LIGHTING THE MODERN AGED CARE FACILITY

“Longer, healthier, happier lives...”
At Eagle Lighting Australia we understand that the challenge of lighting the modern aged care facility is in finding aesthetically pleasing and modern luminaires that meet the building’s diverse functional requirements.

With over 80 years’ combined experience and research within the health and aged care sectors, Eagle Lighting Australia (ELA) and Fagerhult have a reputation for designing luminaires around the people using the space; in this case the staff, customers and families of those working at, living in and visiting the aged care facility.

In this brochure we present a range of lighting solutions based around common room types that meet or exceed the lighting demands of an aged care facility. These luminaires include a choice of aesthetics resulting in a wide range of high quality, low energy solutions.

We also look at some of the research examining the relationship between light, well-being and health; an important relationship to consider within the modern aged care sector that seeks to foster longer, healthier, happier lives.

We look forward to discussing with you how Eagle Lighting Australia can provide lighting solutions for your aged care project.
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BEDROOM / EN-SUITE
The less the residents’ circadian rhythm is disturbed, the better the conditions are for their sleep and general well-being. It is important, therefore, that residents receive sufficient light - natural or artificial - during the day and are not exposed to intense light during the night. Amber night lights, especially in bathrooms, should be considered as standard.

DAY ROOMS
A multiple-use space where stimulating colours and good lighting design are essential, regardless of the time of day.

This is the resident’s place to socialise and relax with friends and family. The room requires balanced lighting to make it feel bright yet welcoming; indirect light makes the room bright whilst suspended luminaires over tables helps to create a more intimate feel without compromising the room’s brightness and ambient light.

ADMIN
Good lighting in the office contributes to a positive work environment where everyone feels comfortable and motivated. It is important that the luminaires selected are designed for visual comfort and to avoid glare for screen work.

Accent lighting on the walls helps the eye to take in more vertical light in order to stimulate the circadian system whilst also contributing to an increased feeling of space.
CORRIDORS
A welcoming and bright environment makes residents, staff and visitors feel relaxed and at home. Badly positioned or glaring lights can create or worsen discomfort.
In corridors lighting controls, such as eSense Move or OR Technology, make sure that adequate light levels are resumed when someone walks in, day or night.

KITCHEN
Adequate and properly designed lighting is essential in commercial kitchens to create an area that is as free from glare and unwanted reflections as is practicable. Light fittings should be designed and installed in a way that facilitates cleaning. Fittings should be generally recessed or surface mounted on ceilings to avoid them becoming a source for contamination.

OUTDOOR / CAR PARKS
The area around the facility entrance has both a welcoming and a guiding function. It is important that visitors are able to quickly recognise where entrance doors are and that stairs, ramps, and direction signs are well lit.
The road from bus stops and parking lots up to the Aged Care facility should stay on at all hours. Pole top fixtures provide good general light, while lower bollard’s facilitate orientation on walkways and sidewalks. Facade lighting accentuates the building and softens the transition between the outside and inside. Wall and ceiling fixtures create a comfortable vertical light and accentuate the signage.
THE VITAL ROLE OF LIGHTING IN AGED CARE

The important balance between darkness and light

Our circadian rhythm controls our alternation between sleep and wakefulness, and is primarily controlled by light. The human circadian rhythm has a period of approximately 24 hours, and to keep this rhythm undisturbed it is important that the balance between light and dark be maintained.

All light—not just sunlight—can contribute to the alignment of an organism’s circadian rhythm to the external rhythm of its environment. Given that people today spend much of their waking day indoors, insufficient illumination or improper lighting design can lead to a drift of the circadian phase, especially if paired with inappropriate light exposure at night.

More alert staff and faster healing

Several international studies conducted in health care show that increased levels of natural light gives a more positive work environment and makes nursing staff feel better [1]. Other research says that nurses residing in daylight at least 3 hours per day feel less stressed than do those not exposed to as much daylight [2].

The availability of daylight in the morning hours, along with the day and night cycles, are key factors for maintaining circadian rhythms. For health care professionals who work day shift light can therefore contribute to increased alertness and better sleep quality at night [3].

In the same way, a disturbed circadian rhythm affects residents’ comfort and well-being. Lack of sleep stresses residents, weakens the immune system and can lead to respiratory problems and disturbances in body temperature [4].

SUMMARY

• Sleep is important for well-being.
• Light controls our circadian rhythm.
• Light make us feel better and facilitates healing.
• Daylight reduces pain and minimises the need for drugs.
• Light reduces depression.
• Right light levels reduce the risk of errors in medication.
In addition, research also suggests that an amber night light not only facilitates a good night’s sleep but also measurably enhances our cognitive functions later during the day.

A joint study by Lund University and Fagerhult [5] investigated the effects of dynamic ambient lighting on the elderly. The study involved one experiment group and one control group in a retirement home in Sweden. Glare-free LED luminaires with indirect light were used in the control rooms. The lighting control system automatically adjusted the light levels to maintain circadian rhythms. The results revealed that the experiment group had [5]:

- Higher alertness during the day
- Better sleep quality
- Reduced feeling of drowsiness
- Reduction in fall incidents.

