Escuyer and Fontoynont, 2001). The highest luminance measured in the 30 workplace assessments reported in this paper was 19 500 $cd.m^{-2}$, which exceeds the 9 000 $cd.m^{-2}$ nominated by Ngai and Boyce as comfortable for 50% of people (Ngai and Boyce, 2000). There were also workers who reported discomfort when the luminaire luminance was 1 895 $cd.m^{-2}$. This magnitude is similar to that reported by Helland and co-authors in an open-plan office which had reflector-louvre luminaires with a luminance of 1000 $cd.m^{-2}$ to 3000 $cd.m^{-2}$ (Helland et al., 2011)

It is possible to use high luminance luminaires in a workplace if they are adequately shielded from view (Grandjean, 1987), if the workstations are configured so that luminaires are not within the field of view of workers, for example, at right angles to the line of sight (Grandjean, 1987, Department of Employment and Industrial Relations Working Environment Branch, 1984), or if the luminaires are directed away from the view of workers, for example, directed toward a wall so that the vertical surface is lit and the workspace is illuminated with reflected light from the wall (these type of lighting are called “wall-washers”) (ERCO GMBH and Julian, 2016). In the open-plan offices analysed for this paper, cost constraints prohibited replacing the existing luminaires with alternative luminaires which may have offered different (and better) shielding. It was also not possible to reconfigure the workstations within the offices due to space constraints.

The local solutions to improve comfort described in this paper (such as installing a barrier to shield a luminaire, or switching off a luminaire) are feasible if an individual works predominantly from a single location, for example, if they have a workstation assigned for their use. However, there are fewer local options available if a worker uses multiple workstations throughout the day, such as with the activity-based work philosophy. This puts the onus back onto the lighting designer to provide lighting which either does not have high luminance, or which can be easily adjusted by an individual worker to reduce its luminance, for example, with a dimmer switch.

There is evidence within the scientific literature for lighting designs which are rated as comfortable by office workers performing computer-based tasks:

- Hedge and co-authors describe an office refurbishment in which some locations within the office were fitted with lensed-indirect lighting and other locations were fitted with parabolic down-lighting (Hedge et al., 1995) (see figures 4 and 5). The lensed-indirect lighting was preferred by 63.8% of the workers, who rated the lighting as less bright, more subdued, pleasant and calming, whereas the parabolic down-lighting was associated with increased reports of tired eyes and self-reported decreased productivity (Hedge et al., 1995). Further practical evidence of their satisfaction (and dissatisfaction) was noted post-installation: some of the workers modified the parabolic down-lighting by removing or switching off the fluorescent lamps, but no modifications had been made to the lensed-indirect lighting (Hedge et al., 1995).
- In an office-refurbishment study in Scandinavia, workers moved from a single occupancy office fitted with reflector-louvre luminaires in which some of the lamps were directly visible (luminance ranged 1000 to 3000 cdm^{-2}) to an open-plan office where the lighting was predominantly indirect (92% indirect, 8% direct). Visual discomfort was associated with glare in the single-occupancy offices but not in the open-plan office (Helland et al., 2011). There was also a reduction in reports of headaches in the open-plan office (Helland et al., 2011).
- In a study of lighting preferences in an open-plan office, Veitch and Newsham report that 46.8% of participants preferred indirect lighting, and that 81% of participants wanted the ability to adjust the lighting, including adjusting the position or angle of the lights (69.2% of participants) or turning the lights on/off (78.5% of participants) (Veitch and Newsham, 2000).

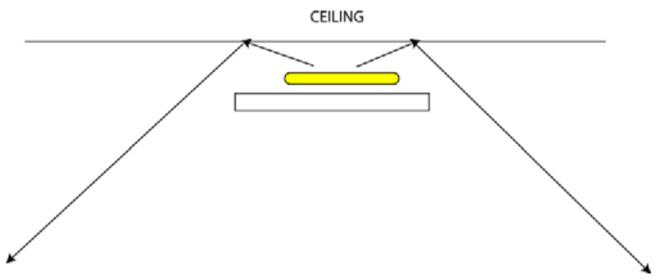

Figure 4 – Indirect lighting: the lamp is shielded from direct view, light is reflected into the room from the ceiling (or from the inside of the luminaire housing).

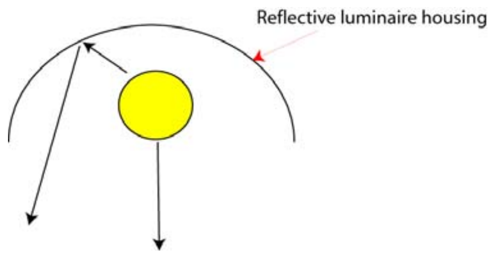

Figure 5 – Parabolic reflector: The room is lit by light directly from the lamp as well as light reflected from inside the reflective luminaire housing.

It is interesting to observe that some workers disliked fluorescent lamps and believed their visual comfort would be improved if the fluorescent lamps in the luminaires were replaced with an alternative light source. This echoes Veitch and co-authors publication 25 years ago which showed that fluorescent lamps are disliked and are perceived as detrimental to health (Veitch et al., 1993). More recent work by Islam and co-authors (a study which investigated observers preference for LED and fluorescent lighting with office-based tasks) showed a preference for LED over fluorescent lighting. The authors surmise that this preference was probably not related to glare but to the spectral power output of the lamps (the relative proportion of light wavelengths emitted by the lamp, which can affect the colour appearance of the light) (Islam et al., 2015).

The data presented in this paper is based on case examples from workplace assessments conducted between 2009 and 2018. The fact that it is based on case examples is a limitation, compared to the robustness of before-after intervention studies (such as those conducted by Hedge et al (Hedge et al., 1995) and Helland et al (Helland et al., 2011)) or laboratory studies (such as those conducted by Ngai and Boyce (Ngai and Boyce, 2000). Nevertheless, the data does show trends associated with visual discomfort related to office lighting and these trends are consistent with what has been previously reported in the scientific literature.

5 Conclusion

This paper adds to the published literature in that it reports some of reasons office workers experience discomfort associated with high luminance ceiling luminaires, the strategies used by office workers to manage discomfort, and some of the difficulties with managing discomfort in modern office environments.

Not all workers will experience discomfort with high luminance luminaires, but those with underlying neurological or physical conditions may be more susceptible to discomfort. If an individual has an assigned workstation then it may be possible to improve their visual comfort by switching off the luminaire or installing a barrier which blocks the luminaire from direct view.

A current trend within office environments is to provide activity-based work areas where workers are not assigned a workstation but can choose their work area according to the task they are performing. If a worker does not have an assigned workstation then there are limited options for addressing their visual discomfort.

This presents a challenge for lighting product manufacturers and for lighting designers to provide lighting which accommodates the business requirements for work design and work space allocation, as well as lighting which meets the diverse visual needs of people who work within the space.

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