White paper

The role of lighting in promoting well-being and recovery within healthcare

PHILIPS

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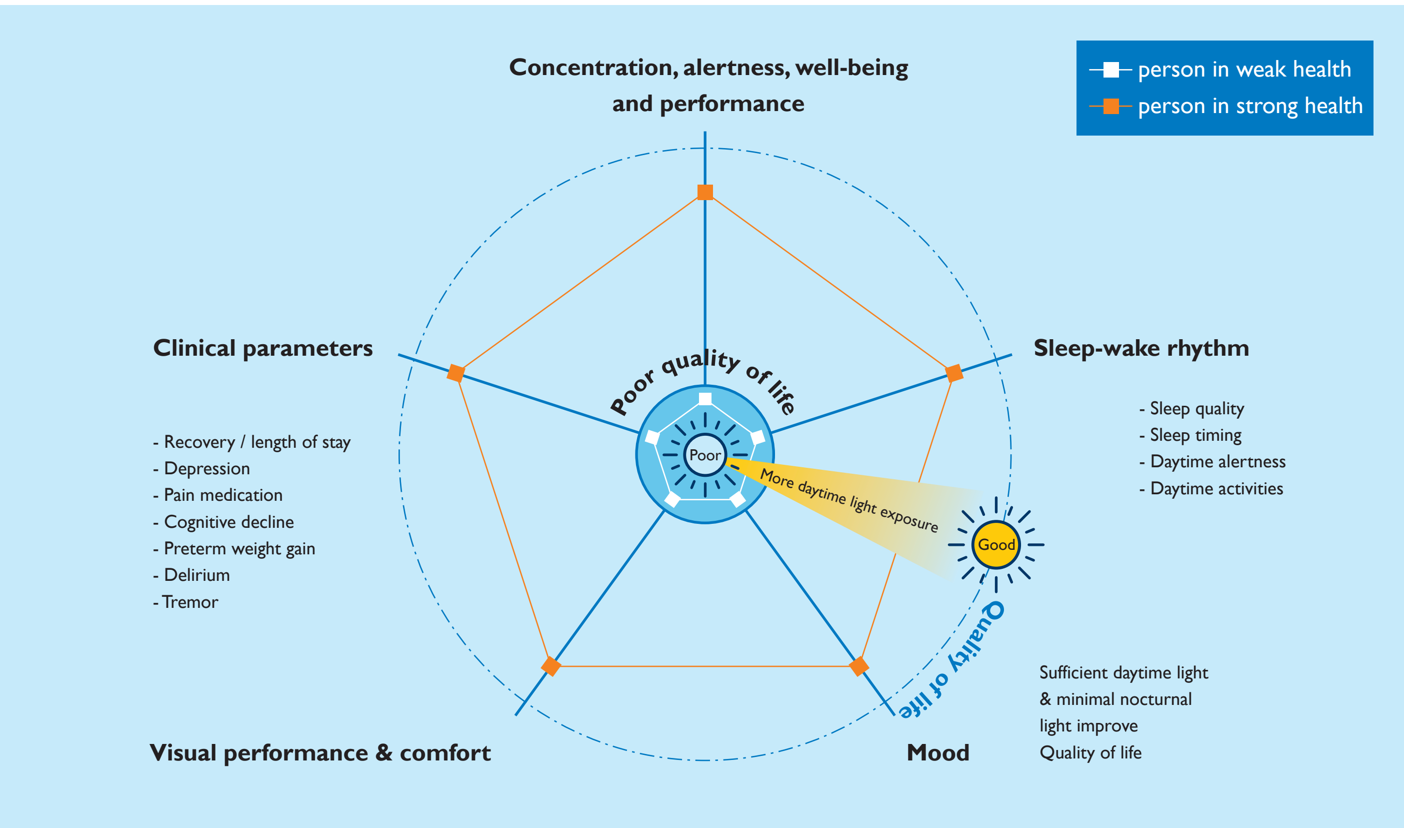
Contents

Summary

Light affects human beings in a variety of ways – visually, (photo-)biologically and psychologically. In healthcare facilities it can play a key role in promoting the recovery and well-being of patients. There is a clear correlation between daytime light exposure and the patient's perceived quality of life. The more time spent in daylight, or in daylight-like artificial light, the better the patient's visual performance and comfort, mood, sleep-wake rhythm, concentration, alertness and performance. Clinical parameters such as recovery/length of stay, depression, pain medication and cognitive decline are likewise positively influenced by adequate daytime light exposure. There is also strong evidence that light – critical to human functioning – can be extremely beneficial to staff in healthcare settings as well as patients.



1 Introduction

Light is a fundamental part of life. Mankind has evolved under the ebb and flow of daylight and darkness. Light gives us the natural rhythm of day and night, determines how we see things, and brings our world to life. Accordingly, it has a major impact on our sense of well-being, our emotions and our functioning.

The notion that a well-balanced and attractive environment is of major importance to patients' health is not new. Florence Nightingale observed: "Little as we know about the way in which we are affected by form, by colour and light, we do know this, they have an actual physical effect. Variety of form and brilliancy of colour in the objects presented to patients are an actual means of recovery." (Nightingale 1888)

This paper aims to show how light and lighting affect people – visually, biologically and emotionally – and how, deployed effectively in healthcare facilities, they can promote patient recovery.

> "Niels Finsen received the Nobel Prize for Medicine in recognition of his contribution to the treatment of diseases, especially the disfiguring disease lupus vulgaris, with concentrated light radiation (Finsen 1903). The beneficial effects are due to a bactericidal as well as a general stimulating effect on the tissues. He used the most refractive rays from the sun, either by concentration on a particular area or employed as general sun-baths, which on Finsen's suggestion was tried in cases of tuberculosis. As is well known, the latter treatment has been found to be excellent in places where the sun is rich in chemical rays, e.g. in the Alps where the absorption of these rays by the atmosphere is rather limited."

'Towards Light' by the artist Rudolf Tegner (1873-1950) in Copenhagen; commemorates Nobel Prize winner Niels Finsen (1860-1904) for his scientific work proving the healing powers of sunlight.

2 Effects of light

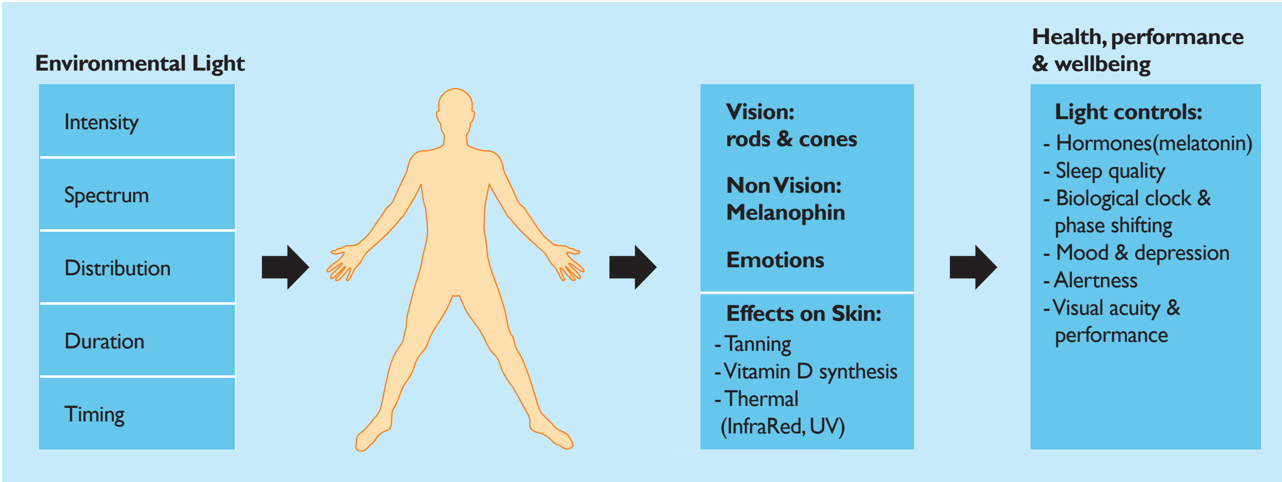


Fig 1
Vision, psycho-emotional responses and non-visual or non-image forming effects together affect performance, well-being and health.