**Lower risk of inaccurate dosing**

A good working light is important for all professions, but the managing of advanced technology and medicine sets increased requirements in aged care. A European study of hospital pharmacies shows that the risk of incorrect mixing ratio was 37 percent higher at light levels from 450 to 1000lux on the working surfaces. When the light level was increased to 1500lux the pharmacists made far fewer mistakes [9]. [NB: lighting levels quoted here refer to European standards]

**References:**

A large part of the information is taken from a Swedish report "The Good Ward", a final report from Program for Technical Standard (PTS Forum) and the Centre for Healthcare Architecture, Chalmers 2011.

1. Verderber and Reuman, 1987; Mroczek et al., 2005.
5. Govén et al, 2015
8. Walch et al., 2005.

**Suppressing depression**

Research has shown that light, be it daylight or bright artificial light, suppresses depression. Research results also say that light therapy is effective and that it can in some cases achieve results that are comparable to those obtained with antidepressant drugs [6]. Other studies have found that depressed patients recover better in rooms with more daylight [7].

**Reduced pain and consumption of painkillers**

A study carried out with surgical patients compared patients in areas with a higher level of natural light with patients who had rooms on the shadow side of the same building. Patients who got more daylight experienced less pain and lower stress levels. In addition, they took 22 percent less painkillers, thus reducing overall expenditure on drugs [8].
Introduction

At Eagle Lighting Australia we are committed to designing and manufacturing luminaires, using the best available technology, that give the utmost priority to human well-being and the environment. This makes it necessary that we closely follow, learn, apply and share the latest advances in lighting technology as well as in the relevant fields of research such as vision, neuroscience, circadian biology and colour science.

Accordingly, this overview is intended to update the reader on some of the non-visual effects of light (and lighting) on our circadian rhythms – currently a very active area of research.

There are numerous biological mechanisms in the human body, interactions and neural pathways that we still know little about. The work for quantifying the non-visual effects of light on the human body clock is progressing rapidly but is currently far from complete and the existing metrics/standards may be due for revision or may even become obsolete with new ones and new standards replacing them in the near future.

What has already been well established, though, is that the quality, intensity and timing of light that one is exposed to can have tremendous effects on one’s well-being. It is now becoming increasingly clear that there is almost no health related condition that is not made worse, if not created, by inadequate lighting.
Circadian Rhythms and Melanopic Light

General

All living organisms on Earth exhibit circadian rhythms; these are biological cycles that repeat themselves on a daily basis and are regulated and/or entrained by environmental signals (cues), the most important one being the natural, 24-hour, light-dark cycle [1].

The suprachiasmatic nuclei (SCN) in the hypothalamus host the master circadian clock that organises and orchestrates the timing of all daily biological functions, from complicated physiological systems to single cells. The SCN in humans have, on average, an intrinsic period slightly greater than 24 hours (24.18 hours on average) that is modulated by the temporal pattern of light and dark on the retina. As a result of the earth’s rotation on its axis, the temporal pattern of light and dark on the retina synchronises the SCN to a matching 24-h period.

Recent research has demonstrated that disruption of the natural, 24-h pattern of light and dark from rapid flight across time zones or from rotating shift work can lead to a wide variety of maladies, from poor performance and sleep loss to higher stress, weight gain, depression, increased smoking, cardiovascular disease, Type 2 diabetes and even breast cancer. Because it is increasingly evident that retinal light and dark exposures can profoundly affect human health and well-being, it is increasingly important to be able to quantify both light and dark as stimuli to the human circadian system [2, 3].

Circadian rhythms are kept in sync by various cues (“zeitgebers”), including light responded to by intrinsically photosensitive retinal ganglion cells (ipRGCs), the melanopsin expressing, non-image forming photoreceptors in the eye [4]. Through ipRGCs, light in short wavelengths (the 480-490nm blue region) promotes alertness, while the lack of this stimulus signals the body to reduce energy expenditure and prepare for rest.

All light—not just sunlight—can contribute to circadian photo-entrainment. Given that people today spend much of their waking day indoors, insufficient illumination or improper lighting design can lead to a drift of the circadian phase, especially if paired with inappropriate light exposure at night.
The Circadian Response Curve

The melanopsin-containing photoreceptors are the primary photoreceptors for non-visual responses to light, although these photoreceptors also receive input from the rod and cone photoreceptors. The sensitivity curves of each photoreceptor in the human retina are shown in Fig. 1 below:

Recent findings suggest that cone photoreceptors contribute identically to non-visual responses at the beginning of a light exposure and at low irradiance, but that melanopsin dominates the response to long duration light exposures and at high irradiances. During exposure to continuous light, melanopsin containing photoreceptors drive sustained responses to light, but the relative contribution of cone photoreceptors to non-visual responses decreases over time [6].

The action spectrum of light for the circadian system is shifted towards shorter wavelength (blueish) light relative to that of the visual system, which is maximally sensitive to (~555nm) “green” light. As a result, humans are not well equipped to self-report the presence or intensity of circadian-effective light based on visual perception [7].

