Daylight for Health and Efficiency – A new career for an old friend

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Abstract
Daylight, rather a fact than a matter of discussion for many millennia, has lost its dominant role in architecture during the years 1950 till 1965. The artificial lighting of interiors had reached its long promised goal and was considered superior to daylighting in quality. In many countries, office buildings and even schools were built without windows because the new techniques of lighting and air conditioning were believed to perform much better than conventional lighting from windows and skylights and air supply through wall openings. Studies of the ERGONOMIC Institute, Berlin, in German office buildings, published first in 1990, revealed that almost 60 % of the workers considered lighting a health hazard, and, in addition, that in work spaces where artificial lighting dominates the self-reported state of health of workers was far below of those working in areas with daylight dominance. Since this was not only true for „vision-related" symptoms like eye fatigue, but also with other health complaints related to temperatures or noise we assumed that the effects are likely to be caused by influences of lighting on the hormonal system. During the 1990s, a series of studies on the impact of lighting on humans were performed in the USA. They included offices, schools and retail buildings. The outcome in short is, that daylight was demonstrated to improve human performance, to change the state of health for the better, to help boosting sales in retail shops. In addition, other studies have demonstrated its impact on the energy efficiency of buildings.

Keywords: Daylighting, biological effects, non-visual effects, health impairments, asthenopia

1. Introduction

For many millennia, people did not discuss about the quality of lighting because the only economic means for lighting built space was daylight. During the dark part of the day, people either stopped working or tried to generate light as good as possible. Even the invention of the incandescent lamp did not change the situation considerably although the artificial light was no more associated with smell and smoke, but still with heat. And energy was expensive. Thus, utilization of daylight has been a major challenge for anyone creating built space, for homes as well as for schools, offices or factories.

The situation changed almost suddenly and dramatically with the introduction of the fluorescent lamp during the 1950s. This type of lamp has been much more energy efficient and enabled the users to create much higher levels of illuminance without causing impairments due to infrared radiation. The way in which office buildings were planned has undergone a major revision; the height of rooms was no more dictated by the (natural) lighting. This lamp paved the way to open plan offices and rooms with low ceilings in comparison to their area. At least two new major players entered the scene, engineers for lighting and air conditioning accompanied by the acousticians with all three groups claiming to achieve a higher degree of comfort in built environments than it had been possible with natural lighting and air flow. And in 1965, a congress of occupational medicine stated that humans do not need natural lighting in work environments "*Humans in windowless work rooms do not have to fear health impairing impacts of the environment as long as that environment is optimal from the point of view of work hygiene*." [1]. This means that any relationship between natural light and work hygiene was denied. Heavily armed with this blessing from the doctors of occupational medicine, the lighting engineers dared a step forward: The major statement of one paper presented on the congress of LiTG (German Society of Lighting Technology) in 1971 on "Vision-Lighting-Work" reads: "*Lateral windows cannot satisfy high lighting requirements as artificial lighting does*…" [1]. The author of this statement was the chairman of the standardisation committee on interior lighting.

In difference to experts, users of workrooms built following this notion have never accepted their physical environment. While engineers for air conditioning have lost their credibility (and big parts of their business) lighting engineers still play an important role, partly because artificial lighting is indispensible, and partly because they have managed introducing long lists for illuminances in lighting and other standards. The culmination of this practice has been a statement issued on a conference held for the preparation of a health and safety guideline for lighting at the workplace in the name of the German Statutory Accident Insurance: „*Today, the state-of-the-art of science and technology is that illuminances for office and VDT-workplaces of 500 lx and of 1.000 lx for those in open plan offices are to be planned. If these illuminance values are maintained - even with partly or fully missing daylight - and the rest of the quality criteria for artificial lighting considered, accidents as well as undue stress and strain and fatigue for the workers will be avoided."* [2]. This statement does not represent a slip or

misunderstanding. According to German law until 2004, daylight was no lighting, and what one should understand as healthy lighting has been defined in lighting standards for artificial lighting.

