Review

THE EFFECT OF LIGHT ON THE HEALTH OF OLDER ADULTS WITH LOW VISION: A NARRATIVE REVIEW

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INTRODUCTION

In the history of medicine, there has always been interest in the interaction between light and health. However, recent developments in technology have led to a lighting revolution and it is now possible to have more light, more control, better aesthetics, and all at less cost than at any time in the recent past. Research exploring the association between light and health is increasing exponentially, and it is clear that good use of lighting can make a dramatic difference to people's lives and overall health. This paper aims to bring some of this literature into focus as a narrative literature review (Grant, 2009) about the effect of light on the health of older adults with low vision. It does not aim to be exhaustive, but rather to provide an overview of the visual and non-visual effects of light on health, particularly that of people with age-related vision loss (ARVL).

Light and the eye

Before starting to talk about the effect of lighting on health, it is necessary to first visit some basic facts about light and the eye in order to provide a context for the following material. For example, the fact that white light is made up of a spectrum including red, orange, yellow, green and blue light rays highlights the idea that light is made up of different wavelengths. There is an inverse relationship between the wavelength of light rays and the amount of energy they contain. Light rays that have relatively long wavelengths contain less energy, and those with short wavelengths have more energy. Rays on the red end of the visible light spectrum have longer wavelengths and, therefore, less energy. Rays on the blue end of the spectrum have shorter wavelengths and more energy (Melton, 2014).

It is possible to make some direct connections between these facts and the effect of light on visual health. For example, concerns about blue light have come to the fore recently (American Medical Association, 2016). As a rule of thumb, the cooler the white light is, the higher will be the proportion of blue light: compact fluorescents (CFLs) contain about 25% of blue light, whereas light-emitting diodes (LEDs) contain about 35% of blue light. Blue light is also part of the LED display on most screens, and this is an increasing source of exposure for many people. There is a narrow spectrum of blue light (between 415nm and 455nm) that has been found to be most harmful to the retina (Melton, 2014). In terms of direct damage to the front of the eye, long wavelengths such as ultraviolet (UV) light may be more significant in terms of cataract formation, whereas shorter wavelengths like blue light tend to cause more damage to the back of the eye (Melton, 2014). For people who have a propensity to macular degeneration (a retinal condition, described below), it is considered important to provide protection against blue light. This can be done using blue-blocking sunglasses (with yellow/amber lenses) (Melton, 2014).

Light makes its way through the eye and is converted into messages that the brain receives. At the first point of entry, the lens at the front of the eyeball focuses light onto the retina, which is a very thin, multi-layered tissue located at the back of the eyeball. Light then enters the optic (or nerve) fibre layer and the ganglion cell layer, under which most of the nourishing blood vessels of the retina are located. This is where the nerves begin picking up the impulses from the retina and transmitting them to the brain. The light is received by photoreceptor cells called rods (responsible for peripheral and dim-light vision) and cones (providing central, bright-light, fine-detail, and color vision). The photoreceptors convert light into nerve impulses, which are then processed by the retina and sent through nerve fibres to the brain (Boyce, 2003).

Until recently, the rod and cone photoreceptor cells in the retina have been credited with total responsibility for light sensitivity. However, recent research has shown that there is a third type of photoreceptor called melanopsin, which is found in "intrinsically photosensitive retinal ganglion cells" (ipRGC). These sparsely situated cells are most sensitive to blue light and they seem to exist principally to help differentiate between day and night (thus modulating the 'sleep/wake' cycles, known as circadian rhythms) (Lucas, Peirson, Berson, Brown, Cooper, Czeisler & Brainard, 2014). It is this effect which gives rise to the non-visual properties of light.

The ageing eye

Optical changes affect the amount of light reaching the retina. Hardening of the crystalline lens capsule and atrophy of the ciliary muscles are primary causes of lost accommodation (the capacity to change focus). There are changes in the thickness and clarity of the lens, which also develops a yellowish tinge. The pupil also becomes smaller (Boyce, 2003). In fact, the visual system can be characterised as 'young' only until it reaches about 40 years of age (Lahti, Helén, Vuorinen & Väyrynen, 2008). In later years, various factors intrinsic to the ageing process decrease the amount of light that is available to the human visual system (Boyce, 2003). It is estimated that a typical 60-year-old only receives about one-third the retinal illuminance of a 20-year-old – i.e., they require 3-10 times as much light (Lahti, Helen, Vuorinen, Vayrynen, 2008).

