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A SYSTEMATIC STUDY OF THE THERAPEUTIC IMPACT OF DAYLIGHT ASSOCIATED WITH CLINICAL RECOVERY

A. Joarder¹, A. Price² and M. Mourshed³

ABSTRACT

Daylight appears to be one of the most important visual and sensual elements of hospital environment for patients' health and wellbeing and is often given insufficient priority by researchers, due to its versatility and far-reaching but complex implications. The information related to daylight in hospitals is spread over a wide range of articles and research reports done by either biologists or researchers of therapeutic built environment. Therefore, it is difficult for daylight researcher to link these two and get a complete picture of the possible influences of therapeutic daylight. This paper is aimed at compiling and arranging the findings of two research groups in a line to explore how daylight impacts on patients' health and recovery gradually from light incident on patients' eye or skin, to the evidences of patients' health outcomes in hospital environment. The findings from literature review will strengthen the foundation of researchers who want to investigate the effect of daylight on clinical recovery and intend to design therapeutic daylight hospital buildings.

KEYWORDS

clinical recovery, daylight, psychological and physical effects, therapeutic impact

INTRODUCTION

Evidence suggests that a patient's visualisation and perception of the hospital environment impact on the health and wellbeing. However, the complex relationships between the environmental stimulus and human response are not yet fully understood (Gesler et al., 2004). The number of evidence based scientific research, focused only on the effect of daylight on patients' recovery as a part of therapeutic built environment is few in number (Rubin et al., 1998) due to versatility and far-reaching but complex implications of daylight (Galasiu et al., 2008) on patients comfort and recovery. In most of the studies, the effect of daylight on patients has been considered as a secondary observation within wider research on natural views, aesthetics or high intensity artificial lighting. The information related to daylight in hospitals is spread over a wide range of articles and research reports published in medicine, psychology, architecture, ergonomics and lighting design journals, periodicals and books. Therefore, it is difficult for daylight related research to build upon these fragmented resources. Some review has done either from a biological point of view narrating the inner body mechanism influenced by incident daylight on eye or skin (Wurtman, 1975), or from a therapeutic research perspective that is the compilation of evidences of psychophysical impact of daylight on human mind and health (Ulrich et al., 2004; Delvin et al., 2003; Edwards et al., 2002; Rubin et al., 1998). However, to our knowledge, no prior review has done to combine the findings of biologists and researchers of therapeutic light in a line. This paper is aimed at compiling all those diverse research sources to explore how daylight impacts on patients' health and recovery gradually from light incident on patients, to the evidences of patients' health outcomes. The paper consists of major two parts. The first part mapped a chain of consequences of the effects of daylight on human body starting from biological effect (chemical reactions in the body), its impacts on nervous system, circadian rhythm, and Vitamin D metabolism to those factors affecting mood and behaviour. The second part relates the consequences of the effects of daylight with evidences of psychological and physical benefit of patients' in healthcare settings.

EFFECTS OF LIGHT ON INTERNAL BODY SYSTEMS

Light is an active neurobiological agent (Zullo, 2007). Ott identified light as a nutrient for body like water or food for metabolic processes (OBS, 1997). The major control centres of the body: the nervous system and the endocrine system are directly stimulated and regulated by light (Liberman, 1994; Edwards et al., 2002). Light radiation is absorbed directly by the body through the skin, and this stimulates chemical reactions in the blood and other tissues (Joseph, 2006). Wurtman (1975) claimed that some of the important biological effects of light on body could be measured in a laboratory. The effects of incident light on body can be categorised in two levels (Edwards et al., 2002; Wurtman, 1975).

- a) Indirect: Light incident on retina and generate neural or neuroendocrine signal by the photoreceptor cell.
- b) Direct: Light incident on the skin and cause photochemical reaction within the tissue.

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LIGHT INCIDENT ON RETINA

The indirect responses of light is the actions of chemical signals generated by neurons or the actions of chemical messengers (hormones) delivered by circulation of the blood (Wurtman, 1975). External light travels on a direct pathway from the retina to the hypothalamus. The hypothalamus is composed of two major zones. One zone controls the sympathetic nervous system and stimulates hormone production, while the other zone controls the parasympathetic nervous system and inhibits hormone production. Information received by the hypothalamus is also used to control the secretions of the pituitary gland and significantly affects the body's other major regulatory system, the endocrine system. In general, the endocrine system regulates the physical and chemical processes involved in the overall maintenance of life (metabolism), as well as the varying rates of chemical reactions within each of our cells. It does this by secreting chemical messengers called hormones directly into the blood stream. Once in the blood stream, these chemical messengers circulate to all parts of the body and affect certain specific target cells that are capable to translate their messages (Liebermann, 1991). Neuroendocrine hormone regulates mechanisms like pubescence, ovulation and a wide variety of daily rhythms (SGMI, 2004). According to visibility, the impact of light can be divided into two situations (Clanton et al., 2004).