2. Lighting and health and safety

2.1 Scientific background – Or fairy tales?

Light and lighting have been considered crucial for worker's performance, health and safety in many countries from the 1920s. Most people including those involved in setting up rules, guidelines or even legal provisions do believe that their products are firmly based on scientific evidence. The CIE has attempted to find out lighting related health and safety provisions in different countries and their justification [3]. The outcome is very simple and disappointing. In 14 countries, national legal provisions have existed before 1993. The question about the scientific background of these provisions did not yield any results. From no country, a justification for the rules has been sent.

In the Federal Republic of Germany, the lighting of workplaces has been regulated by various instances, e.g. by the Federal State (Workplace Ordinance of 1975 [4], and ASR (guidelines to this ordinance, from 1975)), by health and safety authorities (e.g. Statutory Accident Insurance) as legal provisions, in addition by a number of groups and agencies (e.g. by a commission of the civil service for the buildings of them or by DIN) below the level of legal provisions. The common feature of all of these regulations that existed before 2004 has been a total lack of provisions regarding daylight as lighting. The Workplace Ordinance ruled features of artificial lighting, safety lighting etc. and named "view to outside" in the same rule. Thus, daylight was denied a role as lighting. In the documentation of the legal comments to the Ordinance, the responsible director in the Ministry of Work and Social Affairs has declared that daylight was deliberately not ruled because it is not always available throughout the day and not with an even distribution over the space and constantly over time [5]. This means, for a healthy and safe lighting one needs timely constant and evenly distributed light, and remaining always the same during day and night. Exactly this has been the opinion of lighting engineers for about 80 years.

While the Ordinance of the Federal State has partly touched the issue of daylight, the authority responsible for health and safety of German workers, Statutory Accident Insurance, has not even mentioned anything related to daylight and daylighting in their legal provisions [6]. Nothing has changed after this authority was informed about the results of the study "Light and Health" in 1990 with the main outcome that daylight was crucial for the health of working people. Thus, the only legal provisions effectively ruling daylight have been the ordinances of the federal states on building construction. These rule the size of the wall openings (windows) in relation to the entire space of the room. Since all workplaces operated in interiors are located in buildings, these provisions guaranteed a certain level of illumination. But one can easily detect that the regulations have not been made for providing illumination. In 2002, the template for the state ordinances, Musterbauordnung, was changed with the result that buildings need a smaller distance from the next built space. Thus, the amount of daylight entering German buildings will be reduced inevitably.

In other countries, e.g. in the USA, the situation has been even worse [7]. To efficiently utilize office space, deep plan buildings form the usual construction principle, with the outcome that most workplaces have to be placed far from the next window. Since most employees felt that few of them were privileged and would therefore get a workplace in rooms with windows, companies have been trying to be just to their workers. The outcome is the now-typical "American-cubicle office", in a rather sarcastic meaning the "cube farm" [8], with partitions of the size five to six feet placed in the interior space, while the perimeter of the building with windows is being used for circulation. Both books cited here, one about software management and the other a comic strip collection, name the facility managers running such offices "Cubicle Police". The feelings of the people working in such environments can be best expressed by the title of the next book by Scott Adams: "Fugitive from the Cubicle Police". What about the rules for lighting such workplaces? Are there some? In fact, they are included in most the elaborate publication on lighting engineering, "The IESNA Lighting Handbook" [9] from the Illuminating Engineering Society of North America (IES), hailed by its publishers with the words "… is known as the "Bible of Lighting." And the publisher itself is named on the cover of the book "The LIGHTING AUTHORITY".