In fact, ageing of eyes happens even earlier than this. For example, the lens of a 10-year-old transmits 75% of available UV light, but by the age of 25, UV transmission rate drops to 10%. This remarkable change means that 80% of all the damage created by UV light may well happen before age 18 (Karpecki, 2012). These changes happen to everyone as they age. However, there are also a number of common visual impairments (VI) to which older adults are particularly susceptible, and the conditions described here include cataract, macular degeneration, glaucoma and diabetic retinopathy.

Age-related macular degeneration (AMD) can be defined as ageing changes in the central area of the retina (the macula) occurring in people aged ≥ 55 years in the absence of any other obvious cause (Ferris, 2013). The current prevalence of AMD in countries like the US is 6.5% in people over 40 (Klein, Chou, Ahang, Meuer, 2011), and it is currently the leading cause of irreversible visual loss in high-income countries in people aged over 60 (Bunce, 2006). Interestingly, the rates of AMD have declined over the last two decades by about one third, possibly because of public health measures like diet, exercise and a reduction in smoking (Klein, 2011).

Age-related cataract is the most common form of cataracts (Royal College of Ophthalmologists, 2010). This condition involves loss of transparency of the crystalline lens, and a classic symptom is a slow, gradual, painless progressive reduction in the quality of vision (Pesudovs, Elliott, 2003). Prevalence in high-income countries for those over 65 is estimated at 30% (Reidy, Minassian, Vafidis, Joseph, Farrow & Wu, 1998). UV light also plays a key role in cataract genesis (Taylor, 1992), and people who live in high UV exposure areas, such as the equator, are more likely to have advanced cataract development.

Diabetic retinopathy is a chronic, progressive, potentially sight-threatening disease of the retinal microvasculature (Bowen, 2016). The prevalence of diabetic retinopathy is reported to be 25.3% in type 1 diabetes and 45.7% in type 2 diabetes (Younis, Broadbent, Harding & Vora, 2002), out of the total population where diabetes has a prevalence of 9.1% (Valdez, Yoon & Khoury, 2007).

Glaucoma is actually a group of eye diseases that have in common progressive structural damage to the optic nerve head, resulting in functional loss of the visual field, which can lead to blindness if left untreated. Current prevalence is estimated at 2.1% (Gupta, Zhao, Guallar, Ko, Boland & Friedman, 2016)

Of all these conditions, the one that is most likely to be helped by additional lighting is macular degeneration (Lahti, Helen, Vuorinen & Vayrynen, 2008). However, since most older people are likely to be affected by more than one type of visual impairment, it is always important to understand the impact of light at an individual level. Lighting is one of the simplest and most effective ways to improve overall well-being in people with low vision. There are both visual and non-visual mechanisms underpinning how light delivers these benefits: visual mechanisms are delivered in ways that are consciously seen, and benefits include an increase in productivity and a decrease in the potential for falls for people with low vision; non-visual mechanisms are not directly perceived, but still have a major impact on circadian rhythms and effect both mood and sleep.

Visual effects of light

Lighting has a major contribution to make in increasing the capacity of older adults to live safely and well in their own homes (Paul and Yuanlong, 2012). The two areas highlighted here describe the impact of light on overall function and on safety (particularly in terms of reducing the risk of falls).

Function

Any physical impairment, including visual impairment, can lead to disability which may adversely affect quality of life, particularly in older people (Wang, Chan & Chi, 2014). Visual impairment causes significant disability, and comes after arthritis and heart disease as a chronic condition which can affect the ability of older people to perform essential tasks (La Plante & Carlson, 1992). However, there is not a direct relationship between impairment and disability. Visual impairment is not the whole story, and it is important to realise that the visual ability of any individual is defined more by the task demand (and personal characteristics of the individual) than by a specific measure of visual impairment (West, Rubin, Broman, Muñoz, Bandeen-Roche & Turano, 2002).