2.1 Visual effects of light

The visual effects of lighting have been studied for over 500 years. For more than 150 years, scientists considered rods and cones to be the only photoreceptor cells in the eye. These photoreceptor cells regulate the visual effects. When light reaches them, a complex chemical reaction occurs. The chemical that is formed creates electrical impulses in the nerve that connects the photoreceptor cells with the visual cortex at the back of the brain. In the visual cortex the electrical impulses are interpreted as 'vision'.

The rods operate in extremely low-level light situations and do not allow colour vision. The cone system is responsible for sharpness and detail as well as colour vision. The sensitivity of the cone and rod systems varies with varying wavelength of light, and thus with varying colour of light.

Fig 2
Spectral sensitivity of rods, cones and the recently discovered melanopsin photoreceptor in the eye

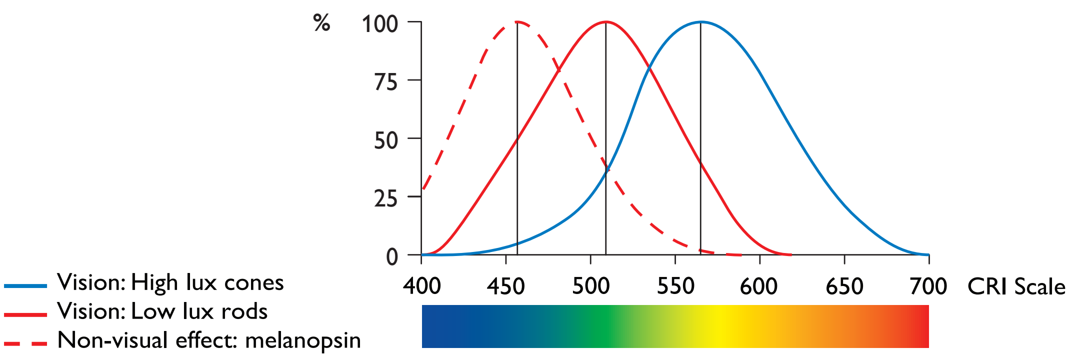
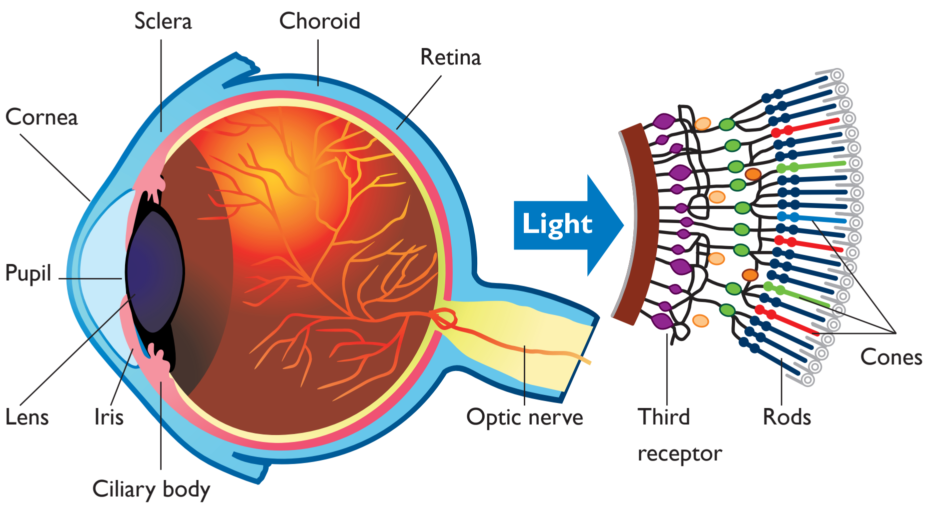


Fig 3
Location of the various kind of photoreceptors in the retina.



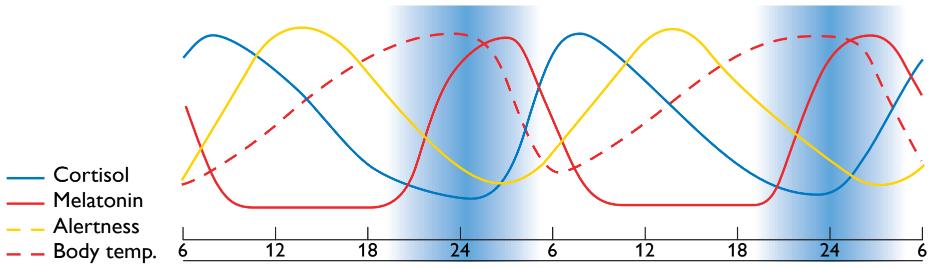
2.2 Biological effects of light

In recent decades we have learned a lot about the non-visual or non-image-forming (NIF) effects of light; some of these NIF effects are indicated in fig 1 above. These effects are, at least partially, mediated by a novel photoreceptor that resides within a cell type in the retina of the eye (Berson et al 2002). It is referred to as melanopsin and it regulates the biological effects of light. It is most sensitive to blue light (peak sensitivity at 480 nm (Hankins et al 2008)). When ocular light (light perceived with the eyes) reaches these melanopsin-containing photoreceptor cells, a complex chemical reaction occurs, producing electrical impulses which are sent via separate nerve pathways to our biological clock, which in turn regulates the circadian (daily) and circannual (seasonal) rhythms of a large variety of bodily processes, including the production of some important hormones essential for a healthy sleep/waking pattern.

> "All functions in the human body are influenced by the rhythm of night and day. Research has shown that we not only have receptors in our eyes which are sensitive to the visible spectrum of light. There are also receptors which cause a biological effect: the production of the hormones melatonin and cortisol. While melatonin makes us sleepy and relaxed, cortisol makes us feel awake and active. This is why we sleep at night, get jet lag when we change time zones, and why our general feeling of well-being varies over the day."
>
> Prof. W. van Bommel, Philips Lighting Research Center, Eindhoven

The hormones cortisol (often referred to as the "stress hormone") and melatonin (the "sleep-promoting hormone" that is produced during nocturnal darkness) play an important role in regulating alertness and sleep. Cortisol, amongst others, increases blood sugar to give the body energy and suppresses the immune system (N.B. This action is not favourable: in the long term stress reduces our resistance). Cortisol levels increase in the morning, the natural morning cortisol peak preparing the body for the coming day's activity. In addition, the level of the sleep-promoting hormone melatonin drops in the morning. Both signals act to reduce sleepiness. Melatonin levels normally rise again in the evening when it becomes dark, enabling healthy and consolidated sleep[1]. Disruption of the circadian rhythm of melatonin or cortisol production has negative effects on the quality of sleep and consequently the ability to perform and our overall sense of well-being.

