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The Impact of Light on Outcomes in Healthcare Settings

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Abstract

Objective: To identify the mechanisms by which light impacts human health and performance and review the literature linking light (daylight and artificial light) with health outcomes in healthcare settings.

Methods: Literature review of peer-reviewed journal articles and research reports published in medicine, psychology, architecture, ergonomics, and lighting design periodicals and books. Keywords used to search for articles included light, lighting, daylight, sunlight, healthcare, hospitals, depression, circadian rhythm, health, patients and nurses.

Key findings: Light impacts human health and performance by enabling performance of visual tasks, controlling the body's circadian system, affecting mood and perception, and by enabling critical chemical reactions in the body. Studies show that higher light levels are linked with better performance of complex visual tasks and light requirements increase with age. By controlling the body's circadian system, light impacts outcomes in healthcare settings by reducing depression among patients, decreasing length of stay in hospitals, improving sleep and circadian rhythm, lessening agitation among dementia patients, easing pain, and improving adjustment to night-shift work among staff. The presence of windows in the workplace and access to daylight have been linked with increased satisfaction with the work environment. Further, exposure to light is critical for vitamin D metabolism in the human body. Light exposure also is used as a treatment for neonatal hyperbilirubinaemia.

Conclusions: Adequate and appropriate exposure to light is critical for health and well-being of patients as well as staff in healthcare settings. A combination of daylight and electric light can meet these needs. Natural light should be incorporated into lighting design in healthcare settings, not only because it is beneficial to patients and staff, but also because it is light delivered at no cost and in a form that most people prefer.

Introduction

Light is critical to human functioning in that it allows us to see things and perform activities. But it is also important because it affects human beings psychologically and physiologically. Several studies have documented the importance of light in reducing depression, decreasing fatigue, improving alertness, modulating circadian rhythms, and treating conditions such as hyperbilirubinemia among infants (Ulrich, Zimring, Joseph, Quan, & Choudhary, 2004). Further, the presence of windows in the workplace and access to daylight have been linked with increased satisfaction with the work environment (Boyce, Hunter, & Howlett, 2003; Edwards & Torcellini, 2002). Studies also show that adequate light levels are linked to reduced medication-dispensing errors in pharmacies. Thus, incorporating light into healthcare settings can be beneficial for patients as well as the staff who work there.

This paper considers the mechanisms by which light impacts human health and performance and reviews the literature linking light (daylight and artificial light) with health outcomes in healthcare settings. Studies conducted in other settings that are relevant to the discussion also are examined. Several studies have addressed the technical, architectural, and energy aspects of providing optimal lighting conditions in different areas of a healthcare facility and are not reviewed here.

Light in buildings

Most healthcare settings, as well as other buildings, are lit by a combination of daylight entering through windows and skylights and electric-light sources. It is important to understand how these two types of light sources differ to understand their relative impacts on human health and performance. Sunlight is electromagnetic radiation in the wavelength range that can be absorbed by the photoreceptors of the eye. Sunlight provides a balanced spectrum of colors with elements in all parts of the visible wavelength range. The actual wavelengths present in daylight vary over the day with latitude, meteorological conditions, and seasons (Boyce, Hunter, & Howlett, 2003; Edwards & Torcellini, 2002).

Building light sources

- Natural daylight entering through windows
- Electric light

Natural light

- A balanced spectrum of colors
- Wavelengths vary over the day with latitude and seasons

Electric light sources

- Wavelengths of light concentrated in limited areas of spectrum (except full-spectrum fluorescent lighting)
- Spectral content does not vary over time

In contrast, light from most artificial electric-light sources, such as cool white fluorescent light and incandescent lights, are composed of wavelengths of lights that are concentrated in limited areas of the visible light spectrum, for example, yellow to red end or orange to red end of the spectrum (Edwards & Torcellini, 2002). Full-spectrum electric-light sources such as xenon lamps and some filtered incandescent lights that have a spectral content similar to daylight, though their spectral content does not vary over time, are now available. Studies suggest that daylight is not inherently superior to artificial lighting for performance of most visual tasks (Boyce, Hunter, & Howlett, 2003). However, natural light has benefits over electric-light sources in regulating circadian rhythms and maintaining overall health.