- a) Exposure to light produce serotonin, dopamine and Gamma-aminobutyric acid (GABA), and
- b) Exposure to darkness produces melatonin, norepinephrin and acetylcholine.

Activity of Serotonin

Serotonin is a neurotransmitter that facilitates emotions including desire, body temperature, sleep, appetite and metabolism. In 2002, The Lancet reported that exposure to high-intensity sunlight increases concentration of serotonin in the central nervous system (CNS), while dark and cloudy days depleted serotonin levels (Zullo, 2007). Low levels of serotonin are associated with increased carbohydrate cravings, depression, heightened sensitivity to pain, and troubled sleep patterns. When serotonin levels are high carbohydrate cravings subside, mood is elevated, pain tolerance improves, and sleep is more restful (Somer et al., 1999).

Activity of Melatonin

Melatonin is normally secreted by the gland in the absence of light. Melatonin is manufactured from serotonin. When melatonin levels increase, serotonin levels usually decrease, since more serotonin is converted to melatonin (Somer et al., 1999). When daylight (SGMI, 2004) and artificial lighting in the interior of buildings are inadequate, the natural suppression of melatonin production during the day fails and is accompanied by feelings of depression (Edwards et al., 2002; Lewy et al., 1985). Melatonin controls our hormonal and immune systems, moods, sleep patterns, body temperature, puberty onset, and tumour development (Edwards et al., 2002), appetites and sex drive. Melatonin levels in the body determine a person's activity and energy level. High melatonin level causes drowsiness, while low melatonin level corresponds to an alert state of consciousness (OBS, 1997).

CIRCADIAN CYCLES

The hormone melatonin works to control the body's "internal clock", or circadian rhythm (biological events that repeat themselves at regular intervals), which is set externally by visible light and controls hormone production and human bodily functions (Clanton et al., 2004). When light falls on the retina and transmitted to the hypothalamus, it controls our circadian rhythms (Samuels, 1990) by synchronizing our internal clock to 24 hours. Little or no light can disrupt the amounts of melatonin being produced, therefore disrupting the natural cycle between night and day (RMI, 2005).

Light reaching the retina of the eye is converted into electrical signals that are transmitted by the optic nerve. Most of these signals end up in the visual cortex of the brain and produce our sense of vision. However, some of the nerve fibers split off from the optic nerve soon after leaving the eye and send signals to the suprachiasmatic nucleus, which is the area of the brain where the main clock for the human body resides (LRC, 1998). The circadian system is organized neurologically to drive bodily functions up and down every day and is a pervasive physiological regulatory mechanism. The timing of such circadian rhythms is independent of an explicit knowledge of external clock time (Edwards et al., 2002). The internal clock produces a "subjective" day length in absence of periodic environmental cues that differs reliably from 24 hours. Human living under experimental isolation conditions may cycle at lengths greater than 24 hours (called infradian rhythms) or less than 24 hours (called ultradian rhythms) (LRC, 1998). This kind of deviation would pose the risk of continual lack of synchrony with the external world and it is difficult to force a daily correction in the internal clock and a strict match to 24 hours by artificial light (Terman, et al. 1986).

LIGHT INCIDENT ON THE SKIN

Direct exposure to sunlight increases the amount of pigment in the skin and the skin remains darker for a few hours due to the photooxidation of a colourless melanin precursor. This is caused by all the wavelength of sun light (Wurtman, 1975). Wavelengths of light also help to control the human body's chemistry (OBS, 1997). Human photobiologic action spectra

are most important between 290 to 770 nanometre ranges. Skin reddening and vitamin D synthesis occur in the range of 290 to 315 nanometre. Tanning or pigmentation of the skin and reduction of dental cavities occur in response to band from 280 to 400 nanometre. Bilirubin degradation occurs in response to light in the 400 to 500 nanometre range (blue light). Vision is the most sensitive to light in the 500 to 650 nanometre range (yellow-green light) (Hathway et al., 1992). Natural light provides the spectral energy distribution necessary for all of these biological functions. Sunlight is very intense electromagnetic energy in a continuous spectrum of colours ranging from the short wavelengths of invisible ultraviolet light through blue, green, yellow, and into the infrared waves (Lieberman, 1991) (Figure 1).