Fig 4
2 x 24-hour graph of selected circadian rhythms



This diagram illustrates some typical circadian (i.e, 24-hour) rhythms in human beings. The figure shows only a few examples: core body temperature, alertness, and the hormones cortisol and melatonin.

Our biological clock controls our biorhythm, and under natural conditions light synchronises our internal body clock to the earth's 24-hour light-dark rotational cycle. Without the regular 24-hour light-dark cycle, our endogenous circadian rhythm – our internal body clock – would be autonomously running, with its own period. The period of the internal clock is precise and intrinsic personal property that varies from person to person. The average period in humans is about 24.2 hours (Czeisler et al 1999), slightly slower than the natural light-dark cycle. Without resetting by light, even this small discrepancy would produce recurrent periods during which our body physiology (melatonin/cortisol/core body temperature) would tell our body that it was time to sleep during the day and to be awake at night. This situation can be compared with jetlag during transmeridianal travel and is associated with negative effects like fatigue, headache and reduced performance and well-being. Some blind people are known to report these phenomena periodically (Lockley et al 1999, Skene et al 1999).

The biological effects of light extend much further than visual effects only and mean that good lighting has a positive influence on health (Riemersma-van der Lek et al 2008), well-being (Partonen & Lonnqvist 2000), alertness (Campbell et al 1995, Phipps-Nelson et al 2003), and even on sleep quality (Campbell et al 1993, Viola et al 2008, Mishima et al 2001).

2.3 Photobiological effects of light through skin

Daylight also has photobiological effects through the skin. Examples being the ultraviolet radiation from the sun and the production of vitamin D associated with it (Holick 2004), and the thermal effects of infrared radiation. Vitamin D prevents rickets, it is reported to be necessary for calcium metabolism and a healthy skeleton. It has a large influence on a range of functions such as maintaining the immune system and preventing osteoporosis (Holick 2005).

[1] Dijk et al, 1997

There appears to be a protective relationship between sufficient vitamin D status and lower risk of cancer (Garland et al 2006). Vitamin D is also available through the diet, either in fatty fish, fortified food or as supplements. For healthy individuals, sufficient vitamin D status is readily achieved through exposure to natural sunlight.

2.4 Psychological effects of light

The psychological effects of light are related to the attractiveness, atmosphere and ambience of the environment (light intensity, intensity distribution, dynamic aspects, light colour and colour distribution within the field of vision) and they affect our mood, feelings, motivation and emotions.

- Visual
- Biological
- Psychological

Effects of light impact our:

- Perception
- Performance
- Moods and emotions
- Overall health and well-being

2.5 Full spectrum lamps vs broad spectrum lamps

Full spectrum fluorescent lamps are said to mimic the spectral qualities of daylight. They emit light in all parts of the visible spectrum and some in the UVA regions (320-400 nm), have a correlated colour temperature above 5000 K and a Color Rendering Index (CRI) of at least 90. For daylight the color rendition is optimal and the CRI scale reaches it's maximum of 100. Conventional fluorescent lighting in workplaces usually has a CRI of 80 or above. The scientific literature does not support the claims that full-spectrum fluorescent lamps can dramatically improve physical or mental health, as compared to other light sources. Widespread adoption of these more expensive and less energy-efficient light sources is unwarranted (McColl & Veitch 2001).

2.6 Effects on staff wellbeing

Hospital lighting should not only meet the patient's personal needs and comfort. It also has to support bed-side activities like nursing care, housekeeping, and medical examinations. Preferably examination lighting is glare-free with minimal "light spilling", simultaneously preventing annoying shades on the task.

Moreover, hospital lighting should permit rapid and correct evaluation of the patient's health status as judged from visual inspection of the color or condition of the patient's skin, eyes or tissue. It is important that medical staff can detect the onset of cyanosis upon visual observation reliably. Cyanosis is a state where the oxygen levels in the blood are dangerously low. It can be diagnosed from the bluish discoloration of the skin. Hereto, the lighting should have adequate output in the red part of the visible spectrum, particularly above 600 nm where the difference in spectral transmittance between oxyhaemoglobin and reduced haemoglobin becomes maximal (Midolo & Sergeyeva 2007). In Australia a special cyanosis observation index has been introduced to assess this quality [AS/NZS 1680.2.5:1997, Interior lighting, Part 2.5: Hospital and medical tasks, Standards Australia, 1997].
Usually, the color-rendering quality of a lamp is described by the CIE general colour-rendering index CRI. For most workplaces, standards recommend to use lighting with a CRI of 80 or above. However, for special hospital areas it may be worth to consider applying lighting with an CRI value of at least 90. This will render medical tasks that require good colour discrimination (dermatological investigation, blood drawing, locating veins, etc.) more easy.

3 Light(ing) and patient well-being and recovery

As we have seen above, light impacts human health and performance by enabling excecution of visual tasks, controlling the body's circadian system, affecting our mood and perception, and enabling critical chemical reactions in the body.

Light is key to human functioning as it enables us to see things and perform activities. However, it is also important as it affects us physiologically and psychologically. A number of studies have noted the importance of light in reducing depression (Tuunainen et al 2004), decreasing fatigue (Terman et al 1995), improving alertness (Phipps-Nelson et al 2003), modulating circadian rhythms (Burgess et al 2003), and treating conditions such as jaundice among infants (Ebbesen et al 2003).

Several very interesting literature reviews have emerged in the area of light, health and performance in recent years (Bommel & Beld 2004, Ulrich et al 2004, Joseph 2006).

3.1 Enabling performance of visual tasks

Light's most obvious effect on humans is in enabling vision and the performance of visual tasks. Studies (Boyce et al 2003) demonstrate that the nature of the task – as well as the quantity, spectrum, and distribution of the light – determines the performance level that is achieved, and that the need for light increases as a function of age due to reduced transmittance of aging eye lenses (Brainard 1994, Lerman 1983, van de Kraats & van Norren 2007).

The need for light increases as a function of age. With increasing age the eye lens transmittance changes. The lens becomes more scattering and yellow.