How light impacts human health and performance

Light impacts human health and performance by four main mechanisms:

- Enabling performance of visual tasks
- Controlling the body's circadian system
- Affecting mood and perception
- Facilitating direct absorption for critical chemical reactions within the body (Boyce, Hunter, & Howlett, 2003; Veitch & McColl, 1993).

In this paper, each of these mechanisms is described and the specific impacts on human health and performance are outlined.

Enabling performance of visual tasks

The most obvious effect of light on humans is in enabling vision and performance of visual tasks. According to Boyce and colleagues (2003), the nature of the task—as well as the amount, spectrum, and distribution of the light—determines the level of performance that is achieved. Performance on visual tasks gets better as light levels increase (Boyce, Hunter, & Howlett, 2003). A study by Santamaria and Bennett (1981) shows that, if the amount and distribution of light are controlled, most everyday visual tasks (such as reading and writing) can be performed as well under artificial light sources (such as fluorescent light) as under daylight conditions. However, daylight is superior for tasks involving fine color discrimination when it is provided at a high level without glare or any reduction in task visibility caused by veiling reflections or shadows (Boyce, Hunter, & Howlett, 2003).

Another factor that affects performance on visual tasks is age, and the need for light increases as a function of age due to reduced transmittance of aging eye lenses (Edwards & Torcellini, 2002). This is significant in that the workforce in American hospitals is aging, and, therefore, there may be a need to critically assess the lighting provisions for different types of tasks performed by nurses and other staff.

Reducing errors

The work environment for nurses and physicians in hospitals is stressful. They are required to perform a range of complex tasks—charting, filling prescriptions, administering medication, and performing other critical patient-care tasks. Inadequate lighting and a chaotic environment are likely to compound the burden of stress and lead to errors. However, very few studies have focused specifically on the impact of different types of lighting conditions on staff work performance in hospitals.

One study examined the effect of different illumination levels on pharmacists' prescription-dispensing error rate (Buchanan, Barker, Gibson, Jiang, & Pearson, 1991). They found that error rates were reduced when work-surface light levels were relatively high (Buchanan et al., 1991). In this study, three different illumination levels were evaluated (450 lux; 1,100 lux; 1,500 lux). Medication-dispensing error rates were significantly lower (2.6%) at an illumination level of 1,500 lux (highest level), compared to an error rate of 3.8% at 450 lux. This is consistent with findings from other settings that show that task performance improves with increased light lev-

Visual task performance

- Task performance improves with increased light levels.
- The need for light for visual task performance increases with age.
- Higher lighting levels were associated with fewer medication-dispensing errors in a pharmacy.

els (Boyce, Hunter, & Howlett, 2003). No studies have looked at the impact of different lighting conditions at the nurses' station on task performance or error rate. More research is needed to understand the optimal lighting requirements for supporting the complex tasks performed by nurses and physicians, especially in the context of the changing demographics of the workforce.

Controlling the body's circadian system

Light falling on the retina and being transmitted to the hypothalamus controls the body's circadian rhythm (biological events that repeat themselves at regular intervals), which are responsible for synchronizing the body's internal clock to 24 hours. If the internal rhythms do not match the workday rhythms, which is the case for many healthcare workers, staff can feel drowsy, tired, and distracted. For example, for individuals working during night shifts, a 24-hour cycle that keeps most people awake and alert in the day and sleepy in the night would result in fatigue and a complete inability to perform during the night shift.

