THE (HIDDEN) BENEFITS OF DAYLIGHTING

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Abstract / Summary:

This white paper aims at providing an overall understanding of the benefits of natural light on people's health and well-being, and therefore its usefulness when designing buildings.

It relies on a vast scientific literature review on the effects of light and daylight. Main references are presented at the end of the document.

Content

Natural light in architecture

“Architecture is the learned game, correct and magnificent of forms assembled in the light”

Le Corbusier

During centuries, human has been living outdoors and has evolved to need exposure to sunlight for its health and well-being. With the advent of architecture, man has continuously sought to let in daylighting by means of openings or windows. From the earliest caves with their initial crude openings, to the magnificent medieval cathedrals flooded with light through stained glass windows, the history of architecture reflects this continuous query for daylight as a primary source of lighting in buildings.

Thanks to its inherent dynamic nature, its variability in direction, tint and intensity, daylight has a unique role on the nature and appearance of indoor spaces in buildings. Through effects of light and shadows, daylight influences and reveals the aesthetics and architectural experience of a building. Even after the invention of artificial light, daylight had remained an essential and irreplaceable design and artistic tool for architects.

Fig. 1: Le Corbusier’s Notre-Dame-du-Haut Chapel at Ronchamp expresses the great interplay between structure, form and light (Source: collinenotredameduhaut.com)

Natural light and health

Light is composed by electromagnetic waves of the visible spectrum. Without light, we would not be able to see and experience the world around us, nor to perform a task safely. But the role of light in our daily life goes far beyond the architectural and vision aspects.

The non-visual effects of light

The effects of light on people's health, and in particular daylight have been an important subject of research since several years now. While the role of light on vision is today well known, and while the link between daylight and health has been largely demonstrated through various empirical studies as it will be described later, it is only recently that scientists have started to understand how light influences our body and mind from a physiological standpoint.

In addition to the classical photoreceptors (rods and cones) that contribute to vision, our eyes also contain light sensitive cells (ipRGC_Intrinsically Photosensitive Retinal Ganglion) involved in several non-image-forming functions, such as alertness, mood, cognition etc. (Bernson et al. 2002). The discovery of those cells has opened the way to a new active field of research on the so-called "non-visual photoreception" or "non-visual light effects".

Those cells are part of the suprachiasmatic nuclear (SCN) of the hypothalamus which is a part of the brain that holds our body clock (Gooley et al, 2003). This body clock, or also called circadian (=approximately 24 hours) clock, regulates many physiological activities that responds to a circadian rhythm such as hormone levels (e.g. melatonin, serotonin, cortisol), timing and structure of sleep, body temperature, cardiovascular functions etc. The action of light on the ipRGC cells enables to synchronize the body clock, thus influencing sleep, alertness but also mood, memory, cognitive performance and even cell division (Gronfier, 2015).

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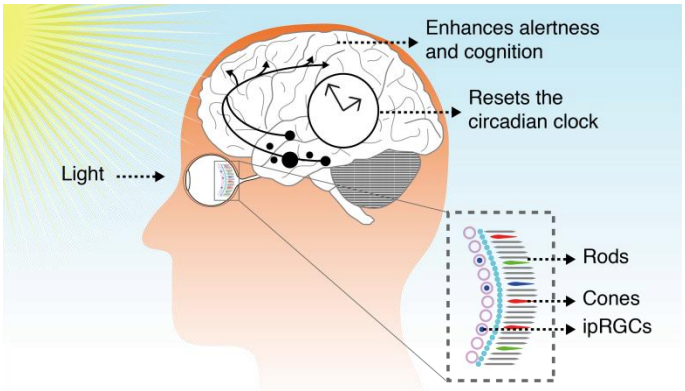

Fig. 3: schematic illustration of the circadian timing system (source: EPFL)

The ipRGC cells are based on the melanopsin photopigment which spectral sensitivity peak is shifted to the blue (~460-480 nm) compared to the usual visual sensitivity (~550nm). This is shown in Figure 2. This sensitivity peak has also been found to be in accordance with the melatonin sensitivity (Brainard et al, 2011; Najjar et Gronfier, 2014). Thus, the effect of light on the non-visual functions previously described highly depends on the light spectrum, and in particular, on the amount of blue light contained in the spectrum.