The circadian spectral efficiency curve (C(λ)) in Fig. 2 is based on the melanopic spectral efficiency function developed by Enezi et al. and Lucas et al. [8,9].

It is clear from Fig. 2 that daylight has very good spectral intensity levels where the C(λ) curve peaks. This is expected since the evolution of the circadian system has been directly shaped by the spectrum of sunlight.
One could cite 6 key factors in relation to circadian lighting:

- **Duration**
  How long? Work ongoing.

- **Timing**
  When? Work ongoing.

- **Thresholds**
  Circadian-effective illuminance levels. Work ongoing.

- **Distribution**
  Angular position

- **Photonic History**
  The effects of exposure up to a number of hours prior to circadian-effective lighting. Wavelength dependent. Work ongoing.

- **Composition**
  Spectral composition of the light as experienced by the occupant, not necessarily the SPD of the light source(s) but with, for example, the modifying effects of the wall colours taken into account

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**Effects of Disruption**

Although there are still many open questions as to the details of the underlying mechanisms, it has been established that the effect of short wavelength light (both wavelength and intensity) on our circadian system is vitally important for maintaining our health. In fact, it is now becoming clearer that there is almost no disease or health condition that is not made worse by long term light-induced disturbance on the circadian system.

Inside buildings, where adults spend 87% of their lives on average [7], lighting is often provided by electrical sources that are adequate for performance of visual tasks (i.e., stimulation of the visual system), but can lack the appropriate spectral composition and intensity required to stimulate the circadian system. Any zones within a building that do not regularly achieve the lighting conditions necessary for effective circadian stimulus can be labeled as biologically dark, and considered as zones where sustained occupancy over extended time periods (e.g. regular workday schedules) may present a risk for disruption of the circadian system in the absence of supplemental electrical lighting capable of effective circadian stimuli.

Inadequate environmental light exposure can cause free-running circadian rhythms. People with normal vision in their mid-twenties free-run at room illuminances under 200 lux or even 80 lux. Astronauts (37–43 years of age) become free-running at typical space shuttle illuminances below 80 lux, producing circadian disruption, poor sleep quality and neuro behavioural performance decrements [10].
One interesting fact should be noted here: Most totally blind individuals have abnormal or free-running circadian rhythms, but some visually blind individuals retain ipRGC photoreception [10]: These individuals have circadian rhythms that are in sync with normal day/night cycles.

Sunlight’s importance is underscored by seasonal and weather-related neuropsychological disorders that would not occur if indoor lighting were sufficient for all neurobiological needs. Midwinter insomnia affects up to 80% of certain populations at higher latitudes. Over 90% of people have some mood reduction during sporadically overcast weather or seasonal decreases in daylight length or intensity. Seasonal affective disorder (SAD) causes disabling depression, hyper-somnolence and weight gain during the autumn and winter in approximately 10% of the population. Non-seasonal depression is also closely associated with reduced light exposure [10].

**Quantifying and Metrics**

For the above reasons, it is very important to develop a metric enabling us to quantify and communicate the levels of non-visual stimuli caused by light. The CIE joint technical committee (JTC 9) is currently working on “quantifying ocular radiation input for non-visual photoreceptor stimulation”, that is, melanopic light.


The term “melanopic” refers to a new photometric measure of light intensity as weighed by the sensitivity of the melanopsin-containing ipRGCs.

Melanopic Ratio is one measure (as there are others) of how effective a given spectrum is in its ability to stimulate a melanopic response in humans through the melanopic photoreceptor channel, starting from the ipRGCs. The axons of the ipRGCs belonging to the retinohypothalamic tract (RHT) project directly to the suprachiasmatic nuclei (SCN), the Master Clock, via the optic nerve and the optic chiasm.

The mechanism of SCN is cell-autonomous, and is duplicated in “slave” clocks in nearly all the cells of the body [13]. The SCN receive and interpret information on environmental light, dark and day length, which is important in the entrainment of the “body clock”. They can coordinate peripheral “clocks” and direct the pineal gland to secrete the hormone melatonin [14]. Each day the light-dark cycle resets the internal clock, which in turn, synchronises the physiology and behaviour controlled by the clock [5].

Melatonin signals time of day and simultaneously provides potent antioxidant and numerous other beneficial effects [10].

Fig.4 Below shows the clear relation between melanopsin suppression/phase shift and illuminance:

![Fig.4 Illuminance-response curve of the human circadian pacemaker (from [15]): A: Melanopsin phase shift vs. illuminance, B: Melanopsin suppression vs. illuminance.](image)
Figure 5 above shows some of the important relations in the circadian system, with the capital letters below providing explanatory notes:

**A.** A network of photosensitive retinal ganglion cells (ipRGCs), which also receive input from rods and cones, are maximally sensitive to blue light between 470 and 480 nm.

**B.** These cells have direct connections to the central circadian oscillator in the SCN where depending on the time of day (circadian time, CT) light induces changes in gene expression.