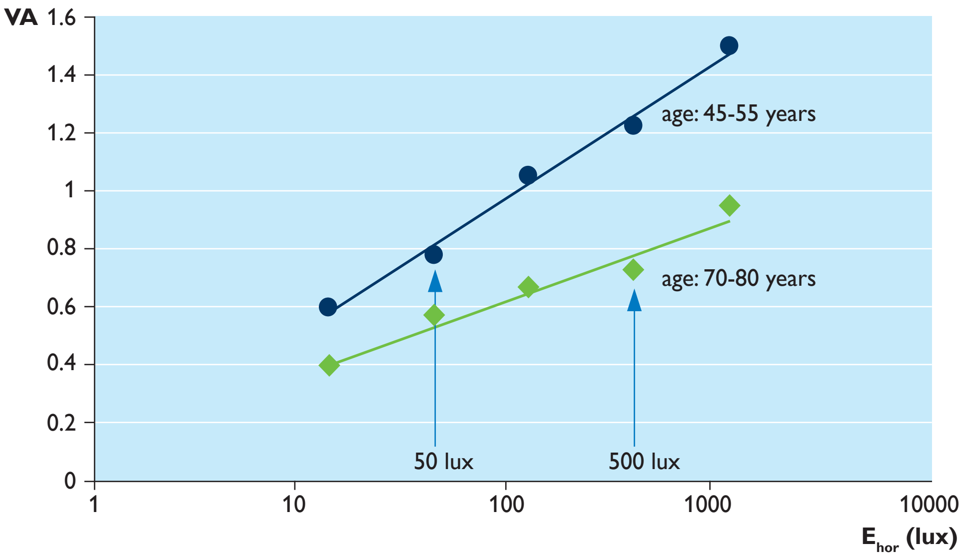
Visual task performance

- General task performance improves with increased light levels
- The light required for the perfromance of a given visual task increases with age

Visual performance can be evaluated through visual acuity measurements with Landolt ring charts or other characters. In general, visual acuity increases with increasing illuminance. This is especially relevant for the more aged part of the population (Sagawa et al 2003). Elderly people (70-80 years) need about ten times more light to achieve the same visual performance as compared to middle-aged people (45-55 years) (Geerdinck et al 2009). Today's lighting standards do not take the increased light need of aged people into account. Many elderly people report to be forced to stop playing cards or doing needlework due to poor sight. In many cases this is unnecessary, as extra light would have improved their visual performance, thus enabling them to remain engaged in social activities longer.

Fig 5

Visual acuity (VA) as a function of illuminance (Ehor) for two different age group. In order to achieve the same visual acuity, 70-80 year-old people need about 10 times more light as compared to people aged 45-55 (Geerdinck et al 2009).



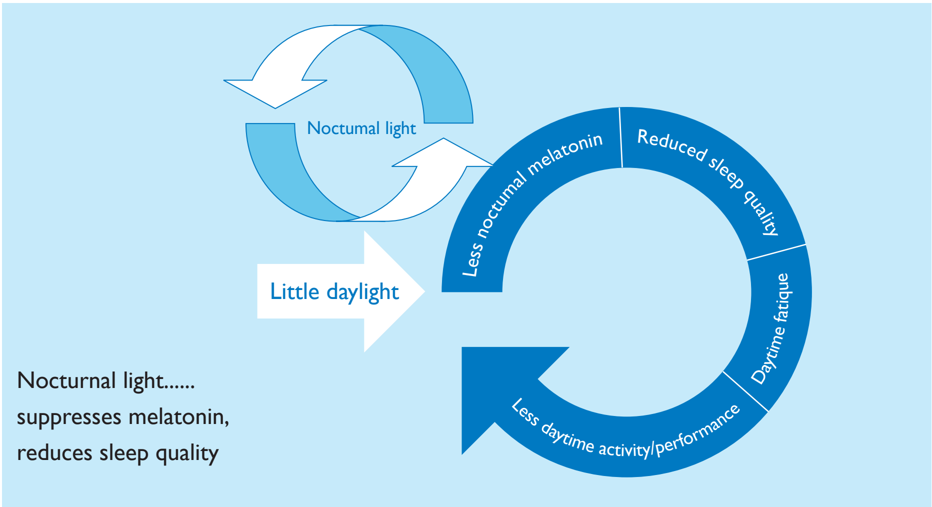
3.2 Controlling the body's circadian system

By controlling the body's circadian system, light – both natural and artificial – influences many health outcomes, e.g. by reducing depression, improving sleep and circadian rest-activity rhythm, easing pain and shortening the stay in the healthcare facility.

Fig 6

Schematic diagram showing how the lack of daylight can reduce sleep quality

Improving sleep and circadian rhythm with light



Poor sleep quality has a major impact on our physical and psychological health. Many problems are associated with poor sleep, such as cardiovascular disorders, impaired functioning of the immune system (Benedict et al 2007) and increased food intake (Spiegel et al 2004). Sleep disorders also have a negative impact on our quality of life, such as impaired cognitive, psychological and social performance, leading to feeling down, nervous and anxious.

Disturbed sleep can affect personal well-being and impede the rehabilitation and recovery of older people from illness (Ersser et al 1999). Greater quality of well-being is known to be associated with greater sleep satisfaction (Jean-Louis et al 2000). Subjective well-being is highest for sleep durations of 7-8 hours and decreases at sleep durations below 6 and above 9 hours (Yokoyama et al 2008).

Circadian timing affects almost all life's processes. It keeps all our cells and tissues working under a tight temporal regimen – and it determines when we sleep.

Several studies have found that timed exposure to artificial bright light might help improve sleep (Van Someren et al 1997) and circadian rhythms (Mishima et al 2001). In one study, community-dwelling older adults exposed to either bright white light or dim red light on 12 consecutive days experienced substantial changes in sleep quality (Satlin et al 1992). Waking time within sleep was reduced by an hour, and sleep efficiency improved from 77.5% to 90%, without altering time spent in bed.

In the case of shifting circadian rhythms, circadian phase needs to be estimated in order to time light or melatonin administration treatments appropriately (Dijk et al 1995, Lewy et al 1998). Circadian phase indicates the status of our internal body clock at a given external time, by indicating how many hours before or after the core body temperature minimum our internal body clock is. Inappropriately timed bright light and exogenously given melatonin will likely worsen a patient's condition.

Morning light exposure:

- increases cortisol levels, reducing morning drowsiness
- advances the endogenous circadian rhythm: sleep timing is advanced and it becomes easier to get up (earlier) the next day

Evening light exposure:

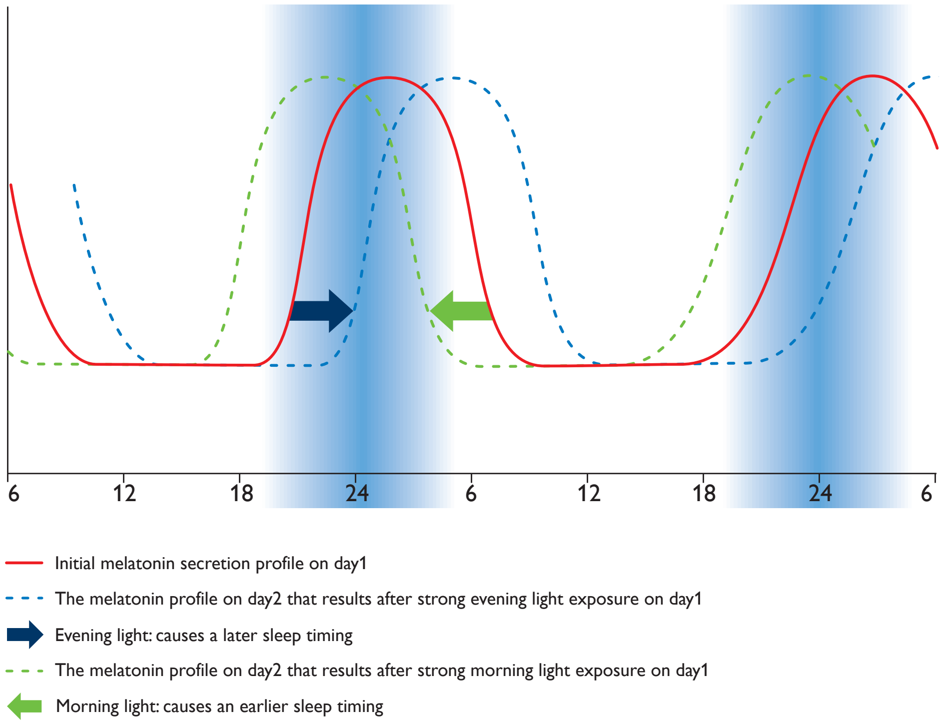
- delays the endogenous circadian rhythm: sleep timing is delayed and it becomes easier to stay up (later) and rise later the next day

Nocturnal light exposure:

- reduces melatonin levels
- increases alertness

Fig 7

Effects of light exposure on the melatonin secretion. At the beginning of the night light exposure causes a phase delay (blue dashed line) and in the early morning hours light causes a phase advance (dotted green line) in the circadian rhythm.