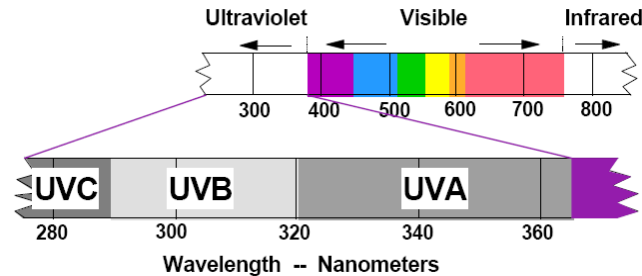


Fig. 1. Ultraviolet Spectrum
(Source: Gibson, 2008)

Sunlight initiates photochemical and photosensitization reactions that affect compounds present in the blood, in the fluid space between the cells or in the cells themselves (Wurtman, 1975). Research shows that most of the vitamin D in the blood can only be derived by exposure to daylight (McColl & Veitch, 2001). If the human skin does not receive some direct or diffused exposure to solar radiation for long periods, there will be a vitamin D deficiency followed by weakened body defences, physiological disorders and an aggravation of chronic diseases (SGMI, 2004). Washington University School of Medicine conducted a study on a population of normal white adults living in St. Louis and found some 70 to 90 percent of the vitamin D activity in blood samples was accountable to vitamin D from Sunlight. The investigators concluded that sunlight was vastly more important than food as a source of vitamin D (Wurtman, 1975).

RELATION BETWEEN DAYLIGHT AND CLINICAL RECOVERY

From the above discussion, it is evident that the quality and quantity of light have major impacts on human body. In a healthcare facility, patients, visitors, and staff are mostly exposed to artificial light. Artificial light has deficiency in wavelengths (colour) and intensity than the sunlight (White, 2006). Humans are affected both psychologically and physiologically by the different wavelengths provided by the various types of light. These effects are less quantifiable and benefits of daylight are easily overlooked (Edward et al, 2002). Physical and psychological impacts of light are the outcome of either some hormonal activity (serotonin/ melatonin) or chemical reactions in the blood and other tissues due to incident sunlight. Collectively these regulate circadian rhythm, better visual acuity, improved motor skills, less physiological fatigue, and the overall improvement of task performance, all are vital for patients' recovery in hospital environment. Several studies strongly support that bright daylight can improve health outcomes (Ulrich et al., 2004). On the other hand, inadequate lighting can cause moodiness, cravings for carbohydrates, an increase in systolic pressure etc (NHS, 2006). Based on the evidence of previous research, the impact of daylight on hospital patients can be divided into two groups:

- a) Impact of daylight on patients' psychology
- b) Impact of daylight on physical diseases

IMPACT OF DAYLIGHT ON PATIENTS' PSYCHOLOGY

Daylighting, the technique that optimises the use of natural light to illuminate interiors, is becoming increasingly popular; not only for its ability to dramatically transform a room, but also for its natural healing powers (SGMI, 2004). The impacts of light on the psychological diseases are due to lights incident on the retina of the eye causing modification of individual endocrine, hormone, and metabolic state. Some of the important psychological impacts of light are discussed here.

Treating SAD

Seasonal Affective Disorder (SAD) is one of the most researched subjects among the psychological effects of light (Edwards et al., 2002). Circadian rhythm is affected by lack of sufficient amount of light and increases the susceptibility to SAD, characterised by fatigue, gloom, change in appetite, weight gain, fitful sleep, insomnia, anxiety and depression. The severity varies with individuals, but everybody is impacted to some extent by the decrease in daylight as summer fades to autumn (SGMI, 2004).

The most effective treatment for these symptoms is, quite naturally, exposure to more light. At least eleven strong studies suggest that bright light is effective in reducing depression among patients with bipolar disorder or SAD (Ulrich et al., 2004). 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).

Positive response of light therapy includes hypersomnia, increased appetite, winter weight gain and complete remission of symptoms in summer. Factors that have been found, less predictably, to correlate with better outcomes include feeling worse in the morning (possibly a phase-shift phenomenon), and eating a lot of sweet foodstuffs late in the day (Eagals, 2004).

