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Healthy, safe, comfortable and productive workplaces: A visual ergonomics perspective

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ABSTRACT

It can be argued that many current visual ergonomics topics are not new issues, but are new applications of visual issues already debated in the scientific literature. Therefore, if we understand the limitations and capabilities of the visual system, then it is a relatively straightforward process to apply existing knowledge to ensure workplaces are healthy, safe, comfortable and productive.

This paper challenges the assumptions underlying this premise. Firstly, we have an evolving understanding of the human visual system, and this limits our ability to apply existing knowledge to solve new visual ergonomics problems. Secondly, we have a limited understanding of how to measure the environment so that it correlates with visual comfort and ability. Finally, even if we did have a complete understanding of visual function and how to measure task-related factors, and were to apply this knowledge to new technology, there are other factors which lead to worker acceptance that a workplace is healthy, safe, comfortable and productive. To support the arguments in this paper, three topical visual ergonomics issues are discussed: the discovery of intrinsically photoreceptive retinal ganglion cells (ipRGC) in the human eye, the use of maintenance illuminance to assess lighting suitability, and blue light emission from digital devices.

There are many research and practical opportunities in visual ergonomics which can further our understanding of healthy, safe, comfortable and productive workplaces. The challenge for HFE professionals is to keep up to date with the factors which contribute to healthy, safe, comfortable and productive workplaces and to integrate evidence based knowledge into their practice.

Keywords: visual ergonomics, lighting, ipRGC, illuminance, visual displays, blue light

INTRODUCTION

The underlying philosophy of human factors and ergonomics (HFE) is to achieve a balance between the demands of the work/leisure environment and the needs, capabilities and limitations of individuals. If there is balance, then the environment will be healthy, safe, comfortable and productive. This is illustrated in figure 1.

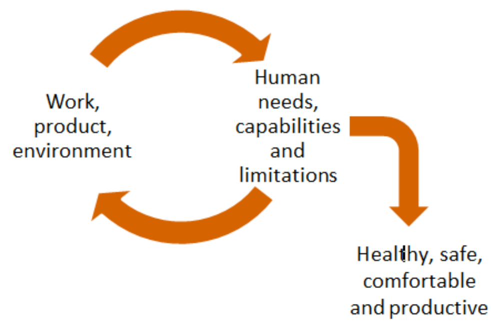

Figure 1. A model to explain the philosophy of human factors and ergonomics.

Within the field of visual ergonomics, the human side of the equation includes visual capabilities, visual perception and cognitive processes related to the visual acquisition of information. The work/product/environment side of the equation includes lighting, signage, visual displays and manufacturing tasks. If there is an imbalance between the two sides of the equation, this can lead to visual discomfort (e.g. headaches, sore eyes), visual disability (e.g. inability to read text or discern colours), accidents, injury and reduced productivity.

In evolutionary terms, the human visual system has been relatively unchanged for millennia, but the way we interact with our environment has rapidly changed. For example, in less than a century, office based equipment has progressed from designated workstations with pens, paper and typewriters, through to activity based workstations with workers having access to multiple digital devices. It has been argued that many current visual ergonomics challenges are not new issues, but are new applications of visual issues already debated in the scientific literature. For example, Watten (Watten 1994) documents nearly 400 years of scientific discussion about the causes of visual fatigue and draws parallels between historical documents and modern research related to visual fatigue and computer use. Fostervold et al (Fostervold, Watten et al. 2014) concludes that visual discomfort and disability associated with computer based work occurs because our visual system is only partially adapted to the physical demands of the work environment. If we understand the limitations and the capabilities of the visual system, then it is relatively straightforward to document this in a format which can be accessed and applied within workplaces and by designers. This is the approach taken by Long et al (Long, Rosenfield et al. 2014) who propose that visual ergonomics standards for contemporary office environments should include basic information about the capabilities of the human visual system so that designers and manufacturers can create products which are healthy, safe, comfortable and productive for end users.

Applying existing knowledge about the human visual system to contemporary working environments makes three assumptions: (1) We already have a full understanding of vision and visual perception (2) The tools we use to assess the environment are accurate and are appropriate (3) End-users are receptive to the application of existing knowledge to new work demands.

This paper challenges these assumptions by describing three emerging issues related to visual ergonomics and lighting and discussing the implications of these issues for HFE practice. The three examples which will be discussed are the discovery of intrinsically photoreceptive retinal ganglion cells (ipRGC) in the human eye, the use of maintenance illuminance to assess lighting suitability, and blue light emission from digital devices.