The human circadian system consists of three components: an internal oscillator, which is located in the suprachiasmatic nucleus of the hypothalamus in the brain; a number of external oscillators (external stimuli such as light-dark cycle between day and night) that can reset (entrain) the internal oscillator; and a hormone, melatonin, secreted by the pineal gland that carries "time" information to all parts of the body through the bloodstream (Boyce, Hunter, & Howlett, 2003; Edwards & Torcellini, 2002). Light activation of the pineal gland results in the suppression of melatonin (Veitch & McColl, 1993). Melatonin levels in the body determine a person's activity and energy level. Where daylight or artificial light is inadequate during the day, the natural suppression of melatonin production fails to occur and is accompanied by feelings of depression and sleepiness (Lewy et al., 1985). High melatonin levels cause drowsiness, while low melatonin levels are related to a state of alertness (Edwards & Torcellini, 2002; Veitch & McColl, 1993).

Exposure to daylight

- Reduces depression among patients with seasonal affective disorder and bipolar depression.
- Decreases length of stay in hospitals.
- Improves sleep and circadian rhythms.
- Lessens agitation among dementia patients, ease pain.
- Improves adjustment to night-shift work among staff.

Exposure to outdoor daylight is a key factor in determining the phase of the circadian rhythm. According to Boyce and colleagues (2003), daylight provides a higher light level at the eye that is matched to the spectral sensitivity of the circadian rhythms than most electric-light sources. By controlling the circadian system, light—both natural and artificial—impacts many health outcomes among patients and staff in hospitals such as depression, sleep, circadian rest-activity rhythms, as well as length of stay in the hospital.

Reducing depression

At least 11 strong studies suggest that bright light is effective in reducing depression among patients with bipolar disorder or seasonal affective disorder (SAD). A majority of the studies have examined the impact of artificial bright light on reducing depression. Artificial light treatments usually range between 2,500 lux and 10,000 lux (Beauchemin & Hays, 1996). The treatment is believed to be effective by suppressing the onset of melatonin. Two studies have shown that exposure to natural bright light is similarly effective in reducing depression (Beauchemin & Hays, 1996; Benedetti, Colombo, Barbini, Campori, & Smeraldi, 2001). Benedetti and colleagues (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 who stayed in west-facing rooms.

There is strong evidence that exposure to bright light in the morning is more effective than exposure to bright light in the evening in reducing depression (Beauchemin & Hays, 1996; Benedetti et al., 2001; Eastman, Young, Fogg, Liu, & Meaden, 1998; Lewy et al., 1998; Oren, Wisner, Spinelli, & Epperson, 2002; Sumaya, Rienzi, Deegan, & Moss, 2001; J. S. Terman, Terman, Lo, & Cooper, 2001; M. Terman, Terman, & Ross, 1998; Wallace-Guy et al., 2002). An experimental study that compared the effect of morning and evening light on patients with winter depression found that morning light was *twice* as effective as evening light in treating SAD (Lewy et al., 1998).

Light & depression

- Bipolar depressed patients in east-facing rooms stayed 3.67 days less than patients in west-facing rooms (Benedetti et al., 2001).
- Morning bright-light exposure is more effective in reducing depression than evening-light exposure.

Decreasing length of stay

Beauchemin & Hays (1996) and Benedetti et al. (2001) documented the impact of light on length of stay among depressed patients. A couple of other studies suggest that exposure to light may be linked to length of stay among clinically nondepressed patients as well. A retrospective study 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 time in sunny rooms (2.3 days in sunny rooms, 3.3 days in dull rooms) (Beauchemin & Hays, 1998). Mortality in both sexes was consistently higher in dull rooms (39/335 dull, 21/293 sunny). Another study found that Veterans Health Administration medical centers located in warmer and drier climates had shorter length of stay of patients (Federman, Drebing, Boisvert, & Penk, 2000). Hospitals in colder climates had longest lengths of stay in winter and fall.