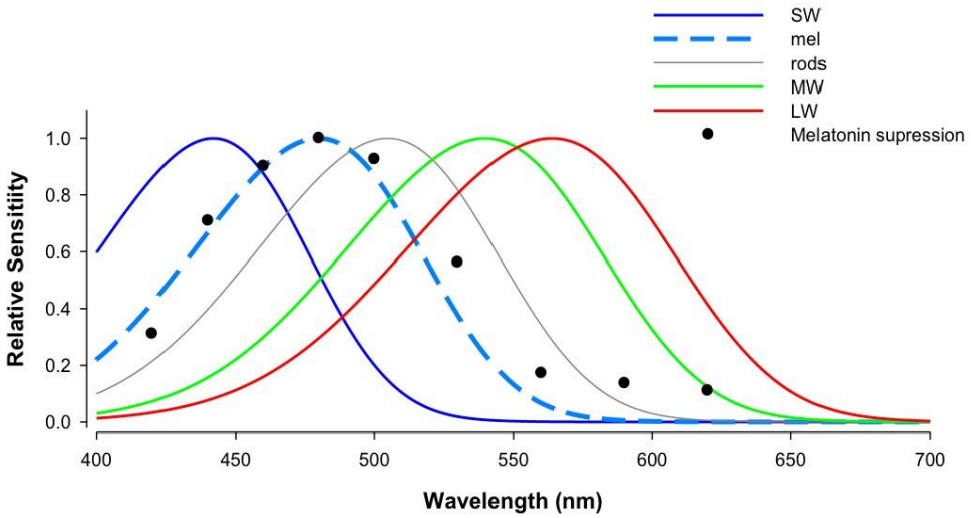

Fig. 4: spectral sensitivity of classical (SW, MW, LW cones and rods) and non-classical (melanopsin: mel) photoreceptors in humans (source: Gronfier, 2015)

However, the precise activation mechanism of these cells also depends on the light intensity, duration and time of exposure besides wavelength (Gronfier, 2015). Hence, an absence of light or inappropriate lighting conditions result in circadian misalignment, causing several disorders both in the short term and long-term. Such risks include circadian rhythm disruptions, brain effects (sleep loss, fatigue…), increased gastrointestinal disorders, increased cardiovascular disorders and cancers, risks for mental health issues (stress, depressions), brain and reproductive effects (Veitch et al. 1996; Vandewalle et al. 2010; Munch et al. 2012; Beute et al. 2014). Such disorders have been for instance observed on night workers.

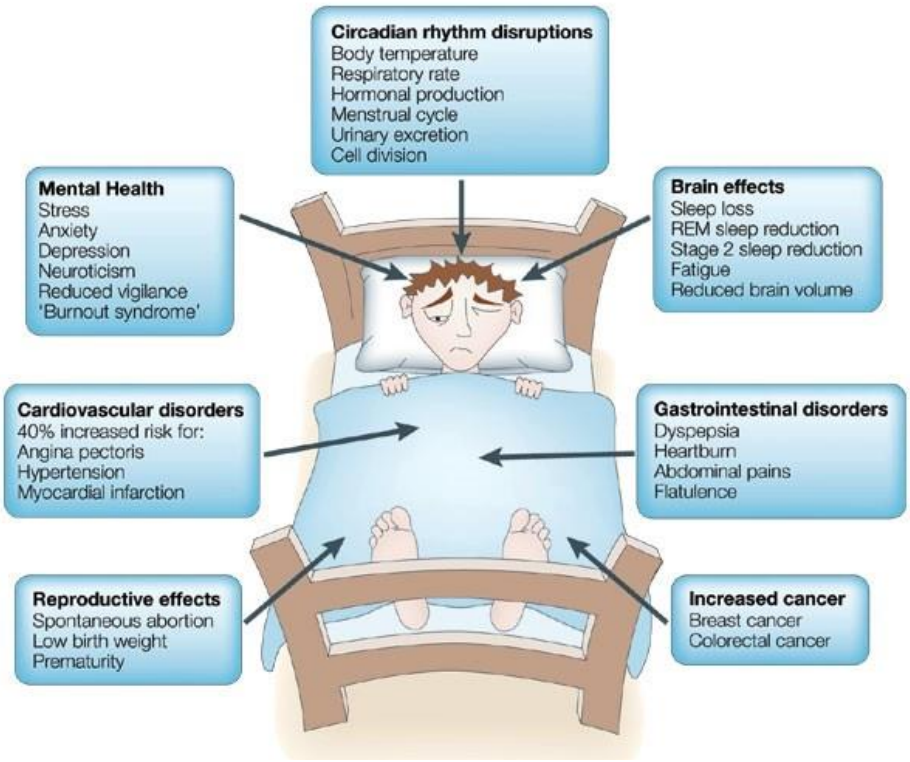

Fig. 5: Health issues related to circadian misalignment (source: R.G. Foster et al, “the rhythm of rest and excess”)

The discovery and understanding of those non visual effects have initiated some changes in the lighting and even design practices. For instance, the International Commission on Illumination (CIE) has released several publications to provide guidance and first recommendations on “the proper light at the right time”. Some research work is ongoing globally to develop criteria and metrics to characterize and evaluate the non-visual light effects.