Light therapy has been successfully applied for Delayed Sleep Phase Syndrome (DSPS) (Terman et al 1995, Rosenthal et al 1990), Advanced Sleep Phase Syndrome (ASPS), non-24-hour sleep phase syndrome, the displaced sleep of shift work (Eastman et al 1994) and jetlag (Boulos et al 1995, Samel & Wegmann 1997, Burgess et al 2003), and the sleep-wake problems of senile dementia (Terman & Terman 2005).

Early morning exposure to light increases cortisol levels, thus reducing morning drowsiness (Scheer & Buijs 1999) / (Leproult et al 2001) / (Thorn et al 2004, Avery et al 2002).

Strength of circadian rhythm is associated with quality of life, age and clinical outcome

Increasing age is associated with progressive deterioration in the structure, 24-hour distribution and quality of sleep (Morgan et al 1998, Bliwise 2005). In general, the endogenous circadian rhythm declines over age, as indicated by the levels of both melatonin and cortisol that decline with age (Sharma et al 1989, Van Cauter et al 2000, Van Cauter et al 1996). Moreover, elderly people like to go to bed earlier compared to younger people (Roenneberg et al 2004). The nocturnal level of melatonin in elderly people can be boosted by daytime illumination (Mishima et al 2001), thus strengthening the endogenous circadian rhythm.

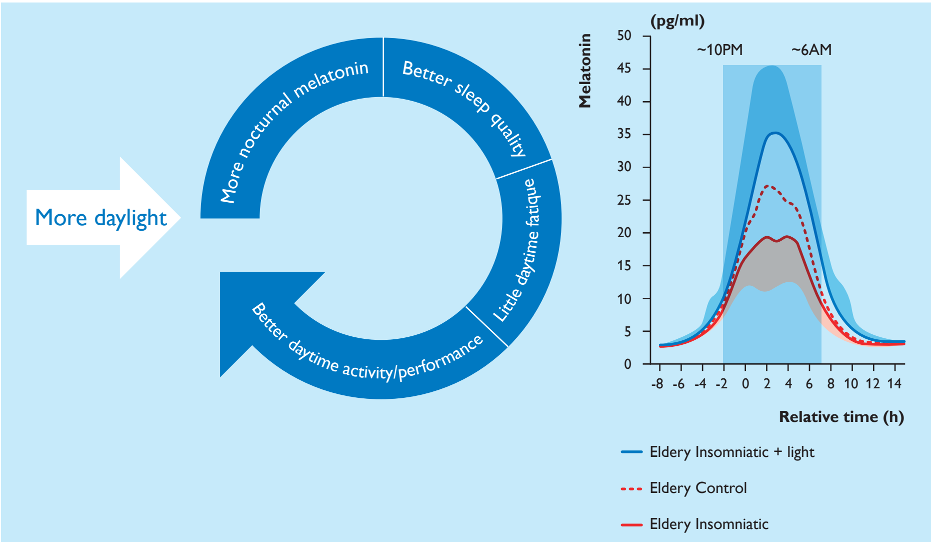
Elderly people need 3 to 5 times more light for the same visual performance compared to younger people (Sagawa et al 2003). In many cases, elderly people live in conditions with insufficient illumination, forcing them to stop activities due to inadequate visual performance. Extra illumination is needed to keep the elderly engaged in activities like playing cards, needlework, reading, etc. This is beneficial for their social engagement, quality of life and can have a positive influence on sleep and the strength of their endogenous circadian rhythm.

The circadian rhythm in physical activity appears to be a prognostic factor for cancer patients' survival and tumour response after chemotherapy (Mormont et al 2000). It also appears to be an indicator of quality of life (Innominato et al 2009). Patients with a more marked rhythm at the start of chemotherapy feel and respond better and survive longer.

Strengthening the endogenous circadian rhythm by providing sufficient daytime illumination and activities can be expected to be of clinical relevance.

Fig 8

Schematic diagram showing how daytime light exposure improves sleep and daytime activity levels



Daytime light stimulates nocturnal melatonin and ameliorates sleep in eldery insomniatics

Pre-term/neonatal infants

For many years continuous lighting was considered necessary for surveillance of all infants in intensive and medium-care facilities. Under continuous lighting (n=9) no differences in activity, respiration rate or heart rate were found between night and daytime (Blackburn & Patteson 1991). For cycled lighting (n=9, lights off any time between 4 p.m. and 12.26 a.m., lights on any time from 6-9 a.m.) there were significant differences for heart rate and activity level (Blackburn & Patteson 1991).

A comparison between groups indicated heart rate to be significantly lower in the cycled lighting group, both during the daytime and during the evening/night hours. During the evening/ night hours, activity was significantly lower for the cycled group (lights off at night) as compared to the continuous group (lights on). In addition, infants in the cycled lighting group tended to have longer periods of inactivity and quiescence similar to quiet sleep. These effects are due to the cycled lighting and the associated environmental changes. Providing an environment that supports an infant's emerging organization and behavioural integration enhances the ability of the infant to respond appropriately to his or her parents and to cope with the home environment after discharge.

Three studies show that providing cycled lighting (reduced light levels in the night) in neonatal intensive-care units results in improved sleep and weight gain among pre-term infants (Blackburn & Patteson 1991, Mann et al 1986, Miller et al 1995).

In one study, 41 pre-term infants in structurally identical critical care units were provided with either cycled or non-cycled lighting (constant light levels during the day and night) during a lengthy hospital stay (Miller et al 1995). Compared to infants in the non-cycled lighting condition, infants assigned to the cycled lighting condition had a greater rate of weight gain, were able to be fed orally sooner, spent fewer days on the ventilator and on phototherapy, and displayed enhanced motor coordination.

Improving quality of life for the demented: reducing nocturnal restlessness, depression and cognitive decline

Among the elderly, chronic sleep disturbance – if left untreated – impairs quality of later life, inhibits recovery and rehabilitation following illness (Ersser et al 1999) , and increases the risk of falls and depression (Leger 1994, Livingston et al 1993). Older people, both at home and in institutional settings, are also the most likely to receive – and are most vulnerable to – hypnotic drugs (Whalley 2001). In this age group, these drugs are associated with risks of diminished daytime functioning, falls, dependence, and rebound insomnia on withdrawal (Dinges & Kribbs 1991, Morgan et al 1998, Morgan 1998, Busto et al 2001, Martin 2002). Among the very elderly, poor sleep quality and hypnotic drug use have been repeatedly shown to exacerbate frailty and cognitive impairment (Whalley 2001, Glass et al 2005). There is a clear need to provide effective non-pharmacological approaches to sleep management. Light exposure is one example of such a non-pharmacological treatment.