Every task carries its own lighting demands: threading a needle requires more light than making toast. Yet we know that the lighting levels in the houses of older adults with low vision consistently fall below recommended levels for any specific task (Bakker, Lofel & Lachs, 2004; Bhorade et al., 2013; Chu, Kaldenberg & Huefner, 2009). There is also evidence that many rest home and residences have inadequate lighting (Bakker, 2004). Lighting is one way of adapting a task, and therefore one of the first things to do for people with low vision (alongside checking whether the refractive error has been corrected with glasses) is to provide them with good task lighting.

There are many reasons why older adults with low vision live in homes with inadequate lighting (De Lepeleire et al., 2007); these may be institutional in the case of rest homes, or they may be physical, personal (by choice), cognitive, emotional, or financial in origin. For example, the inability to physically change a light bulb is a very different type of demotivator than the desire to conserve electrical power for economic reasons. However, if people stop doing valued activities because they do not have adequate lighting, it can lead to depression and mood disorders, which are frequently associated with visual impairment (Pelletier, Thomas & Shaw, 2009). Conversely, for those who do have good lighting, there is a positive association with quality of life, and research indicates that older adults who live in well-lit buildings perceived their quality of life to be higher than their counterparts living in low-lit rooms and buildings (Shikder, Price & Mourshed, 2010; Sorensen & Bruunstorm, 1995).

There is some research indicating the direct effect of light on function. For example, according to Richter (1989), increasing the light level from 500 to l000 lux (lux is a measure of light intensity) raised the work productivity of older employees by 6%. Among people with macular degeneration, increased lighting can often result in the capacity to read without magnification (Sloan, Habel & Fejock, 1973) or to read much faster (Eldred, 1992). This is a major increase in overall ability, which is available even when the person has significant visual impairment.

Function will also be affected by the general distribution of the light, because the older eye generally struggles with adaptation from light to dark and vice versa. It is therefore important that the light from a task lamp is uniformly distributed so that shadows are not formed, and this helps with overall function for the person with ARVL (Boyce, 2003). It is similarly crucial that there should be a relatively equal distribution of ambient light, so that the individual does not move suddenly from light to dark. These rapid changes in light can be one of the causes of falls in adults with ARVL (Lahti et al., 2008).

Falls

In the UK, it is estimated that 30% of people aged > 65 and 50% of people aged > 80 fall at least once per year (NICE, 2013). Falls make up the largest percentage of accidents among older adults and are caused by complex interactions between human and environmental factors. Light is one part of the environment that is highly likely to impact on the mobility of adults with ARVL, since poor vision affects a person's ability to maneuver around obstacles in a low-lit environment (Paul & Yuanlong, 2012). Brown and Jacobs (2011) demonstrated that participants reporting inadequate natural light in their residences were 1.5 times as likely to report a fall when compared with those satisfied with the light levels in their homes. Many falls happen in the bathroom and bedroom, which are typically places with inadequate lighting (Carter, Campbell, Sanson-Fisher, Redman & Gillespie, 1997; Liu, Paul & Orchanian, 2003).

There is also an association between low light and changes in older people's gait, balance and reaction times which leads to falls, trips or slips (Buckley, Heasley, Twigg & Elliott, 2005). A simple test of postural sway (for example, standing on one leg) demonstrates that even adults with no problems with low vision will experience increased problems in conditions of low light (Brooke-Wavell, Perrett, Howarth & Haslam, 2002). This is intensified in adults who have low vision, and there is increased postural sway in adults with low vision in conditions of low light (Brooke-Wavell et al., 2002; Reed, Lowrey & Vallis, 2006). This finding implies that low light could lead to responses that increase the likelihood of falling.

Connell and Wolf (1997) identified other patterns of environmental and behavioural circumstances linked to falls and near-falls experienced by older adults. These included collisions in the dark, failing to avoid temporary hazards, preoccupation with temporary conditions, frictional variations between shoes and floor coverings, excessive environmental demands, habitual environmental use, and inappropriate environmental use. Many of these patterns are compounded by the failure to turn on the light, or to increase the light level in different areas of the home.

One thing that seems particularly important to note is the association between VI and other forms of impairment. For example, there is a high prevalence of visual impairment in all people living with dementia (Bowen et al., 2016). Both dementia and VI are risk factors for falls (Bowen, Edgar, Hancock, Haque, Shah, Buchanan & O'Leary, 2016), so it is always worth thinking about visual impairment whenever there is age-related impairment. One indirect, negative impact of sleep disturbances is the risk of falling, which is exacerbated by disrupted circadian rhythms (see below). Often these patients get out of bed, either to use the restroom or just wander around their room. Persons with dementia are about three times more likely to fall (Shaw, 1998) and their recovery is generally longer than that of healthy older adults (Allan, 2009). One creative way that light has been successfully used with people with ARVL and dementia is the use of lighting strips around doors and along corridors for the prevention of falls at night (Hanford & Figueiro, 2013).