However, note that this field is still “premature”, and a lot more research needs to be conducted before firm recommendations can be drawn, with quantitative values required to optimize non-visual functioning.

The specificities of natural light

Natural light is composed of direct sunlight and atmospheric light (sun radiation dispersed by water and dust). It is composed of a broad electromagnetic spectrum with excellent colour rendering quality. It also varies in intensity, direction, and tint along the hours and seasons. In that way, it informs us about the time of the day, the seasons, the weather, helping to maintain our psychological and social equilibrium. Due to its richness and universality, natural light is our reference illumination source, so that we have naturally a strong preference for it as opposed to artificial light (Beute, 2014).

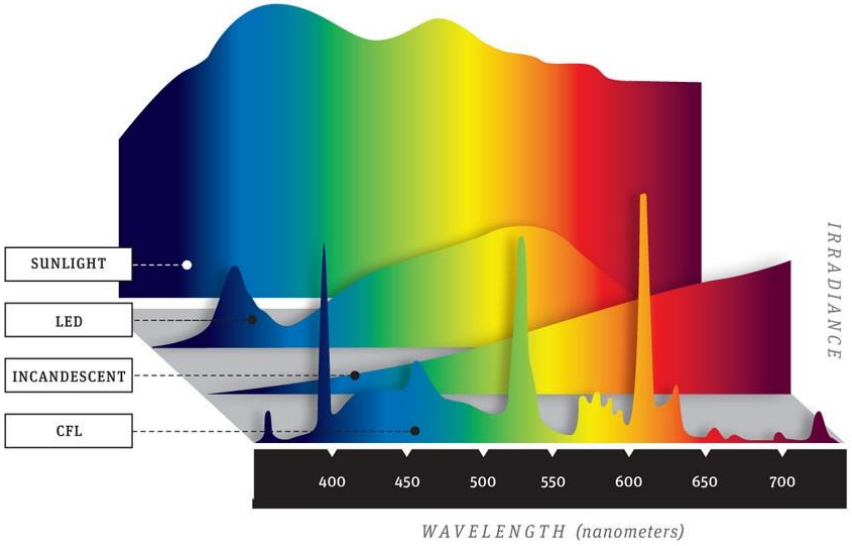

Fig. 6: spectrum of different light sources (source: popularmechanic.com)

Moreover, given the biological mechanisms described earlier, one can also understand why sunlight will have a stronger effect than artificial light on circadian clock synchronization and non-visual functions activation. Not only the intensity levels are much greater (e.g. 10000 to 100000 lux by daylight, vs. a few hundred lux or artificial light indoors) but also its light spectrum is much richer in short wavelength (blue) light than artificial light. In other words, the day/night cycle of a solar day is the most powerful signal for our body clock and biological circadian rhythms entrainment (Léger et al, 2011).

Thus, a lack of exposure to sunlight could translate into several disorders, such as Seasonal Affective Disorder (SAD). Seasonal affective disorder is a depression-related illness linked to the availability and change of outdoor light in the winter. Symptoms of SAD include lethargy, drowsiness, low levels of concentration, oversleeping, anxiety and depression. 12 million people are known to be affected in Northern Europe, 2 million people in the UK, and 11 Millions in the U.S. The exact cause of SAD is not fully understood yet, but it is often linked to a reduced exposure to sunlight during the shorter autumn and winter days which has consequences on our circadian clock synchronization. If exposure to natural light is not enough or possible, bright light therapy has been shown to be an effective cure in the treatment of SAD, besides psychotherapy and medication (Boubekri, 2008).

The observed benefits of daylight in buildings

Today, there is a vast scientific literature demonstrating both the negative impact of poorly daylit and viewless spaces on day-to-day mood, job satisfaction, and even health, and alternatively the benefits of daylight and associated views in most building use types. Studies cover all building use types, such as hospitals, schools, offices and even retail spaces.