**C.** ipRGCs also mediate the synchronisation to LD cycles of locomotor activity, and light-induced phase shifts.

**D.** ipRGC connections (to the olivary pretectal nucleus) mediate light-sensitive pupil constriction.

**E.** Indirect input via the SCN regulates the light-sensitive suppression of melatonin production in the pineal.

**F.** The ipRGC network has direct connections to sleep regulatory structures such as the VLPO (ventrolateral preoptic nucleus) and thereby modulates sleep and the ECoG (electrocorticographic activity) during wakefulness.

**G.** Blue light can modify brain responses to an executive task.

**H.** It can improve alertness during the morning, lunch time, and early evening.

Note that, although probably more well-known due to its adoption in the WELL standard [4], the Melanopic Ratio is not the only metric available in attempting to assess the non-visual effects of light:
Several researchers have proposed alternative models of the spectral sensitivity of the circadian system that can be used to relate the SPD from various light sources to objective and subjective stimulus effects [7]:

The model developed by Rea, Figueiro et al. [17] is based on published studies of nocturnal melatonin suppression using lights of various SPDs. The model relates a given SPD to a Circadian Stimulus (CS) effect from 0% (no effect) to 70% (maximum suppression level achievable after 1-hour) characterizing the relative effectiveness of the source as a stimulus. The model can be applied to convert various light sources to units of Circadian Lux (CLA) for relative comparison using a publicly available circadian stimulus calculator [18] that can be accessed on http://www.lrc.rpi.edu/programs/lightHealth/.

The model developed by Andersen et al. [19] is based on both night-time [20] and daytime [21] studies and “sets a tentative lower and upper bound for the likelihood that a given light exposure will have an effect on alertness,” with a linear ramp-function applied to interpret intermediate values. The upper and lower bounds of the model can be converted into the standard photometric unit of illuminance (lux) using the approach described in Pechacek et al. [22] for any SPD of interest by applying a conversion factor.

Finally, Amundadottir et al [23] have developed a framework to describe the circadian effectiveness of light that can be explored using an online calculation and visualization tool [24] available at http://spektro.epfl.ch/.

The framework incorporates dose-response models of melatonin suppression, melatonin phase shift, and perceived alerting effect, enabling users to predict and compare the biological effect for various light source SPDs. The framework incorporates a lens transmittance model [25] and requires the user to specify the age of the observer to account for the relative loss in retinal exposure due to age.

In relation to the subject, Inanici et al [26] developed a simulation procedure to more accurately compute the spectral content of light for the purpose of analysis using circadian lighting indicators such as EML. The procedure is implemented in a free software tool (Grasshopper plugin) entitled “Lark Spectral Lighting” which can be used by designers to obtain point-in-time calculations of EML [27]. The tool is available at http://faculty.washington.edu/inanici/Lark/Lark_home_page.html.

### Designing for Circadian Stimulus

When it comes to designing for circadian light, researchers recommend [1] that one should:

- Request the SPD of the light sources under consideration, and be careful not to rely exclusively on their CCTs.
- Design for vertical (≈ corneal) illuminance \( (E_V) \) at the eye, not just horizontal illuminance \( (E_H) \) on the workplane.
- Choose luminaires that provide the best \( E_H \) to \( E_V \) ratio. The optimum types of luminaires for this purpose are, in general, the direct-indirect ones.
- Bear in mind that light level and spectrum are two sides of the same coin: Lower light levels will achieve relatively lower CS values unless compensated for by an SPD with more power at shorter wavelengths.
- All-day light matters too. While morning light is important for circadian entrainment, light at other times can elicit an acute alerting effect from people, which may not be the desired outcome. People should not be kept in darkness at any time of day. But if the space is also being used in the evening, its lighting system should be dimmed or its SPD should be adjusted to emit less CS (Circadian Stimulus).
- Carefully consider who will be occupying the space. Lighting control schedules for schools will be different from those for nursing homes, for example, because children tend to be night owls and older adults tend to be larks.
- Think about layers of light. In cases where site specific design restrictions prevent CS targets from being met, saturated blue (e.g., peak wavelength = 470 nm) LEDs can be used to boost CS.
The WELL Standard

The International WELL Building Institute has recently developed a building certification system with the stated objective of, “measuring, certifying and monitoring the performance of building features that impact health and well-being”. The EML contribution value is one of the mandatory (“precondition”) benchmarks in the WELL Standard, meaning that designs must meet the circadian-related requirements, among others, as described in the standard in order to obtain certification [4].

At present, there is no consensus for the appropriate minimum light exposure threshold to ensure effective circadian stimulus in buildings, or for the duration at which the effects of light exposure saturate [7]. According to the approach in [12] melanopic ratio multiplied by the vertical illuminance level gives the equivalent melanopic lux (EML) value. The WELL Building Standard’s Circadian Lighting Design precondition (Option 1) implements a minimum threshold of 250 EML (equivalent to 226 lux from D65), which must be available for at least 4 hours each day and can be provided at any point during the day. As noted previously, this requirement can be met with daylight, electrical light (exclusively), or a combination of both sources. The 250 EML threshold and 4-hour exposure requirement currently implemented in the WELL Building Standard are based on best judgments derived from recent studies [15, 28] and should be expected to be refined as the relationships between spectral distribution, duration, timing, and intensity of light exposure for optimal circadian health are further clarified by the research community. For comparison, Figueiro et al recommend exposure to a CS of 0.3 or greater at the eye for at least 1 hour in the early part of the day (equivalent to 180 lux, D65) [29].