Non-visual effects of light

The most obvious of the non-visual effects of light is on circadian rhythms, which feature in nearly every physiological, metabolic and behavioural system. This brings a wide array of biological processes under indirect retinal control. Non-visual effects of light refer to aspects of human physiology and behaviour that are influenced by retinal illumination, where the responses originate in the eye, but they are referred to as 'non-image-forming' or non-visual because they can be elicited even in some blind people. Since the discovery of melanopsin it has become obvious that any wavelength of light can, in principle, activate the non-visual response. However, generally non-visual responses are activated by the blue/green regions of the visible spectrum and, conversely, they tend not to be activated by the longer visible wavelength range (red end of the spectrum) (Lucas et al., 2014).

The term 'non-visual response' also encompasses a number of more acute effects of light. For example, light constricts the pupil, suppresses pineal melatonin production, increases heart rate and core body temperature, stimulates cortisol production and acts as a neurophysiological stimulant (increasing subjective and objective measures of alertness and psychomotor reaction time, and reducing lapses of attention) (Lucas et al., 2014). We also know that UV light can have non-visual effects, such as helping the body manufacture adequate amounts of vitamin D (Melton, 2014). Without vitamin D, calcium absorption and utilisation would not occur, which are needed to maintain healthy bones. Inadequate exposure to vitamin D results in weakened bones, which make the older adult with low vision vulnerable to breaks if they do happen to trip or slip.

The recent recognition of non-visual effects of light has led to the development of a number of new therapeutic applications and, in some cases, helped us to understand why some interventions have historically been effective. For example, light has been known for a long time to have anti-depressant properties, particularly in the treatment of seasonal affective disorder (SAD) (Lam, 1996). More recently, appropriately timed light exposure has been developed as therapy for circadian rhythm sleep disorders and circadian disruption associated with jetlag and shift work (CIE, 2015). In addition, light has been explored as a treatment for non-seasonal depression, menstrual-cycle-related problems, bulimia nervosa, and cognitive and fatigue problems associated with senile dementia, chemotherapy and traumatic brain injury (Lucas et al., 2014). In the following sections, the non-visual effects of light on mood and alertness/sleep for people with ARVL are particularly examined.

Mood

There is a strong association between visual impairment and negative feelings including frustration, anger and feeling low; the prevalence of depression in people with ARVL is approximately 30% (Margrain, 2012). These feelings may be part of the normal grieving process for the loss of vision. However, persons with ARVL are also susceptible to wintertime barriers to socialisation and physical activities, since wintertime darkness and icy outdoor areas pose significant hurdles to people with reduced vision.

Recent studies indicate that severe visual impairment or blindness can also increase the risk of Seasonal affective disorder (SAD) (Madsen, Dam & Hageman, 2016). Seasonal affective disorder occurs as a reaction to reduced sunlight and is an example of a non-visual response to lighting. Three quarters of those affected by SAD are women, and up to two thirds of these can experience depressive symptoms every winter (Magnusson & Boivin, 2003). The causes of SAD are complex and include both biological and psychological factors. Climatic factors such as global radiation, length of day, temperature and hours of sunshine seem to be important for the annual onset of the disease (Molin, 1996). The main biological factors include biological rhythms and/or neurotransmitter levels, genetic variations and retinal subsensitivity (Rohan, Roecklein & Haaga, 2009), in all of which light is involved. Light also plays a major role in the treatment of SAD, and the clinical effect of therapy with bright white light for SAD has been demonstrated to be equivalent to that of antidepressant pharmacotherapy (Golden, Gaynes, Ekstrom, Hamer, Jacobsen & Suppes, 2005; Nussbaumer, Kaminski-Hartenthaler, Forneris, Morgan, Sonis, G, Greenblatt, Wipplinger, Lux, Winkler, Van Noord & Hofmann 2015).