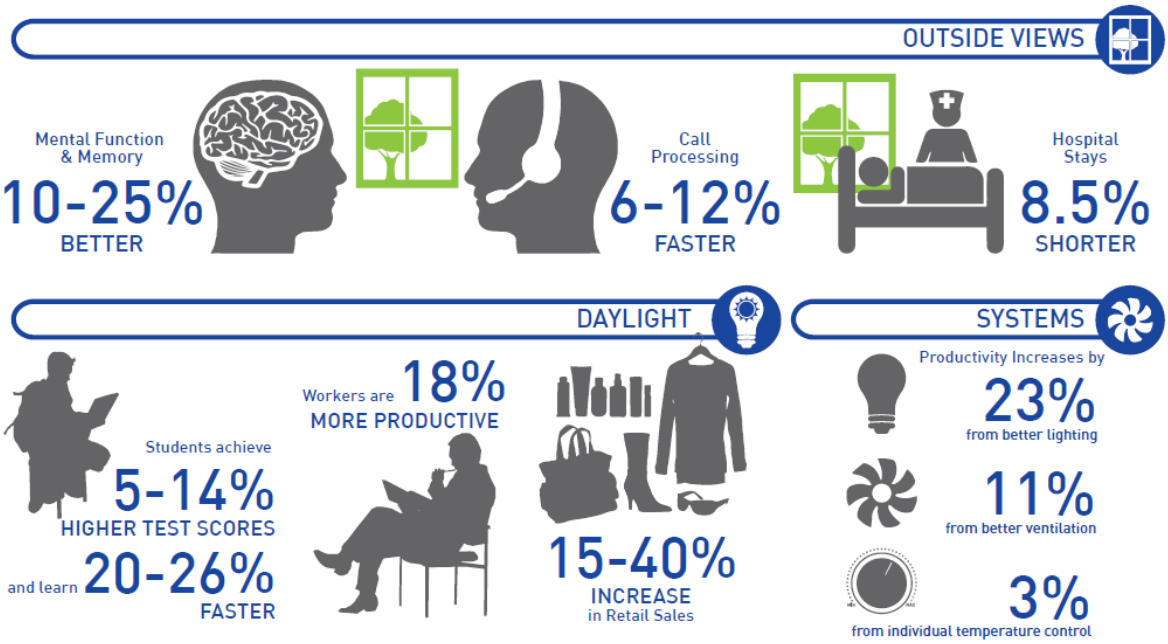

Fig. 7: benefits of daylight and views in different sectors (Source: the business case for green building Report, WGBC, 2013)

In offices, large evidence of increased job satisfaction, reduced stress and absenteeism, better sleep quality, and improved perceived well-being and productivity in well-daylit offices has been collected (Finnegan et al, 1981, Ulrich, 2008; Elzeyadi, 2011; HMG, 2011; Human Spaces 2015; Chueng; Farley, 2001). In hospitals, it has been observed that patients in rooms with good daylight level need less pain relief medications (Walch, 2005, Ulrich, 1984) and recover faster from depressive illness and after surgery (Edwards et al, 2002, Wilson, 1972, Benedetti, 2001). In schools, daylight and views has been shown to enhance pupils' concentration and alertness, resulting in higher learning rates and test scores (Boubekri, 2008, HMG, 2001, Elzeyadi, 2004, Maesano, 2015). Such empirical studies also exist in retail spaces although less extensive, showing that daylighting is well valued by the shoppers who may be willing to stay longer in the store, buy more and even pay a higher price for a same product (HMG, 2003, Terrapin Bright Green, 2012).

"It is the unqualified result of all my experience with the sick, that second only to their need of fresh air is their need of light; that, after a close room, what hurts them most is a dark room. And that it is not only light but direct sun-light they want."

Florence Nightingale, 1860

Daylight as a key parameter in the design process

With the advent of cheap and powerful artificial lighting in the late 19th century, daylight has been progressively neglected in the design of our buildings. Today we spend around 90% of our time in enclosed spaces, lit with fluorescent light, and barely with any connection to the outdoors. A recent study of office workers in over 16 countries revealed that natural light and view of the sea, and most generally of the outdoor nature, were identified as among the top five most desired aspects of the office environment. Yet, this same study indicated that 47% of the respondents reported they have no natural light at work and that they have felt stressed within the last three months (Human Spaces, 2015).

Today, with the increasing stringency of building energy efficiency targets in Europe and indeed globally, daylight as it is free has been considered as a great asset to reduce the energy use in buildings.

Besides, the recent research findings regarding non-visual effects of light has raised back awareness on the importance of daylight for people's health, and pushed designers and builders back to consider daylight as key design parameters.

Fig. 7: natural light appears as the most wanted element in the office space (source: Human Spaces, 2014)

Some European countries have already introduced a daylight factor and minimum glazing requirements within their national construction regulations such as UK and France. Since 2016, a new European standard for daylight in buildings (prEN 17037:2016) has been proposed, and specifies

minimum recommendations for daylight provision in indoor spaces. It also defines metrics used for the evaluation of daylighting conditions and gives methods of calculation and verification. Green building certifications such as LEED, BREEAM, HQE all include natural light and quality views in their requirements. The latest WELL certification, focused on the well-being of occupants, goes even further by including a “circadian lighting design” criterion, for which the requirement relies on melanopic light intensity rather than photopic light intensity.