VISION AND VISUAL PERCEPTION

The 20th century explanation for human vision is that there are rods and cones within the eye's retina. The rods enable us to see in low light (scotopic) visual conditions and are very sensitive to temporal changes in light (flicker), while the cones enable us to see colour and detail under lit (photopic) conditions. In 2002 Berson et al (Berson, Dunn et al. 2002) described a new type of cell in our retina called intrinsically photoreceptive retinal ganglion cells (ipRGC). These cells respond to visible light, and have a maximum sensitivity at 482nm (i.e. in the blue colour range of the electromagnetic spectrum)(Feigl and Zele 2014). The cells have various functions, including helping to regulate our internal circadian body clock, controlling our pupil reactions, and adjusting our upper eyelid position in response to glare (Markwell, Feigl et al. 2010; Feigl and Zele 2014; Sliney 2016). These functions are sometimes referred to as "non-visual effects" but this term is controversial because it is believed that the calls also contribute in-part to vision (Sliney 2016).

Research into ipRGC cells has captured the imagination of the general public and resulted in a proliferation of products which promise to modify our blue light exposure, improve our sleep and increase our productivity e.g. software to modify light from computer monitors and dynamic lighting products marketed as useful for night shift workers. Lucus et al (Lucas, Peirson et al. 2014) agree that there is scope for considering the non-visual effects of light in contemporary lighting designs. However, they also place a caveat that industry should be clear about the purpose of a lighting design because the visual and non-visual functions of light can have contradictory effects e.g. dim lighting may be useful for night shift workers to minimize disruption to the internal circadian body clock, but the dim light levels could adversely affect work performance.

One of the roles of HFE practitioners is to assess workplaces in-situ and compare measurements against standards and guidelines. There are two barriers to achieving this aim with respect to ipRGC. Although there is an increasing body of knowledge about ipRGC, there has not been scientific agreement about how to quantify ipRGC function (Lucas, Peirson et al. 2014) nor do we fully understand how ageing affects ipRGC function (Markwell, Feigl et al. 2010). This makes it difficult to establish meaningful standards and guidelines for use in workplaces.

There is also debate whether we have appropriate tools to measure the non-visual effects of light in workplaces. Some authors assert that it is theoretically possible to collect relevant data by using modified computerized technology (Cuttle 2010), while others argue that simple, straightforward measurement tools are not possible until a spectral weighting function is developed for ipRGC (i.e. an understanding of how the ipRGC cells function across each of the wavelengths in the visible spectrum) (Lucas, Peirson et al. 2014).

A limited understanding of ipRGC and lack of measurement tools does not preclude HFE practitioners from providing advice to workplaces on this topic, e.g. it is possible for HFE practitioners to raise awareness of the non-visual effects of light and have informed discussion with their clients in the workplace. However, until measurement tools and definitive standards are developed, advice given to workplaces on the topic of ipRGC function is confined to generic advice.

QUANTIFYING MEASUREMENTS

Illuminance is a widely used metric for assessing the adequacy of lighting in an environment. Depending on the lighting's purpose, illuminance may be measured with an illuminance (lux) meter at task level, at a height of 70cm from the floor (e.g. to assess the illuminance within a room) or at floor level (e.g. to assess the illuminance in a corridor). In Australia, lighting is deemed inadequate if the measured illuminance is less than the maintenance illuminance values published by Australian Standards (e.g. AS/NZS1680 series for interior and workplace lighting)(Standards Australia). Other countries around the world adopt a similar approach and have their own national standards against which illuminance is assessed.

A problem often encountered in workplaces is dissatisfaction and discomfort with lighting that complies with maintenance illuminance values given in the Australian Standards. One explanation for discomfort and dissatisfaction is that there are differences between individuals and their tolerance for light levels. This may result in some individuals wanting additional light on tasks, while others request that overhead luminaires are switched off. It has been argued that the maintenance illuminance values specified in standards exceed the values required for task visibility (Cuttle 2010) and that high illuminance values are specified to minimize the risk of errors in visual tasks while catering for a wide range of visual abilities (Bean and Bell 1992). One option to address this issue and achieve a balance between task demands and individual preferences is to provide overall lower illuminance throughout a workplace and supplement it with task illumination as required (Long 2013).