Sleep

In addition to mood disorders, there are also indications that persons with visual impairment are at risk of sleep disturbances and circadian misalignment (Nyman, Gosney & Victor, 2010). Sleep disorders can include insomnia, early morning waking and inability to return to sleep. Prevalence rates of insomnia in people aged over 65 ranges from 12-40% (Paul & Dennis Jane, 2002). These prevalence rates are doubled with people who also have a visual impairment (Seixas, Ramos, Gordon-strachan, Aparecida, Fonseca, Zizi & Jean-louis, 2015). Once institutionalised, patients who suffer from the most sleep disturbances at night are likely to become aggressive during the day (Cohen-Mansfield, 1995). For these reasons, there is considerable interest in the use of light therapy in rest homes and other residential units for older people.

In recent years, it has been increasingly recognised that the removal of all blue (white) light in a person's environment for several hours before bedtime can significantly improve sleeping patterns (Wirz-Justice, 2005). A controlled study was carried out in a cardiology hospital (Philips, 2014) where the whole lighting system followed the pattern of natural daylight, and included a yellow/amber light in the evening. This study demonstrated that patients had longer sleep duration and fell asleep more rapidly (reduced sleep onset latency). As it can be seen from these effects, the circadian system is very sensitive to blue light. In 2016 the American Medical Association brought out a statement against the use of blue light for street lighting. Their argument against the effects of blue lighting at the non-visual level is that these white LED lights have five times greater impact on circadian sleep rhythms than conventional street lighting. Surveys found that this brighter residential nighttime lighting is associated with reduced sleep times, dissatisfaction with sleep quality, excessive sleepiness, impaired daytime function and obesity (American Medical Association, 2016).

DISCUSSION

The effects of light on physiology and behaviour have evolved over millennia, during which environmental illumination provided a reliable indicator of time of day. The advent of electrical lighting originally disrupted this relationship, with patterns of light exposure increasingly reflecting personal tastes and social pressures. However, the advent of new lighting technology means that the effect of light on health and wellbeing is increasingly recognised as an important public health topic. Research and technology in this area is evolving so quickly that it can be difficult to make an informed decision about the right kind of lighting for both visual and non-visual performance. In addition, what we know about eyes and visual impairment indicates that any advice will have to be individualised. Until the same level of understanding of the visual effects of light is achieved for the non-visual effects, this is likely to be an active and important area of research.

However, what we know already is that many people with ARVL can function more effectively and safely with access to increased lighting; and that there could be a concomitant potential improvement in their mood and sleeping patterns. These are gains worth pursuing. Many people with ARVL depend greatly on others to regulate their light exposures, and hopefully to provide timely daytime access to the outdoors. They also need good access to lighting for the visual benefits it confers in terms of performance and safety, and also for the non-visual effects on mood and sleep. It is important that these needs should not be overlooked or trivialised, and it is the intention of this narrative literature review to make the benefits of lighting more accessible to this population.

Mary Butler is an occupational therapist with a background in anthropology. A low-vision theme has informed her research, practice and teaching over recent years. Mary says: "Teaching and research have become the deepest expression of the kind of transformational change that I enjoy being part of. My research and practice is driven by a nexus of interests that has the students' experience at the core, but which draws on practice, research and enterprise as ways of informing their learning." Mary emigrated from Ireland a generation ago and says that she and her husband "have raised the next branch of our family as Kiwi kids."

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REFERENCES

Allan LM, Ballard CG, Rowan EN, Kenny RA (2009) Incidence and prediction of falls in dementia: A prospective study in older people. PLoS ONE 4, e5521

American Medical Association. (2016). *AMA adopts guidance to reduce harm from high intensity street light. Chicago*. Retrieved on 29/4/17 from: https://www.ama-assn.org/ama-adopts-guidance-reduce-harm-high-intensity-street-lights

Bakker, R., Iofel, Y., & Lachs, M. S. (2004). Lighting levels in the dwellings of homebound older adults. *Journal of Housing for the Elderly,* 18(2), 17–27. http://doi.org/10.1300/J081v18n02_03

Bowen, M., Edgar, D. F., Hancock, B., Haque, S., Shah, R., Buchanan, S. O'Leary, N. (2016). The Prevalence of Visual Impairment in People with Dementia (the PrOVIDe study): a cross-sectional study of people aged 60–89 years with dementia and qualitative exploration of individual, carer and professional perspectives. *Health Services and Delivery Research,* 4(21), 1–200. http://doi.org/10.3310/hsdr04210

Boyce, P. R. (2003). Lighting for the elderly. *Technology and Disability,* 15, 165–180. doi:10.1201/b16707-17

Brooke-Wavell K., Perrett L. K., Howarth, P. A., & Haslam, R. A. (2002). Influence of the visual environment on the postural stability in healthy older women. Gerontology, 48, 293-297.