Improving sleep and circadian rhythm

A small number of studies have found that timed exposure to artificial bright light might be helpful in improving sleep and circadian rhythms. 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, Volicer, Ross, Herz, & Campbell, 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 (Satlin et al., 1992). Two other studies showed that exposure to evening bright light was related to improved rest-activity rhythms among persons with dementia in nursing homes (Satlin et al., 1992; Van Someren, Kessler, Mirmiran, & Swaab, 1997). When the daytime environmental illumination level was increased in different living spaces of a dementia unit, it was found that, during increased illumination periods, the stability of the rest-activity rhythm increased in patients with intact vision, but not in visually impaired patients (Van Someren et al., 1997).

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 preterm infants (Blackburn & Patteson, 1991; Mann, Haddow, Stokes, Goodley, & Rutter, 1986; Miller, White, Whitman, O'Callaghan, & Maxwell, 1995). In one study, 41 preterm infants in structurally identical critical-care units were provided either cycled or noncycled lighting (constant light levels during the day and night) during a lengthy hospital stay. Compared to infants in the noncycled 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 (Miller et al., 1995).

Lessening agitation

Sloane and colleagues (1998) found that residents in facilities with low light levels displayed higher agitation levels. La Garce (2002) studied the impact of environmental lighting interventions (full-spectrum lighting, microslatted glazed windows, and electronic controls to maintain a constant level of light intensity) on agitated behaviors among residents with Alzheimer's disease. She found a significant drop in disruptive behaviors when residents were in the experimental setting (constant light levels) rather than the control setting (varying light levels) (LaGarce, 2002).

Exposure to bright morning light has been shown to reduce agitation among elderly patients with dementia. When elderly patients with dementia were exposed to 2,500 lux for 2 hours in the morning for two 10-day periods, their agitation reduced. Patients were significantly more agitated on nontreatment days (Lovell, Ancoli-Israel, & Gevirtz, 1995).

Easing pain

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

Improving adjustment to night-shift work among nurses

There are approximately 8 million workers in the United States who regularly work at night, and, for many of these individuals (e.g., nurses and physicians, airline pilots), peak functioning is critical at all times (Horowitz, Cade, Wolfe, & Czeisler, 2001). Night-shift workers not only experience loss of sleep and misalignment of circadian phase, they also suffer greater risk of gastric

Better outcomes for patients on the unit's bright side

- Experienced less perceived stress.
- Experienced less pain.
- Took 22% less analgesic medication per hour.
- Incurred 21% less medication costs (Walch et al., 2005).

and duodenal ulcers and cardiovascular diseases (Horowitz et al., 2001). Their decreased alertness, performance, and vigilance may be responsible for more errors on the job (Smith-Coggins, Rosekind, Buccino, Dinges, & Moser, 1997).

The timing of the sleep–wake schedule and work schedule of night-shift nurses remains permanently out of phase with the natural light/dark cycle, and this causes health problems. Several studies show that exposure to intermittent bright light during the night shift is effective in adapting circadian rhythms of night-shift workers (Baehr, Fogg, & Eastman, 1999; Boivin & James, 2002; Crowley, Lee, Tseng, Fogg, & Eastman, 2003; Horowitz et al., 2001; Iwata, Ichii, & Egashira, 1997; Leppamaki, Partonen, Piiroinen, Haukka, & Lonnqvist, 2003). Exposure to bright light during the night shift may also improve mood and sleep. In one study, 87 female nurses were exposed to brief periods (4 x 20 minutes) of bright (5,000 lux) light during scheduled times every night during a 2-week night shift. The treatment alleviated the nurses' subjective distress associated with night-shift work (Leppamaki et al., 2003). In addition to bright-light exposure during the night, studies have shown that additional measures such as using dark sunglasses during the commute home and a regular early daytime sleep schedule ensure complete circadian adaptation to night-shift work (Boivin & James, 2002; Crowley et al., 2003; Horowitz et al., 2001).

Affecting mood and perception

Boyce and colleagues (2003) describe studies that clearly show that people's moods are affected by different types of lighting conditions. Changes in mood are likely to affect changes in behavior and performance at work. However, mood changes do not remain the same across different people with the same lighting conditions. Rather, for the same lighting conditions, an individual's discomfort, preferences, expectations, and gender impact how mood changes (Boyce, Hunter, & Howlett, 2003).