Finally, past history of light exposure (photic history) has an effect on sensitivity of the circadian system to light [30]: Higher levels of light exposure during the day cause the sensitivity of the circadian system to decrease over time, and lower exposure levels causes sensitivity to increase. A detailed review of the parameters that control the response of the circadian system to light can be found in Amundadottir et al [31].

Clearly, the EML is directly, but not solely, dependent on a luminaire’s spectrophotometric performance, i.e., both the spectral composition and beam properties have an impact on the resulting EML contribution. Building and lighting design parameters such as luminaire spacing, orientation, additional layers of lighting, ceiling height, window locations, workstation locations, room reflectances and even furniture have effects on results.

In other words, it is generally not possible to talk about the WELL standard compliance of a luminaire in isolation since it is the combined result of the building design, lighting design and interior design as well as the luminaire itself that will, or will fail to, comply. In many cases the luminaire “contributes” to securing WELL points but cannot itself guarantee compliance. [32]
Aged-Care Related

Adequate lighting, in addition to environmental illumination, is inversely correlated with insomnia and depression, both of which increase with ageing. Chronic sleep disturbances affect 40–70% of elderly populations. Chronic insomnia and depression are closely associated. Up to 30% of older populations have depression, which, like insomnia, frequently goes undiagnosed. Insomnia and depression are significant risk factors for cancer, diabetes, cognitive deficiences, dementia, cardiovascular disease and premature mortality. Reduced circadian amplitudes are also associated with higher risks of cancer and other diseases. Bright light (≥2500 lux) particularly from bluer sources such as outdoor daylight can reduce or eliminate insomnia and depression; immediately increase brain serotonin, mood, alertness, and cognitive function [10].

Young adults in industrialised countries typically receive only 20–120mins of daily light exposure exceeding 1000 lux. Elderly adults’ bright light exposures average only 1/3 to 2/3 that duration. Institutionalised elderly receive less than 10mins per day of light exposure exceeding 1000lux, with median illuminances as low as 54 lux. The declining bright light exposure of many older adults combined with their reduced retinal illuminance due to pupillary miosis and crystalline lens yellowing places them at risk for retinal ganglion photoreception deficiency, possibly contributing to age-related insomnia, depression and cognitive decline [10].

The Aging Eye

Particularly important for Aged-Care facilities is the fact that in specifying any (circadian) threshold levels, the age of the occupants is an important consideration, as the relative level of light reaching the retina decreases due to age [7]: The pupil dynamics and lens opacity can change with aging, corneal light exposure may be quite different from retinal light exposure in older subjects [33]. See Fig.6.

Reduced retinal illuminance - The retina receives less light as one ages because pupil size becomes smaller (senile pupillary miosis) and the crystalline lens becomes thicker and more absorptive. [34]

Reduced contrast and colour saturation - The crystalline lens becomes less clear and, as a result, begins to scatter more light as one ages. This scattered light reduces the contrast of the retinal image. This effect also adds a "luminous veil" over coloured images on the retina, thus reducing their vividness (saturation). Reds begin to look like pinks, for example. [34]

Reduced ability to discriminate blue colours - The older eye loses some sensitivity to short wavelengths (blue light) due to progressive yellowing of the crystalline lens. [34]

The visual system is often characterized as “young” until it reaches about 40 years of age. After that, normal changes to the aging eye become more noticeable as visual capabilities decrease. [34]

Reduced retinal illuminance - The retina receives less light as one ages because pupil size becomes smaller (senile pupillary miosis) and the crystalline lens becomes thicker and more absorptive. [34]

Reduced contrast and colour saturation - The crystalline lens becomes less clear and, as a result, begins to scatter more light as one ages. This scattered light reduces the contrast of the retinal image. This effect also adds a “luminous veil” over coloured images on the retina, thus reducing their vividness (saturation). Reds begin to look like pinks, for example. [34]

Reduced ability to discriminate blue colours - The older eye loses some sensitivity to short wavelengths (blue light) due to progressive yellowing of the crystalline lens. [34]

![Fig.6](From [35], the blue line added later to denote the melanopsin sensitivity peak) Age related losses in retinal illumination due to decreasing crystalline lens light transmission and pupil area.

It is possible that in older individuals with ocular problems (e.g., cataracts), light transmission to the circadian pacemaker could be altered, which in turn could further reduce their responsiveness to moderate levels of light, and even reduce their response to bright light [33].
The Aging Circadian System

There is a difference in the degree of melatonin suppression between the older and young subjects’ responses to light [33]: The melatonin suppression data suggest that there may be an age-related change in the light transmission system between the SCN and the source of plasma melatonin (pineal gland). Alternatively, there may be a pathway from the retina to the SCN or other hypothalamic target that is involved in the acute cessation of melatonin production, but not in entrainment, and this pathway may be selectively affected by aging.