Brown, M. J., & Jacobs, D. E. (2011). Residential light and risk for depression and falls: Results from the LARES study of eight European cities. Public Health Report, 126(Suppl1), 131-40.

Buckley, J. G., Heasley, K. J., Twigg, P., & Elliott, D. B. (2005). The effects of blurred vision on the mechanics of landing during stepping down by the elderly. *Gait Posture,* 22(1), 65-71.

Bunce C, Wormald R. (2006). Leading causes of certification for blindness and partial sight in England & Wales. *BMC Public Health,* 6:58. http://dx.doi.org/10.1186/1471-2458-6-58

Carter, S., Campbell, E., Sanson-Fisher, R., Redman, S., & Gillespie, W. (1997). Environmental hazards in the homes of older people. *Age and Ageing,* 26, 195-202.

CIE TN 003:2015. (2015). Report on the First International Workshop on Circadian and Neurophysiological Photometry, 2013. *CIE Technical Report.*

Cohen-Mansfield J., Werner P., & Freedman L. (1995) Sleep and agitation in agitated nursing home residents: An observational study. Sleep 18, 674-680

Connell, B., & Wolf, S. (1997). Environmental and behavioural circumstances associated with falls at home among healthy elderly individuals. *American Congress of Rehabilitation Medicine and the American Academy of Physical Medicine and Rehabilitation*, 78, 179-185.

De Lepeleire, J., Bouwen, A., De Coninck, L., & Buntinx, F. (2007). Insufficient lighting in nursing homes. *Journal of American Medical Director's Association,* 8(5), 314-317.

Eldred, E.K. (1992) Optimal illumination for reading in patients with age-related maculopathy, Optometry and Vision Science 69 (1992), 46–50.

Ferris F. L, Wilkinson C. P., Bird A., Chakravarthy U., Chew, E., Csaky, K., et al. (2013) Clinical classification ofage-related macular degeneration. Ophthalmology 120:844–51. http://dx.doi.org/10.1016/

Golden R. N., Gaynes B. N., Ekstrom R. D, Hamer R. M., Jacobsen F. M., Suppes T (2005). Reviews and overviews the efficacy of light therapy in the treatment of mood disorders: a review and meta-analysis of the evidence. *Am J Psychiatry,* 162: 656–62.

Grant, M. J., & Booth, A. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information and Libraries Journal, 26*(2), 91–108. http://doi.org/10.1111/j.1471-1842.2009.00848.x

Gupta, P., Zhao, D., Guallar, E., Ko, F., Boland, M. V., & Friedman, D. S. (2016). Prevalence of Glaucoma in the United States: The 2005–2008 National Health and Nutrition Examination Survey. *Investigative Opthalmology & Visual Science, 57*(6), 2905. http://doi.org/10.1167/iovs.15-18469

Hanford, N., & Figueiro, M. (2013). Light therapy and Alzheimer's disease and related dementia: Past, present, and future. *Journal of Alzheimer's Disease, 33*(4), 913–922. http://doi.org/10.3233/JAD-2012-121645

Klein, R., & Chou CF, Zhang X, Meuer SM., (2011). Prevalence of Age-Related Macular Degeneration in the US Population. *Archives of Ophthalmology, 129*(1), 75. http://doi.org/10.1001/archophthalmol.2010.318

Klein, R. (2011). Study finds reduced prevalence of AMD. *Ocular Surgery*, 46–48.

Karpecki, P., (2012) The role of UV damage in ocular disease. *Review of Optometry.* October 2012. Retrieved on 29/4/17 from https://www.reviewofoptometry.com/ce/the-role-of-uv-damage-in-ocular-disease

La Plante MP, Carlson D. Disability in the United States: Prevalence and Causes, (1996) Washington, DC: *Disability Statistics Rehabilitation Research and Training Centre*, Institute of Age and Aging

Lahti, T., Helén, M., Vuorinen, O., & Väyrynen, E. (2008). *AARP Book 3. Lighting Research Center.*

Lam, RW. Beyond seasonal affective disorder: Light treatment for SAD and non-SAD disorders. Washington, D.C.: *American Psychiatric Press,* Inc; 1996.