Studies have shown that people prefer daylight to artificial sources of light for work and like to be close to windows (Heerwagen & Heerwagen, 1986). Heerwagen and Heerwagen (1986) found that office occupants preferred daylight over electric lighting for seven different purposes: psychological comfort, office appearance and pleasantness, general health, visual health, color appearance of people and furnishings, work performance, and jobs requiring fine observation. Greater sunlight has also been linked to higher job satisfaction (Leather, Pyrgas, Beale, & Lawrence, 1998).

Windows

- People prefer daylight to artificial sources of light for work and prefer to be close to windows.
- Glare and thermal discomfort may impact mood and task performance negatively.

Windows are a source of daylight and views, and it seems natural that the presence of windows at work would be related to improved mood and work performance. However, this has been challenging to prove. In some studies, having access to a window reduced negative mood in some people, though not in other studies (Boyce, Hunter, &

Howlett, 2003). Boyce and colleagues (2003) suggest that the findings from these studies vary because people's preferences and expectations may impact how they respond to different lighting conditions. Also, factors such as glare and thermal discomfort may actually affect mood and task performance negatively. While there isn't convincing evidence linking the presence of windows to improved mood and performance outcomes, it is clear that natural light is the preferred source of light for most people. It is important to provide access to daylight along with opportunity to control glare and lighting levels (Boyce, Hunter, & Howlett, 2003).

Affecting perceived stress and satisfaction

There are few empirical studies that have examined the impact of light—artificial or natural—on mood or task performance in healthcare settings. A study of 141 nurses in Turkey found that nurses who were exposed to daylight for at least 3 hours a day experienced less stress and were more satisfied at work (Alimoglu & Donmez, 2005). A survey conducted at a new medical center incorporating many daylight-enhancing features (such as atriums and windows in patient rooms and operating rooms) examined the impact of natural light on staff satisfaction. Forty-three percent of the staff rated the increased natural light in the new facility as having a very positive impact on their work life, and 27% rated it as having a positive impact (Mroczek, Mikitarian, Vieira, & Rotarius, 2005). However, in most hospitals, nurses' stations and break rooms do not have windows or access to natural light. There is need for further research to understand the importance of natural light to staff, as well as the impact of artificial light on staff mood and performance.

Facilitating direct absorption for critical chemical reactions in the body

Light radiation is absorbed directly by the body through the skin, and this stimulates chemical reactions in the blood and other tissues. There are two implications of this on health outcomes in healthcare settings. It

- supports Vitamin D metabolism and
- prevents jaundice.

Supporting vitamin D metabolism

One of the well-known beneficial photochemical process that occur this way in the body is the metabolism of vitamin D. Research shows that most of the vitamin D in the blood can only be derived by exposure to light (McColl & Veitch, 2001). The ultra violet (UV) radiation in the daylight is considered to be important for this process to occur. Most people are able to metabolize vitamin D by exposure to light. However, some people, such as chronically ill institutionalized individuals, elderly, shift workers, and those living in extreme polar latitudes, may not be able to obtain that necessary sunlight exposure. McColl and Veitch cite a couple of studies that suggest that full-spectrum fluorescent lighting might be able to support this important bodily function, but conclude that there is insufficient evidence for the use of such lighting for vitamin D metabolism (McColl & Veitch, 2001).

Preventing neonatal hyperbilirubinaemia

Studies suggest that exposure to light is an effective treatment for neonatal hyperbilirubinaemia (neonatal jaundice) (Giunta & Rath, 1969). This disorder is common to premature infants who lack the ability to metabolize bilirubin, a product of the decomposition of hemoglobin in dead red blood cells (McColl & Veitch, 2001). Exposure to light bleaches the bilirubin into a form that can excreted from the body. In a controlled study of 96 preterm infants, 47 unclothed (except for diapers) babies were exposed to bright light (90 footcandles) and 49 fully clothed babies to dim light (10 footcandles). The group of infants exposed to light showed lower serum bilirubin as compared to the infants who were not exposed to the light (Giunta & Rath, 1969).