The changes include smaller phase shifts in response to light, a smaller range of entrainment, greater light levels necessary for stable entrainment, and changes in the rate of re-entrainment. These reductions at the whole animal level may be due to observed age-related changes in the response to light at the cellular level in the SCN, including a higher threshold for cellular responses and/or decreased response to light. There is also evidence that age-related structural changes in the circadian and/or visual systems may contribute to a reduction in light sensitivity, including reduced light transmission through the eye (especially of shorter wavelengths), and a reduction in the number of circadian photoreceptors [33].

A change in the photic sensitivity of the human circadian timing system might manifest as a change in sleep patterns. Some reports suggest that older individuals living in their home environments receive lower levels of light exposure and fewer minutes of bright light exposure per day than do young adults, although not all studies agree on this [33].

The Risks and the Benefits

Institutionalized elderly have been reported to receive even less bright light than healthy elders, and there is also an association between daytime light exposure and night time sleep quality and consolidation in both institutionalized and healthy older people with exposure to greater amounts of daytime light associated with better night time sleep quality. A recent study comparing light exposure between young and middle-aged subjects found that while the daily exposure to different levels of light did not differ with age, the pattern of light exposure across the day was different. Timed artificial light exposure has been shown to improve sleep maintenance insomnia in community-dwelling older people, and increasing the duration and strength of daytime lighting has been reported to be associated with greater night time sleep consolidation and improved sleep efficiency in institutionalized elders [33].

As mentioned previously in this document, an illuminance level of 80–200 lux does not prevent free-running with its adverse consequences in 25-year-olds. This means that even much higher illuminances would be inadequate for older people with their declining crystalline lens transmittance and smaller pupil area. Residential illuminances are much lower than those needed to prevent free-running in older adults, typically averaging only 100 lux. This light level is very dim compared with natural outdoor lighting [10].

Together, these reports suggest that reduced light exposure levels and/or a decreased sensitivity to light with aging might contribute to age-related increases in sleep disruption and the age related alteration in the phase relationship between sleep timing and the timing of the biological clock that have been reported previously.

It has been widely believed that attenuation of short-wavelength light by the aging lens could lead to diminished non-visual light responses (e.g., pupillary light responses, melatonin
suppression, and circadian entrainment). This is because non-visual light responses are mediated by ipRGCs that contain the short-wavelength sensitive photopigment melanopsin. It has been estimated that the amount of 480-nm light that can pass through the lens in late adulthood (80-year-old lens) is less than a third relative to childhood [35, 36 and 37]. This age-dependent reduction in short-wavelength light reaching the retina has been hypothesized to contribute to reduced circadian responses to light and sleep disturbances [36].

The study in [36] tested the hypothesis that older individuals show greater impairment of pupillary responses to blue light relative to red light. Irrespective of wavelength, pupillary responses were reduced in older individuals and further attenuated by severe, but not mild, cataract. Interestingly, the reduction in pupillary responses was comparable in response to blue light and red light, suggesting that lens yellowing did not selectively reduce melanopsin-dependent light responses. Compensatory mechanisms likely occur in aging that ensure relative constancy of pupillary responses to blue light despite changes in lens transmission [36, 38].

Alzheimer’s disease (AD) patients exhibit random patterns of rest and activity rather than the consolidated sleep/wake cycle found in normal, older people. Light treatment has been shown to improve rest and activity rhythms and sleep efficiency of AD patients, presumably through consolidation of their circadian rhythms.

Two independent studies show that 30 lux at the cornea of blue light (\( \lambda_{\text{max}} = 470 \, \text{nm} \)) from LEDs for 2 h in the early evening improved sleep efficiency of older adults, including those with AD, compared to exposure to the same dose of red light [39].

It must be noted, in relation to aged-related reduced circadian responses, that these deficits will be underestimates if ipRGC populations decline with ageing as do those of non-photoreceptive retinal ganglion cells. Additional reductions in ipRGC photoreception may occur if ocular light transmission is decreased further by factors such as ethnicity, iris pigmentation, reduced corneal clarity, cataract or sunglass usage. Cataract surgery, for instance, provides older adults with more youthful circadian photoreception [10].

For an aged-care facility, the research results cited mean that:

- Independent of the spectra, all light levels need to be adjusted for reduced light reception capabilities.
- Short wavelength light (blue region), the necessary stimulus for the circadian system, although no more affected than longer wavelengths, is still affected and the levels need to be adjusted.
- Where possible, the lighting designer should collaborate with building/interior designer to take into account room surface colours including the floor and the walls as well as furniture, window glazing sizes (ratios) and window orientation.
- The use of a climate-based modelling approach to take into account the geographical location and the realistic daily/seasonal changes to the natural light levels and spectra would be ideal.