Liu, Y., Paul, S., & Orchanian, D. P. (2003). Demographic information of falls among community dwelling elderly adults over 65 of age, *Michigan. Medicine & Science in Sports & Exercise, 35*(Suppl.), S334.

Lucas, R. J., Peirson, S. N., Berson, D. M., Brown, T. M., Cooper, H. M., Czeisler, C. A., … Brainard, G. C. (2014). Measuring and using light in the melanopsin age. *Trends in Neurosciences*, 37(1), 1–9. http://doi.org/10.1016/j.tins.2013.10.004

Madsen, H. O., Dam, H., & Hageman, I. (2016). High prevalence of seasonal affective disorder among persons with severe visual impairment. *The British Journal of Psychiatry, 208*(1), 56–61. http://doi.org/10.1192/bjp.bp.114.162354

Magnusson, A., & Boivin, D. (2003). Seasonal Affective Disorder: An Overview. *Chronobiology International, 20*(2), 189–207. http://doi.org/10.1081/CBI-120019310

Margrain TH, Nollett C, Smith DJ. (2012) Depression and vision loss in aging. *Optometry Pract*, 13:77–84.

Melton, R., (2014). The lowdown on blue light: good vs. bad, and its connection to AMD. *Review of Optometry.* February. Retrieved from https://www.reviewofoptometry.com/ce/the-lowdown-on-blue-light-good-vs-bad-and-its-connection-to-amd-109744 on 29/4/17

McCurry SM, Reynolds CF, Ancoli-Israel S, Teri L, Vitiello MV (2000) Treatment of sleep disturbance in Alzheimer's disease. Sleep Med Rev 4, 603-628

Molin J, Mellerup E, Bolwig T, Scheike T, Dam H. (1996) The influence of climate on development of winter depression. *J Affect Disord 37:* 151–5.

NICE. (2013). NICE clinical guideline 161. Falls: Assessment and prevention of falls in older people. *National Institute of Health and Care Excellence,* 161(June), 1–315. http://doi.org/10.7748/nop.26.6.18.e586

Nussbaumer B, Kaminski-Hartenthaler A, Forneris CA, Morgan LC, Sonis JH, G. B., & Greenblatt A, Wipplinger J, Lux LJ, Winkler D, Van Noord MG, Hofmann J, G. G. (2015). Light therapy for preventing seasonal affective disorder. *Cochrane Database of Systematic Reviews,* (11). doi.org/10.1002/14651858.CD011269.pub2.www.cochranelibrary.com

Nyman SR, Gosney MA, Victor CR. (2010) Psychosocial impact of visual impairment in working-age adults. *Br J Ophthalmol,* 94: 1427–31

Paul, S., & Yuanlong, L. (2012). Inadequate light levels and their effect on falls and daily activities of community dwelling older adults: A review of literature. *New Zealand Journal of Occupational Therapy, 59*(2), 39–42

Paul, M., & Dennis Jane, A. (2002). Bright light therapy for sleep problems in adults aged 60+, (2). doi.10.1002/14651858.CD003403

Pelletier, A. L., Thomas, J., & Shaw, F. R. (2009). Vision loss in older persons. *American Family Physician,* 79(11), 963-70.

Perlmutter, M, Bhorade, A, Gordon, M, Hollingsworth, H, Engsberg, JE & Baum, CM. (2013). Home lighting assessment for clients with low vision. American Journal of Occupational Therapy, 67, 674-681. doi: 10.5014/ajot.2013.006692

Peterson, J., Pearce, P. F., Ferguson, L. A., & Langford, C. A. (2016). Understanding scoping reviews: Definition, purpose, and process. *Journal of the American Association of Nurse Practitioners*, 1–5. http://doi.org/10.1002/2327-6924.12380

Philips. (2014). *Backgrounds on Light & Health and description of the HealWell System. White Paper.* Downloaded 29/4/17 from: http://images.philips.com/is/content/PhilipsConsumer/PDFDownloads/Global/ODLI20150416_001-UPD-en_AA-healwell-white-paper-2014-int.pdf

Pfeifer GP, You YH, Besaratinia A. Mutations induced by ultraviolet light. Mutat Res. 2005 Apr 1;571(1-2):19-31. Epub 2005 Jan 20.