One potential negative outcome that might occur as a result of overexposure to light in healthcare settings is retinal damage in preterm infants, and a few studies suggest that reducing ambient lighting conditions in hospital nurseries might improve outcomes (Ackerman, Sherwonit, & Fisk, 1989; Mann et al., 1986). Neonatal infants have thinner eyelids and usually have not developed the ability to constrict their pupils in response to light exposure. The high intensity of illumination in their environment makes them susceptible to retinal damage. However, studies that have examined the impact of reduced ambient lighting conditions on the development of retinopathy among premature infants have failed to detect a causal link (Kennedy et al., 2001; Reynolds, Hardy, Kennedy, & Spencer, 1998; Seiberth, Linderkamp, Knorz, & Liesenhoff, 1994).

Implications

There is strong evidence that light is critical to human functioning and can be extremely beneficial to patients as well as staff in healthcare settings. Adequate lighting conditions are essential for performance of visual tasks by staff in hospitals, and poor lighting conditions can result in errors. A point that must be noted in this regard is that lighting levels preferred by people are significantly higher than today's indoor lighting standards and correspond to levels where biological stimulation can occur (Begemann, van den Beld, & Tenner, 1997). Begeman and colleagues (1997) suggest that biological lighting needs of humans are different from visual lighting needs, and lack of adequate light for biological stimulation can lead to health and performance problems. This is particularly important for staff who work during night shifts, but is also relevant for staff who work for long periods of time without exposure to daylight. There is also strong evidence that shows that exposure to light helps in reducing depression, alleviating pain, and improving sleep and circadian rhythms among patients and, thus, supports the healing process.

Lighting in healthcare settings

- Provide windows for access to natural daylight in patient rooms, along with provisions for controlling glare and temperature.
- Orient patient rooms to maximize early-morning sun exposure.
- Assess adequacy of lighting levels in staff work areas.
- Provide high lighting levels for complex visual tasks.
- Provide windows in staff break rooms so staff has access to natural light.

Clearly, an important goal for facility designers should be to fulfill human needs for light and provide a high-quality lighted environment. Building interiors are lit by a combination of daylight and electric lighting. There is clearly a strong preference for daylight over electric light. Daylight entering through windows can be extremely beneficial to patients, provided there is no glare and it is possible to control light levels. However, in addition to natural light, electric light is needed in all parts of the hospital, though the need for artificial lighting can be reduced by efficient utilization of sunlight wherever possible.

While making decisions regarding lighting, economic factors (first costs, energy consumption, and maintenance) must also be taken into consideration (Veitch, 1993). Proponents of full-spectrum fluorescent lighting argue that this lighting source is superior to other artificial light sources (e.g., cool white lamps) because it provides a full-spectral wavelength similar to natural light and has the advantages of natural light for health and performance. However, there is inadequate evidence to support this claim except in special situations (e.g., for tasks requiring fine color discrimination) (Veitch & McColl, 1993). Further, Veitch (1993) suggests that full-spectrum fluorescent lighting is not feasible from an economic standpoint. Compared to cool white lamps, full-spectrum fluorescent lights are about 6 times more expensive and provide less light per unit electrical energy (Veitch, 1993). To maintain current recommended light levels, full-spectrum lights would result in higher electricity costs than other lamp types. Also, lamp life for full-spectrum fluorescent light in some installations may be less than other lamp types (Veitch, 1993).

Where good color rendering and bright, changing, visual environments are desirable, energy-efficient natural light is ideal. Wherever possible in healthcare settings, natural light should be incorporated into lighting design not only because it is beneficial to patients and staff, but also because it is light delivered at no cost and in a form that is preferable to most people.

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