Reduce Depression

Light is very effective to remedy some of the root causes of depression. Bright light causes an anti-depressant response, activates the production of brain serotonin. One reason people become depressed is the malfunction of brain centre, called 'suprachiasmatic nucleus' or 'body clock' that controls hormone cycles. When the body clock becomes imbalanced it produces the incorrect hormones; causing insomnia, energy problems, and mood problems. As many as seven studies show that exposure to morning light is more effective than exposure to evening light in reducing depression (Ulrich et al., 2004). Beauchemin and Hays (1996) found that patients hospitalised for severe depression reduced their stays by an average of 2.6 days if assigned to a sunny rather than a dull room overlooking spaces in shadow. Light is also specifically associated with reduced depression for pregnant women (Oren et al, 2002).

On the other hand, treatment of depression by medications can cover only some symptoms and cause a multitude of unwanted side effects. But light causes no long-term side effects. Additionally, people responded to light within a week; instead of the several weeks required of many medications without any need for a readjustment (Zullo, 2007).

Reduce Agitation

It has been found that exposure to bright morning light can reduce agitation among elderly patients with dementia. When elderly patients with dementia were exposed to 2,500 lux for two hours in the morning for two ten-day periods, their agitation reduced. Patients were significantly more agitated on non-treatment days (Lovell et al., 1995). There is also strong evidence that exposure to bright light improves sleep and circadian rhythms. 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).

Reduce length of stay

Climate and sunlight influences length of hospital stay as well as sleep-wake patterns among hospitalized patients (Ulrich et al., 2004). It has been shown that psychological patients in brightly lit rooms have a shorter length of stay compared to patients in dull rooms (Zullo, 2007). One research group studied the impact of the amount of natural light on the length of hospitalization of patients with unipolar and bipolar disorder. The researchers found that bipolar patients randomly assigned to the brighter, eastern rooms (exposed to direct sunlight in the morning) had a mean 3.67 day shorter hospital stay than patients in west-facing rooms (Benedetti et al., 2001).

IMPACT OF DAYLIGHT ON PHYSICAL DISEASES

With the gradual progress of lighting research, now a day the impact of daylight has been recognized more than only psychological. Light can improve health and help to cure medical ailments by affecting the human body's chemistry. Terman, et al. (1986) claimed that improved interior lighting could lessen the common subclinical problems in the population at large such as oversleeping, overeating, energy loss, and work disturbance. The impacts of light on the physical diseases are due to lights incident on the skin that results in production of vitamin D, skin tanning, and dissociation of bilirubin etc. Some of the important physical impacts of light are discussed here.

Visual Requirement with age

Studies show that higher light levels are linked with better performance of complex visual tasks; and that light requirements increase with age (Zullo, 2007). To obtain the proper visual sharpness, the average 60 year old person needs two to three times the light of a 20 year old, and an 86 year old person may require five times the lighting levels (Jones, 1996). These lighting level differences are due to age clouding the lens, creating a decline in retinal illuminance, which makes the effective adaptation luminance lower for older adults (Veitch, 2001). Therefore, older adults generally require better contrast and higher task luminance to obtain the same visibility level as a younger person. Proper lighting also allow the elderly to function more independently by improving social contact, appetite, mood, self-confidence, and anxiety levels (Edwards et al., 2002).

Diseases Related to Bones and Skeleton

We need sunlight with its UV rays to metabolize vitamin D, necessary for the absorption of calcium into bones and other body tissue. On the other hand, if vitamin D is absent, the body will not absorb the amount of calcium required for normal growth and development of the bones. This deficiency leads to rickets in children and osteomalacia in adults, which is characterized by a weak, porous, and malformed skeleton. Both the development and maintenance of healthy bones are dependent upon the body's ability to absorb calcium and phosphorus (Edwards et al., 2002).

Diseases Related to Skin and Cancer

Studies have found a potential link between light pollution and hormone production, specifically related to melatonin and estrogen levels in women. Light at night reduces melatonin levels, which can be causally related to elevated estrogen levels in women and increased responsiveness of estrogen-dependent tissues to cellular proliferation. Collectively, these changes are linked to increased breast cancer risk. Light-related decreases in melatonin may also increase the risk of other kinds of cancer like lung, prostate (GGHC, 2008), ovarian and colon cancer (Freedman et al, 2002).

Just as overexposure can be unhealthy, regulated doses of sun and UV can be therapeutic. UV is currently used to treat psoriasis and, experimentally, genital herpes and some forms of cancer in the early stages of the illness (Lieberman, 1991). Light exposure is also used as a treatment for Neonatal Hyperbilirubinaemia (Zullo, 2007). In Hyperbilirubinemia condition, the red blood cells die and release haemoglobin, which soon degrades into the yellow compound bilirubin. An increase in the concentration of bilirubin in the blood, due to excessive production of the compound or to failure of the liver to remove it, gives the skin its characteristic jaundiced colour (Wurtman, 1975).