Note that the latter two bullet items should apply for general indoor lighting as well.
Amber light

Dual Benefits

Benefit-1: Non-Interference

The benefit of using amber light as a night light is two-fold: The first and more intuitive benefit is its non-interference with sleep patterns: The typical orange/amber LED emits in the region of 590-600nm which lies away from the melanopic region of 480-490nm. So the long wavelength light from an amber LED light source would not cause melatonin suppression at night which, otherwise, would disrupt a person’s sleep or prevent the person from going to sleep due to an increase in alertness, causing a shift in the circadian phase.

Benefit-2: Photic Memory and Improved Cognitive Function

The second benefit is related to the “photic memory” of the non-image-forming part of our photoreception system [40]:

The fact that the human circadian system has a “memory” and that it adapts to prior history of light exposure is not new [30]: Previous studies have shown that light history affects the suppression of melatonin in response to a subsequent light exposure. It was also shown in [30] that “very dim light history, as opposed to a typical indoor room illuminance, amplifies the phase-shifting response to a subsequent sub-saturating light stimulus by 60–70%”.

However, the connection between the photic history and cognitive functions is quite new: Evidence supporting the role of melanopsin in the facilitation of cognitive processes has been only indirect [41] until recently.

A recent study [40] published in the Proceedings of the National Academy of Sciences by Sarah Chellappa and her colleagues at the University of Liège in Belgium and the French Institute of Health and Medical Research in France provides support for the hypothesis that melanopsin is indeed involved in our capacity to remember things in the short term [41].

Melanopsin exists in two different states; a photosensitive or ‘active’ state and a photo-insensitive or ‘passive’ state. Long-wavelength light (i.e. orange/amber) triggers the transformation of melanopsin from the photosensitive state, while shorter wavelengths (i.e. blue) do the opposite. This means that orange/amber light increases the amount of ‘active’ melanopsin units in the retina while blue light increases the number of ‘inactive’ units.

Chellappa and her colleagues used this information to try to understand whether melanopsin did indeed influence cognitive brain function. If so, exposure to orange/amber as opposed to blue light would increase performance of cognitive tasks because a larger proportion of photosensitive melanopsin would be present in the retina [41].

To test the effects of different light wavelengths on cognitive function, the researchers exposed 16 participants to 10mins of blue or orange/amber light (Fig.7). The volunteers were subsequently blindfolded for a period of 70mins and then asked to perform memory tasks while in a magnetic resonance imaging (MRI) scanner, which allowed the scientists to see what parts of the brain were stimulated while the participants performed the tests. The MRI scans showed that, compared with blue light, pre-exposure to orange/amber light had a significantly higher impact in several regions of the prefrontal cortex and other regions of the brain crucial for the regulation of cognition, arousal and even emotional processes [41].

Fig.7 Experimental runs in [40]. A: Single run enlarged. B: All three consecutive runs.
According to the results of the study,

1. Light specifically activates brain regions (such as the prefrontal cortex) involved in executive functions and improves cognitive task performance;

2. The degree of activation depends on the spectral quality of a pre-exposure to light one hour earlier, with long wavelength orange light producing the most significant increase in brain activity in these cortical regions and short wavelength light inducing a relative decrease compared to orange light pre-exposure [42]

3. The current findings are also consistent with Vandewalle’s previous study [43], demonstrating that in blind humans – that is, those lacking rods and cones but presumably with functional melanopsin – light stimulates brain activity during a cognitive task [42].

4. The study demonstrates that melanopsin participates in memory and cognitive functions, and considering these diverse functions, melanopsin may play the broadest functional role of any photopigment in the mammalian retina [42].

One difficult challenge is to reconcile the optimal lighting for biological effects or for visual perception. It must be recalled that melanopsin is a basically blue light-sensitive photopigment, even though prior light exposures to orange light increase this response [42].

(Recent rodent and human data suggest that exposure to longer wavelength light (590–620 nm; amber/orange) increases the photosensitivity of ipRGCs. Conversely, exposure to shorter wavelength light (~480 nm; blue) decreases the photosensitivity of ipRGCs [44, 45]).

In contrast, photopic sensitivity for visual perception is maximal in (greenish) yellow light. Thus, future lighting schemes must take into account this dual function of the retina to increase or decrease visual and non-visual functions according to the desired outcome. Finally, our retinal light detection systems have evolved under, and are therefore adapted to, sunlight spectral and intensity changes occurring throughout the day. It thus seems obvious that use of natural light should also be an essential part of domestic and commercial lighting design [42].

Although more research is required, the results mentioned above suggest that melanopsin is involved in the facilitation of cognitive processes and that the impact of light on cognition rises with orange/amber light by increasing the ‘active’ state of the photopigment [41].

The findings emphasize the importance of light for human cognitive brain function and constitute compelling evidence in favour of a cognitive role for melanopsin and support the idea that the integration of light exposure over long periods of time can help optimize cognitive brain function.

Based on experimental results and some unique properties (the dual states) of melanopsin, the impact of a given test light on cognitive brain responses would be increased, decreased, or intermediate after prior exposure to longer, shorter, or intermediate wavelength light, respectively.

In other words, the brain dynamics required to perform cognitive tasks are influenced by prior light exposure, presumably by melanopsin dependent ipRGCs intrinsic photosensitivity.