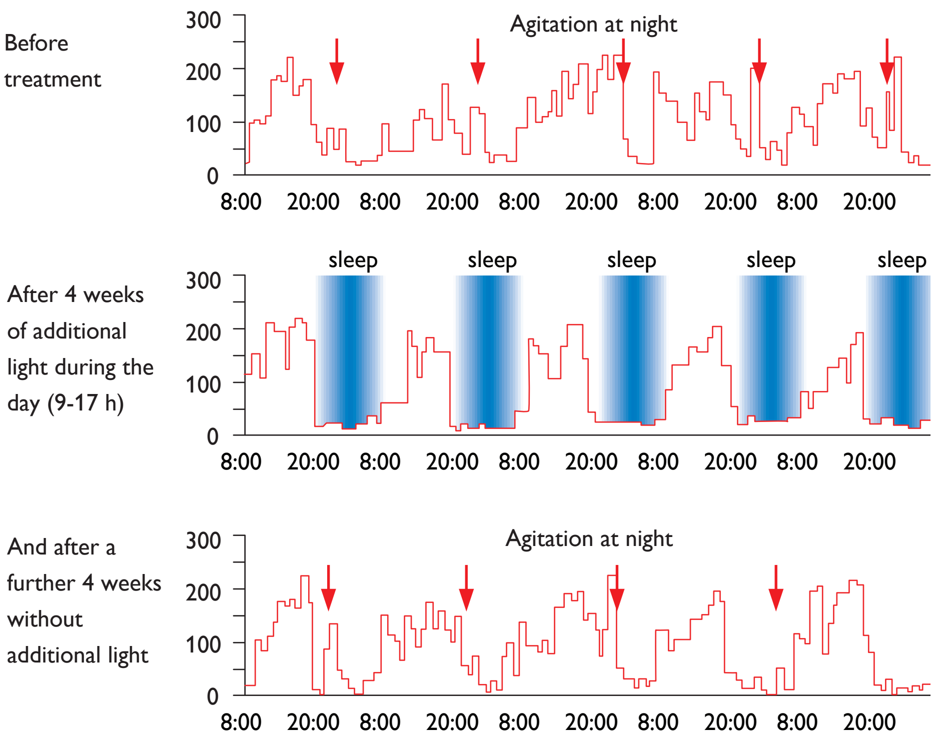
As the population gets older, the number of people suffering from memory impairment increases. Memory impairment is the most obvious symptom of dementia, which eventually precludes leading lead a normal life. It is often accompanied by depression and agitation (restlessness) at night.

Dementia may be associated with impairment of the biological clock. As they age, people spend less time outdoors, so their biological clock receives less light stimulation. Elderly people with dementia living in a nursing home experience a reduction in exposure to daylight of 2000 lux or above from a few hours per day to just one hour, or even as little as 1.6 minutes (Campbell et al 1988, Shochat et al 2000). Moreover, elderly eyes are less clear, which means that less light reaches the retina, which itself has also deteriorated.

In 1997, Dr Eus van Someren (Netherlands Institute for Neuroscience) studied elderly people suffering from dementia. The light intensity was increased from an average of 400 lux to 1100-1200 lux. Consequently, agitation at night was greatly reduced and a much more stable sleeping/waking pattern was obtained (see figure 8 below). More recent studies also indicate that the development of Alzheimer's disease can be slowed down by means of light therapy (Riemersma-van der Lek et al 2008). This treatment resulted in reduced cognitive decline (5%), ameliorated depressive symptoms (19%) and attenuated the increase in functional limitations (53%).

Fig 9

Beneficial effect of light therapy during the day on the sleeping/waking pattern of an elderly dementia patient. During the periods with more light, the patient sleeps longer and more deeply and there are fewer periods of agitation at night. This was assessed on the basis of physical activity, measured with a movement sensor worn on the wrist. The measurements covered five days (Someren et al 1997).



Daytime light exposure:

- improves sleep
- increases daytime activities
- strengthens the endogenous circadian rhythm
- decreases length of stay in hospitals
- lessens agitation among dementia patients
- eases pain

Due to natural aging effects like pupil size reduction (Winn et al 1994), a decreasing lens transmittance (van de Kraats J. & van Norren 2007) and the degradation of visual neurons (Adrian 1993), people at higher age need more light to see as compared to younger people (Sagawa et al 2003, Geerdinck et al 2009). Moreover, seniors are more sensitive to glare and are more bothered by brightness contrasts. In many cases the provision of extra light can compensate for the age-related decrease in visual performance (CIE 1997). As shown in figure 5, in later life vision benefits from extra light exposure, provided this is offered in a glare-free manner (NSVV Committee on Light and Health 2006). Extra daytime light allows seniors to see better and to remain engaged in social activities longer. This is beneficial for their sleep quality, but also delays the functional or cognitive decline that is associated with increasing age during later life.

3.3 Affecting our mood

Daylight – the form of light with which we are most comfortable – is never constant. It changes throughout the day and over the seasons, affecting our emotions, moods, perception and performance.

In the absence of incident daylight, artificial lighting with daylight-like dynamics can be used to create a natural lighting ambience that has a positive stimulating effect on patients.

Reducing depression

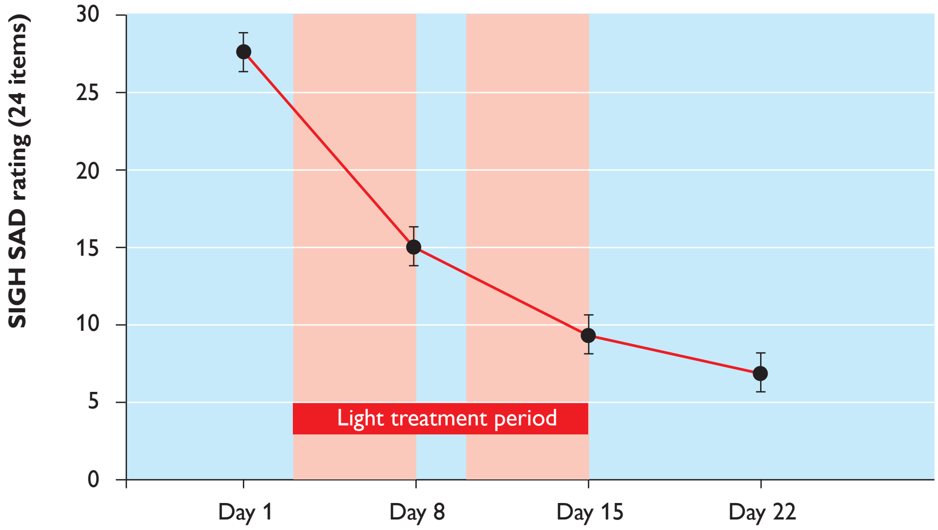
Research has shown that an individual's psychological state can affect their risk of mortality following physical illness. In one study, immediately following a life-threatening illness, approximately 34% of the patients were depressed, but the depressed group did not have a more severe physical illness. However, the depressed patients had a significantly poorer outcome over the 28 days following admission, with 47% of the depressed patients dying or having life-threatening complications, as opposed to 10% of the non-depressed group (Silverstone 1990).