Physical Pain reduction

Research indicates that light increases the concentration of serotonin. Serotonin acts as an inhibitor of pain pathways in the central nervous system (Guyton & Hall, 2000). Data from over 40 controlled trials indicates that serotonin reduces a patient's pain perception (Lynch, 2001) when tricyclic antidepressants (TCAs) block the removal of serotonin from the synaptic cleft (Fields, 1984). In a study, two groups of patients undergoing elective cervical and lumbar spinal surgeries admitted postoperatively at the bright or the dim side of the same hospital was compared. The outcomes measured included the standard morphine equivalent of all opioid medication used postoperatively by patients and their subsequent pharmacy cost. This study found that patients exposed to an increased intensity of sunlight (46% higher) 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).

Post-Surgical Improvement

Improving the mental well-being of patients improves their recovery rates. Studies show that post-surgical facilities with daylighting improve this mental well-being. Intensive Care Unit (ICU) areas in hospitals can be very stressful for patients and workers. Wilson conducted a study to see whether windows had an effect on the postoperative delirium rates in hospital units. He found that the windowless ICU had twice as many patients developing post-operative delirium and depression (Collins, 1975).

Daylight reduced hospital mortality and length of stay in patients experiencing myocardial infarction in cardiac intensive care unit (CICU). A number of 628 patients, with a first attack of myocardial infarction, treated in sunny rooms and in dull rooms were retrospectively compared for fatal outcomes and for length of stay in the CICU. Patients stayed a shorter time in the sunny rooms, but the significant difference was confined to women (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) (Beauchemin et al, 1998).

Windows provided a psychological escape that decreased the stress level for patients. This environment provides a necessary mental balance for patients and reduces the tendency toward brief psychotic episodes (Collins, 1975). Ulrich (1984) reported that patients who could see trees through their windows spent less time in hospital than those with views of a brick wall: 7.96 days compared with 8.70 days per patient. In addition, the former group also took fewer doses and had slightly lower scores for minor post-surgical complications.

SUMMARY OF THE FINDINGS

This paper has tried to map a chain of consequences of the effect of daylight on human body starting from psychological impact and then link it with physical and psychological recovery of hospital patients. Visible light travels on a direct pathway from the retina to the part of the pineal, pituitary and hypothalamus, involved in running our biologic clock. The path continues to the tiny, cone-shaped pineal gland (Lieberman, 1991), which secretes the hormone serotonin that regulates sleep, reduces pain and appetite, and generally calms down and improves patient's mood. With the reduction of light

exposure, serotonin converted to melatonin. Melatonin works to control the body's internal clock or circadian rhythm. Therefore, without sufficient daylight, circadian rhythms are affected, which results into insomnia, SAD, depression and other mood & sleep disorders. By maintaining the body's circadian system, daylight impacts outcomes in healthcare settings by reducing depression among patients, improving sleep, lessening agitation etc. The psychological benefits from daylight may catalyze clinical recovery of patients. At the same time synthesis of vitamin D by different wavelengths of daylight directly impact on human skin, bones and dissociation of bilirubin. Many functions, including the nervous system, pituitary gland, endocrine system, and the pineal gland are affected by different wavelengths of light (Edwards et al., 2002). Natural light provides the spectral energy distribution necessary for all of these biological functions. Begeman et al. (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. Lastly, it can be ended in Liberman's (1991) words: "the major control centres of the body (the nervous system and the endocrine system) are directly stimulated and regulated by light, to an extent far beyond what modern science, until recently, has been willing to accept".

CONCLUSION

From the above literature it can be concluded that psychological benefit of daylight is mostly due to light incident on retina and can be substituted by high intensity artificial light, though it is costly and very difficult to match with human circadian system. But the physical promotion of daylight on health due to light incident on skin and production of vitamin D is impossible without daylight. For an overall health improvement of hospital patients both psychological and physical improvement is necessary and obviously psychological improvement consequently accelerates the rate of physical recovery. For people who are outdoors for a significant part of each day, the quality of indoor lighting to which they are exposed may be of little consequence. But for people who spend almost all of their time indoors, like hospital patients, there psychological and physical need for daylight is vital. The systematic outcomes from literature review presented in this study shows a clearer and complete picture of the impact of daylight on patients' health and recovery gradually from light incident on patients' eye or skin, to the evidences of patients' health outcomes and should encourage architects/planners/ designers to consider the impact of daylight exposure for patients more sincerely as part of the design of therapeutic hospital buildings.

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