Pesudovs K, Elliott DB. (2003). Refractive error changes in cortical, nuclear, and posterior subcapsular cataracts. Br J Ophthalmol 87:964–7. http://dx.doi.org/10.1136/bjo.87.8.96

Reed, R. J., Lowrey, C. R., & Vallis, L. A. (2006). Middle-old and old-old retirement dwelling adults respond differently to locomotor challenges in cluttered environments. *Gait and Posture*, 23, 486-491.

Royal College of Ophthalmologists. (2010). Outcomes and complications. *Cataract Surgery Guidelines*, (September), 60–66. http://doi.org/10.1038/sj.eye.6700282 (accessed 7 May 2017)

Reidy A, Minassian DC, Vafidis G, Joseph J, Farrow S, Wu J, et al. (1998) Prevalence of serious eye disease and visual impairment in a north London population: population based, cross sectional study. BMJ, 316:1643–6. http://dx.doi.org/10.1136/bmj.316.7145.1643

Richter, H. J. (1989). Planning of new and modernization of old lighting system – Demands are rising. Humane Produktion – Humane Arbeitsplatze, 11(1), 16-21

Rohan KJ, Roecklein KA, Haaga DAF. (2009) Biological and psychological mechanisms of seasonal affective disorder: a review and integration. *Curr Psychiatry Rev* 5: 37–47.

Sample PA, Esterson FD, Weinreb RN, Boynton RM. The aging lens: in vivo assessment of light absorption in 84 human eyes. Invest Ophthalmol Vis Sci. 1988 Aug;29(8):1306-11.

Seixas, A., Ramos, A. R., Gordon-strachan, G. M., Aparecida, V., Fonseca, S., Zizi, F., & Jean-louis, G. (2015). Relationship between visual impairment, insomnia, anxiety/depressive Symptoms among Russian Immigrants. *J Sleep Med Disorder,* 1(2), 1–10.

Shaw, F.E.,Kenny, R.A.(1998) Can falls in patients with dementia be prevented? *Age Ageing*, 27, 7-9.

Shikder, S., Price, A., & Mourshed, M. (2010). A systematic review on the therapeutic lighting design for the elderly. *18th CIB World Building Congress CIB W084 - Building Comfortable Environments for All*, pp. 65-79.

Sloan, A. Habel, A, Feiock,K (1973) High illumination as an auxiliary reading aid in diseases of the macula, American Journal of Ophthalmology 76, 745–757.

Sorensen, S., & Brunnstrom, G. (1995). Quality of light and quality of life: An intervention study among older people. *International Journal of Lighting Research and Technology*, 27, 113-118

Taylor HR, West S, Muñoz B, et al. (1992), The long-term effects of visible light on the eye. Arch Ophthalmol. Jan;110(1):99-104.

Valdez, R., Yoon, P.W., Liu, T., & Khoury, M. J. (2007). Family History and Prevalence of Diabetes in the U.S. Population. *Diabetes Care*, 30(10), 2517–2522. http://doi.org/10.2337/dc07-0720.The

Wang C-W, Chan CLW, Chi I (2014). Overview of quality of life research in older people with visual impairment. Adv Aging Res 2014; 3:79–94. http://dx.doi.org/10.4236/aar.2014.32014

West SK, Rubin GS, Broman AT, Muñoz B, Bandeen-Roche K, Turano K. (2002) How does visual impairment affect performance on tasks of everyday life? The SEE Project. Salisbury Eye Evaluation. *Arch Ophthalmol*, 120:774–80. http://dx.doi.org/10.1001/archopht.120.6.774

Wirz-Justice A (2005). Chronobiological strategies for unmet needs in the treatment of depression" *Medicographia* 27 (3): 223–7

Younis N, Broadbent DM, Harding SP, Vora JR. (2002). Prevalence of diabetic eye disease in patients entering a systematic primary care-based eye screening programme. Diabet Med 2002; 19:1014–21. http://dx.doi.org/10.1046/j.1464-5491.2002.00854.x