It has been shown that having enough light during the day, particularly during winter, has a beneficial effect on mood and general quality of life.

For patients suffering from non-seasonal depression, bright light therapy offers modest though promising anti-depressive efficacy, especially when administered during the first week of treatment, in the morning, and as an adjunctive treatment to sleep deprivation responders (Tuunainen et al 2004).

Many studies have shown that exposure of the eyes to light of appropriate intensity and duration, at an appropriate time of day, can have marked effects on the timing and duration of sleep and on the affective and physical symptoms of depressive illness (inter alia (Beauchemin & Hays 1996, Benedetti et al 2001). A number of studies also suggest that bright light is effective in reducing depression among patients with bipolar disorder or seasonal affective disorder (SAD) (Terman & Terman 2005). In some countries, light therapy is the first choice for the treatment of SAD. Artificial light treatments usually range between 2,500 lux and 10,000 lux for a few hours per day to 30 minutes respectively (Terman et al 1990). Often a treatment period of one or two weeks is considered appropriate.

Fig 10
Light is highly effective in treating Seasonal Affective Disorder (Gordijn et al 2006)



In North America and Europe, about 3% of the population suffers from Seasonal Affective Disorder, also denoted as 'winter depression' (Michalak et al 2001, Mersch et al 1999). Symptoms include a seasonal pattern of depressive mood symptoms which emerges every autumn and winter and is associated with carbohydrate craving and weight gain. A much larger proportion of the population (approximately 8.5%) suffers from a light form of SAD (sub-SAD), also known as 'winter blues' (Mersch et al 1999). The symptoms include a lower energy level and mild mood swings.

About two-thirds of those affected by SAD or sub-SAD respond well to light therapy (Lam et al 2001). Bright light treatment (2500 lux) has also been successfully implemented against sub-SAD in workplace settings (Avery et al 2001).

Parkinson's disease; reducing depression and tremor

In Parkinson patients, it is known that morning bright-light therapy not only reduces depression, it also significantly reduces tremor (Paus et al 2007). In a group of Parkinson patients, 2 weeks of light therapy in the evening, just before going to bed, resulted in elevated mood, improved sleep, decreased seborrhea, reduced impotence, and increased appetite (Willis & Turner 2007). Marked improvements in bradykinaesia and rigidity were observed after the light treatment in most patients. Moreover, agitation, dyskinaesia and psychiatric side effects were reduced. However, tremor was not affected by the evening light treatment.

Decreasing length of stay

Light has been shown (Beauchemin & Hays 1996, Benedetti et al 2001) to have an impact on length of stay among depressed patients. One study (Benedetti et al 2001) found that bipolar depressed inpatients in east-facing rooms (exposed to bright light in the morning) stayed an average of 3.67 days less in the hospital compared with similar patients in west-facing rooms. Other studies suggest that exposure to light could be linked to length of stay among clinically non-depressed patients as well. A retrospective study (Beauchemin & Hays 1998) of myocardial infarction patients in a cardiac intensive-care unit treated in either sunny rooms or dull rooms found that female patients stayed a shorter length of time in sunny rooms (2.3 days in sunny rooms, 3.3 days in dull rooms). Mortality in both sexes was consistently higher in dull rooms (39/335 dull, 21/293 sunny).

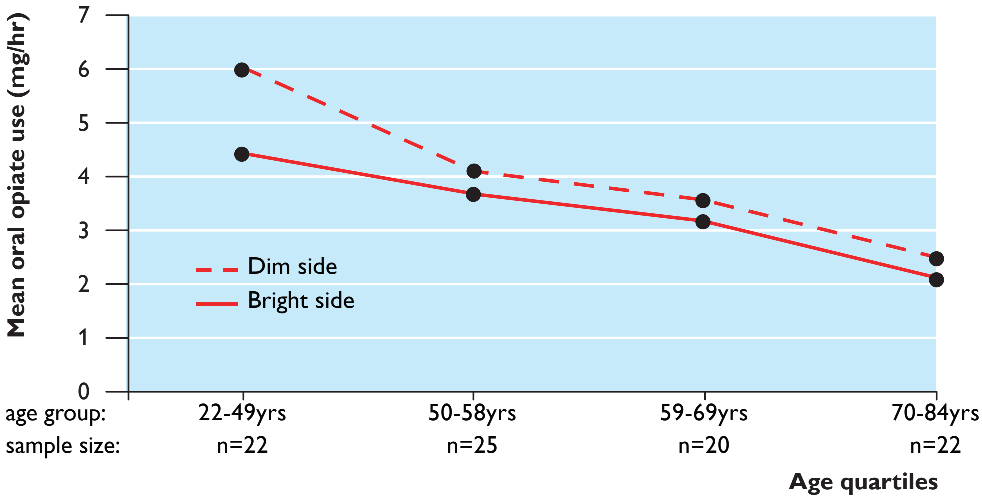
In yet another study, 23 surgical patients assigned to rooms with windows looking out on a natural scene had shorter postoperative hospital stays, received fewer negative evaluative comments in nurses' notes, and took fewer potent analgesics than 23 matched patients in similar rooms with windows facing a brick building wall (Ulrich 1984).

Easing pain

A randomized prospective study (Walch et al 2005) evaluated whether the amount of sunlight in a hospital room affects a patient's psychosocial health, quantity of analgesic medication used, and the cost of pain medication. Patients undergoing elective cervical and lumbar spinal surgery were admitted to the bright or the dim side of the same hospital unit after the operation. The outcomes measured included the standard morphine equivalent of all opioid medication used after the operation by patients and their subsequent pharmacy cost. Patients staying on the bright side of the hospital unit were exposed to, on average, 46% higher-intensity sunlight. This study noted that patients exposed to a higher intensity of sunlight experienced less perceived stress, marginally less pain, took 22% less analgesic medication per hour, and had 21% less pain medication costs.

Fig 11

Mean oral opiate use in different age quartiles, for the dim and bright side of the hall, (adapted from Walch et al 2005)



Better outcomes for patients on the unit's bright side

- Less perceived stress
- Less pain
- Took 22% less analgesic medication per hour
- Incurred 21% less medication costs

Reducing delirium in the intensive care unit

Retrospective surveys were carried out on two groups of patients who had survived a stay of at least 48 hours in an intensive care unit. One group had been kept in a unit without windows, and the other in a similar unit with translucent but not transparent windows. Survivors from a windowless intensive therapy unit had a less accurate memory of the length of their stay, and were less well orientated in time during their stay as compared to patients from a unit with windows. The incidence of hallucinations and delusions was more than twice as high in the windowless unit (Keep et al 1980).

Postoperative episodes of organic delirium were much more common (two-three times) in a windowless intensive care unit (n=50) as compared with a daylight one (n=50) (Wilson 1972). The presence of windows in the intensive care unit is highly desirable for the prevention of sensory deprivation.

The postoperative delirium crisis rate of patients after surgery for oesophageal cancer can be reduced by bright light therapy (Taguchi et al 2007). Strengthening circadian rhythms by means of bright light therapy may allow early ambulation of surgery patients.