Therefore, not only does incorporating an amber component in a night-time light fitting facilitate a good night’s sleep but can also measurably enhance our cognitive functions later during the day.
THE IMPACT OF A DYNAMIC AMBIENT LIGHTING SYSTEM ON THE WELL-BEING OF ELDERLY LIVING IN A RETIREMENT HOME

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Introduction

In Europe, the number of elderly is growing fast. An estimation says that the number of people older than 65 years will be 25% of the total population 2050. Elderly people often have difficulties staying outdoors, especially when they live in a retirement home. It is also a well established fact that this group needs more light in order to fulfill visual tasks. However, recent research has shown that the non-visual effects of light needs to be taken into account in relation to elderly.

The circadian system of elderly is affected due to the fact that the ageing eye leads less light to retina, the number of neurons on the retina and in the suprachiasmatic nuclei (SCN) is reduced, and there are also changes on the molecular level of the SCN, all factors that lead to a lower sensitivity to light.

The aim of the present study was to investigate if ambient dynamic lighting in the home of the elderly has a positive effect on alertness, arousal and sleep during night. Furthermore, the authors wanted to examine if the glare-free improved ambient lighting also had a positive visual effect.

Method

A longitudinal study with one experiment group and one control group were studied at a department of a retirement home in the south of Sweden. The experiment group consisted of 5 subjects (3 women 2 men, mean age 90 yrs.) and a control group of 5 women out of which only 3 completed the study, mean age 91.7).

All subjects were relatively healthy without signs of senile dementia. The subjects lived in single-room apartments. All rooms were identical in the layout and orientated in a north-south direction with windows either to the east or to the west.

In the control rooms all existing light sources were shifted to LED retrofit lamps. In the experiment rooms a specially designed wall-mounted luminaire was installed together with a new luminaire in the entrance hall.

The special luminaire was equipped with LED modules of 3000K with a CRI of 80 and SDCM of 3. The light distribution was indirectly towards the ceiling with a smaller proportion towards the wall. The luminaire was completely glare-free.

A control system was used to automatically adjust the light to set the circadian rhythm in accordance with the individual non-visual needs: It increased the light in the morning, reduced the amount of light during the afternoon and completely turned off in the evening (see Fig 1).

Physiological and psychological measurements were conducted at three consecutive occasions (September, December and March), with first occasion as a baseline.
Results

The results revealed that during the darkest period of the year the experimental group displayed a higher alertness over the whole day with a peak before lunch. The quality of sleep was also better for the experiment group; they tended to wake up less during the night. Furthermore, the experiment group seemed to feel less drowsy during daytime than their counterparts in the control group. A final result on the individual level was that the experiment group had less severe fall incidents. Only one of the five subjects had an incident, while two out of the three in the control group (see Figs 2-5).

It is worth mentioning that all subjects in the experiment group wanted to keep the new dynamic lighting system after the study was completed.

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2. Lund University, Lund, Sweden

THE RESULTS PROVIDE

• An indication that a brighter indoor environment can have a positive effect on people living in retirement homes regarding alertness and sleep quality.
• The experiment group seemed to feel less drowsy during the daytime than the control group.
• The experiment group had less severe fall incidents.

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PRODUCTS BY ROOM TYPE

We have identified a selection of key room types with solutions for each that meet the varied demands of the aged care environment. Contact your local ELA representative to discuss these and other lighting solutions.

**BEDROOM**

- Discovery Evo
- Aluflex Medica (With Amber)
- WL2
- Aureled (With Amber)
- Bells LED

**EN-SUITE**

- V-Series (Type fixed 2)
- Monitor LED (With Amber)
- Aqua LED

**DAY ROOM**

- Aureled Vista
- Dino Classic
- Dino Apollo
- Dino Ring
- Scoot
- Sweep
- Gaudi Linear
- Globia LED
### ADMIN
- Vertex
- Aureled Flow
- Enviro Evoline
- Indigo Maestro Delta
- Multifive LED
- DTI LED type 2

### CORRIDOR
- Beetle
- Wallwing
- Fasett
- D63-Wall
- V-Series (Type fixed 3)
- Pleiad Wallwasher G3
- Pleiad G3 Comfort
- Gondol LED

### KITCHEN
- Vertex
- Cleanroom LED IP44
- Allfive LED

### OUTDOOR
- Evolume 1
- Vialume
- Densus LED
- QuadEvo
- Duomo
- Cool Applique
- Minicolumn
- Talos Wall
References:


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33. Decreased sensitivity to phase-delays of moderate intensity light in older subjects Jeanne F. Duffy, Jamie M. Zeitzer and Charles A. Czeisler.

34. The aging how - how does vision change as one grows older? Healthcare AARP, LRC, Rensselaer Polytechnic Institute http://www.lrc.rpi.edu/programs/lightHealth/AARP/healthcare/lightingOlderAdults/agingEye.asp.


42. Thanks for the memories: Plant-like photopigment in the eye may play key role in human cognitive brain function March 25, 2014, Stuart Mason Dambrot, Medical Xpress.


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