A second explanation for dissatisfaction and discomfort with lighting is that task illuminance only describes one aspect of how we use and perceive light. Other parameters which can affect our satisfaction and comfort include the distribution of light within an interior space, colour appearance (e.g. warm versus cool light), the ability to faithfully render colours (colour rendering) and the illuminance of ceilings and walls. The International Commission on Illumination has published a protocol for measuring and describing light (International Commission on Illumination 2014). This document includes metrics for quantifying various lighting parameters and examples of qualitative tools for appraising lighting installations and measuring occupant satisfaction. The procedures described range from simple assessments to complex analysis requiring specialized tools. Other authors propose new metrics, e.g. Bean and Bell's (Bean and Bell 1992) comfort, satisfaction and performance (CSP) index to quantify visual effectiveness, and Cuttle's (Cuttle 2010; Cuttle 2013; Cuttle 2015) metrics which take into account light reflected from walls, ceilings and other surfaces.

It may be some time before maintenance illuminance is no longer used as the principle parameter for assessing the success and suitability of lighting installations. Some of the cited barriers to the widespread implementation of alternative metrics include a perception that measurements will be complex, that the theoretical understanding and skill-set of those making measurements will need to improve, and that there is potential for any metric to be misused, particularly if installations need to comply with a specified value (letters in response to (Cuttle 2013)).

If alternative metrics replace maintenance illuminance, then it is likely that new instruments (other than illuminance meters) will be required for measuring these parameters in workplaces and new standards and guidelines will need to be developed.

SEEING BLUE

Lighting is an intrinsic part of all our lives, but it is an entity which has long been shrouded in controversy. For two centuries there was debate among scientists whether light is a wave or a particle. This debate was settled at the start of the 20th century by physicists agreeing that light behaves as both a wave and a particle. Modern debates related to lighting include the wavelengths of light which are visible to the human eye and whether the boundary of visible light/ultraviolet radiation is at 380nm or 400nm (Sliney 2016).

A controversy relevant to contemporary workplaces is whether blue light emanating from digital displays will affect eye health. This is reminiscent of fears promulgated in the 1970s and 1980s about radiation emitted from desktop computer monitors causing cataracts and other ocular disease. Epidemiology studies later showed these fears to be unfounded (Cole, Maddocks et al. 1996). The issue has arisen again because of the way handheld digital devices are used:

- They are often held close to the face, which increases the dose of light at the eye compared to conventional desktop computers.
- They are often used for prolonged periods of time, which increases the eye's exposure to the light.
- They are used by a large proportion of the community, including children, so there is potential for more people suffering harm.

Short wavelength visible radiation (blue light) can damage the retina (Bullough 2000), but recent research shows that the blue light dose received while viewing a digital device is below accepted exposure limits. Therefore the risk of ocular damage is minimal, even when devices are used for prolonged periods of time (O'Hagan, Khazova et al. 2016). Despite this, there are a range of products marketed to digital device users aimed at reducing their long-term risk of ocular damage from blue light exposure.

In theory, it should be relatively straightforward to use the model in figure 1, apply existing knowledge about the human eye, blue light hazards and exposure standards, and demonstrate minimal risk to ocular heath from handheld digital devices. In practice it is not easy to achieve because radiation is an emotive topic, public knowledge may be lacking (e.g. exposure limits and lighting concepts may not be fully understood) and media coverage of the topic may be biased or not comprehensive. Factors such as these can lead to an inaccurate perception of the risk and resistance to modifying existing belief about harm (Slovic 1986).

Although it is not an easy task to change public perceptions, this should not deter HFE professionals from providing evidence based information to help allay fears about ocular health and digital device use. These conversations could also serve a segue for addressing broader ergonomics issues which have a greater potential for harm e.g. physical ergonomics issues associated with holding devices in static postures, for prolonged periods and at short viewing distances; cognitive issues associated with multitasking; and the use of digital devices at all periods of the day/night including immediately before sleep.

CONCLUSION

This paper presents three issues related to lighting which are relevant for workplace HFE practice.

The first two examples (the discovery of ipRGC in the human eye, and debate in the lighting community about the validity of measuring illuminance) highlight the fact that we do not have a complete understanding of the human visual system. Nor do we have a complete understanding of a fundamental physical parameter relevant to most workplaces: light. The third example (blue light exposure from digital devices) demonstrates that even with an understanding of human capabilities and task parameters, there may be other factors which lead to acceptance by end-users that a workplace is healthy, safe, comfortable or productive.

This presents many opportunities for those interested in visual ergonomics. For example, in research, by quantifying and describing light in a meaningful way, establishing relevant exposure standards and developing new measurement tools. In practice, opportunities include testing and applying theoretical knowledge to real-world problems and providing informed and accurate advice to workplaces. The challenge for HFE professionals is to keep up to date with the factors which contribute to healthy, safe, comfortable and productive workplaces and to integrate evidence based knowledge into their practice.

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