3.4 Direct absorption for critical chemical reactions in the body

Light radiation is absorbed directly by the body through the skin. This stimulates chemical reactions in the blood and other tissues, helping to support Vitamin D metabolism (Holick 2005) and to prevent (neonatal) jaundice (Ebbesen et al 2003). Light is also known to be effective in treating psoriasis (Han et al 2008) and is also used in photodynamic therapy for topical and non-topical applications (Mitton & Ackroyd 2008).

3.5 Staff well-being – caring for the carer

There is strong evidence that light is critical to human functioning and can be extremely beneficial to staff in healthcare settings as well as patients. Hospitals are high-intensity 24/7 working environments. Staff must be able, on the one hand, to communicate effectively with patients, and on the other to concentrate on demanding tasks and make quick decisions under pressure at any time of the day or night. In this respect, their sense of well-being and motivation play a significant part in how a hospital performs and as such also have an influence on patient recovery processes.

Light affecting staff performance

In hospital spaces with no direct natural light, dynamic lighting solutions can be applied to make staff feel connected to the outside world. These solutions utilize certain dynamic characteristics of daylight to enhance the well-being, motivation and performance of those working indoors by giving them control over their lighting and creating a stimulating lighting ambience (changes in the level and tone of white light) that follows the rhythm of human activity. This makes it possible to create 'natural' lighting that helps healthcare professionals perform even more effectively, for instance by boosting alertness and concentration levels, e.g. on the night shift. Independent research has corroborated that daytime blue-enriched white light in the workplace improves self-reported alertness, performance and nocturnal sleep quality (Viola et al 2008).

In a high-volume Army outpatient pharmacy, the relationship between the level of illumination and the prescription-dispensing error rate was investigated. The prescription error rate was determined by direct, undisguised observation and retrospective prescription review under three levels of illumination (45, 102, and 146 foot-candles) during 21 consecutive weekdays. The overall prescription error rate (including both content and labelling errors) was 3.39% (369 prescriptions). An illumination level of 146 foot-candles was associated with a significantly lower error rate (2.6%) than the baseline level of 45 foot-candles (3.8%) (Buchanan et al 1991).

Light affecting motivation

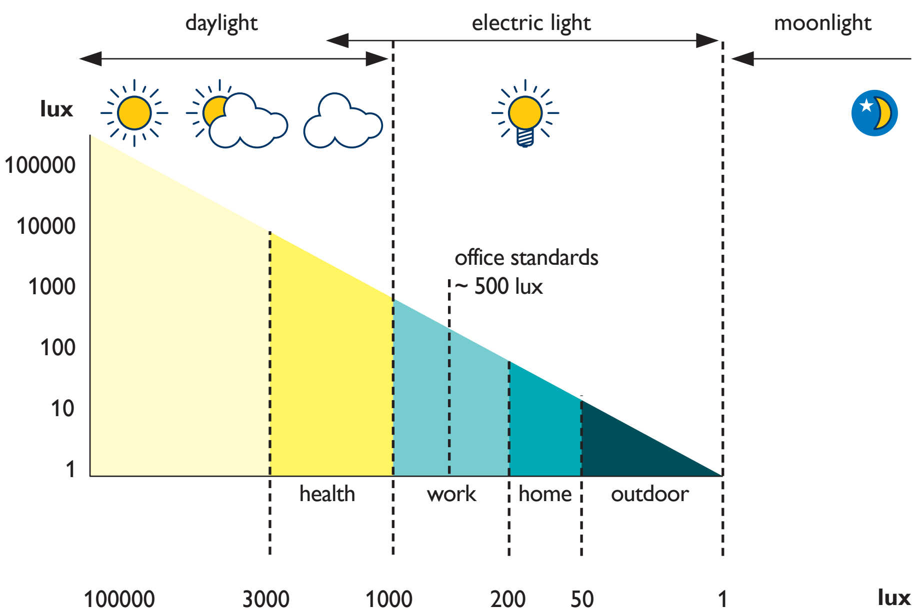
Sunlight penetration is known to have a significant direct positive effect on job satisfaction, intention to quit, and general well-being (Leather et al 1998).
Exposure to daylight at least 3 hours a day was found to cause less stress and higher nurse satisfaction at work (Alimoglu & Donmez 2005). Many similar reports describe benefits in studies using natural sunlight; artificial light is expected to deliver similar benefits as sunlight and can be used to compensate for the lack of sunlight entry, for instance for north-facing hospital rooms or in wintertime. Artificial light in itself is known to be effective in treating depression (Kasper et al 1989, Tuunainen et al 2004, Terman et al 1995) and improving nocturnal sleep quality (Terman et al 1995, Wakamura & Tokura 2001). Its relevance for, and further benefits in, the clinical setting merits further evaluation.

3.6 Light and eye safety

Virtually all general indoor lighting systems produce light levels that remain well below the intensities experienced outdoors on an overcast day (2000 lux, see figure 12).

Fig 12

The range of light levels encountered in daily life. Current office standards prescribe a horizontal illuminance of 500 lux.



This applies to all wavelengths. Therefore, general lighting systems do not present a greater retinal health risk than being outdoors on an overcast day. Retinal damage may only be an issue in the case of small, point-like and very bright light sources. For these cases, exposure limitations as laid down in the standards (ICNIRP 1997) for blue-light hazard (CIE 2002) apply. All general lighting applications and even light therapy using an A3-size device that achieves 10,000 lux of blue-enriched fluorescent white light (correlated colour temperature of 17,000 K) remain within the limits set by these standards and can be considered as safe.

For most studies with light of 2500 lux, side-effects like headaches, nausea and eye strain are mild and quickly disappear after the exposure to bright light has stopped. For bright light therapy at higher light intensities, ophtalmological monitoring before the onset of therapy is desired (Meesters & Letsch 1998). It should not be applied to people with eye diseases other then normal aging, nor should it be used for diabetics or epileptics. Hypomania as a potential adverse effect is infrequent but needs to be considered when giving light therapy (generally exposures well above 2500 lux). Moreover, people subjected to bright light therapy should not be on photosensitive medication.

As far as visual comfort of (compact) fluorescent lighting is concerned, flicker is no longer a problem with the new High Frequency (HF) ballasts (42-50 kHz), whereas it was an issue with the old ballasts that operated at 50 Hz.

4 Conclusion

We are currently witnessing a fundamental shift in the way we look at hospitals and clinics, with a growing trend to view them not so much as 'healthcare facilities', but as 'healing environments', in which patients become active participants in their own care and well-being.

This is reflected in, for example, the Planetree model of care – a patient-centred, holistic approach to healthcare, which promotes mental, emotional, spiritual, social, and physical healing. One of the cornerstones of the Planetree model is the belief that physical environments can enhance healing, health and well-being – with light as one of the key environmental conditions.

At Philips, we take people's needs as the starting point for our innovative lighting solutions. In the area of healthcare, this means focusing on physical and emotional comfort for patients, staff well-being and motivation, visitor hospitality and the business challenges facing hospital management.

By combining state-of-the-art technology and scientific insights with our people-centric approach, we can help transform the entire hospital experience with lighting that meets the visual, emotional and biological (rhythm) needs of patients and healthcare professionals alike.

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