Simply said, either the "Bible of Lighting" does not tell the right things, or it is being ignored by the practice. What about the authority? The true nature of the authority of lighting engineering in general has been unveiled by an author who is considered an "authority" himself during a conference of IES [10]. Although the title of the paper, "Illuminance Selection Based on Visual Performance - and Other Fairy Stories" and the introduction "*Once upon a time, there were three illuminating engineers who lived in a small house on Wall Street. They were poor but they were honest. They made their living by providing clear advice on good lighting practice.* …" sounds provocative enough, the main body of the

article shed even less pleasant light on the scientific background of normative provisions in lighting. The story told continues with these words "*Their nights were haunted by the knowledge that much of what they recommended was based on accumulated experience and judgment - it was a matter of consensus. In the darkest hours of the night they often thought that one day the wolf of litigation would come to their door and would huff and puff and blow their house down.*"

Consensus instead of scientific evidence? The author describes how the "magic formula", a relationship between the lighting conditions and the performance of any task has been found. The engineers would give the formula, and the users should select which level of performance they would need. "*Year after year they persisted with their search for the magic formula. After many years and several false dawns the magic formula was found and they all lived happily ever after*." The conclusion of the author of the tale is: "*This paper explains why a magic formula describing the relationship between lighting conditions and task performance cannot exist in any general form; discusses the difference between visual wants and visual needs and concludes that consensus is an inevitable component in all illuminance recommendations*."

The paper referenced above has analysed the recommendations issued by IES in the years from 1947 to 1993 and demonstrated that the illuminance levels have been a result of economical and political state during the years when they were formulated rather then a consequence of scientific evidence on vision or safety and health. Honestly written, the IESNA Lighting Handbook does not include a chapter on occupational health and safety, and one cannot find in it anything suggesting that the recommended illuminance levels have a relationship to this subject.

The opposite is true e.g. for German DIN Standards for artificial lighting of work areas. The former DIN 5035 [11] defined work safety as one of the goals of lighting: "*Goals of lighting - By its quality, lighting has an effect on human visual performance, activation, work safety, and well-being. Lighting should therefore be designed in a manner as to fulfil its respective goals and to integrate harmoniously into the given room.*" In Part 2 of DIN 5035 [12] the basis for the requirements for work environments was defined as here: "2. ***Fundamentals for guide values*** *– (…) /-Visual performance/ - Well being/ -* ***Occupational safety****/ - Economy …*". Interestingly, none of these fundamentals is properly defined in this standard or elsewhere. Not even "visual performance" is defined although most people tend to believe that the ultimate goal of the lighting of work environments is assuring a certain level of visual performance. The only existing definition is far from being applicable for determining physical properties such as illuminances *"performance of the visual system as measured for instance by the speed and accuracy with which a visual task is performed*" [13]. Not a single term in this definition is defined, and the true nature of it is a vague description.

In addition to this aspect, DIN recommendations had another important difference to those by IES. While the recommendations of the IES from 1981 on always made a difference between "regular" and "difficult" visual tasks, and gave a range for the recommended illuminance (e.g. 200-300-500 lx for regular, 500-750-1000 lx for difficult) DIN requirements gave only one value (e.g. 500 lx) for a specific type of workplace. This is the nominal value or the "rated illuminance".

The standard superseding most parts of DIN 5035, EN 12464-1, has overtaken the typical values of DIN 5035-2 and modified some. The biggest difference is that the value given for a certain task (e.g. 500 lx) remained, but as the minimum value. This means that allegedly established values for the most important feature of lighting, the illuminance, have been increased by about 20% to more than 100% [14] just by redefining what it was to mean.

First, this development reaches far beyond telling a fairy tale. Secondly, the question of the importance of the illuminance of artificial lighting of workplaces in Europe, whatever it means in reality, was never raised. Nobody has ever asked why daylight would not contribute to lighting of workplaces. And even people with good knowledge in raising chicken or cucumbers more efficiently by optimizing lighting have never asked why the needs of humans in their working environments can be satisfied just by shedding a minimum level of light in their environment. Thus, the consensus, as described in [10] has been an agreement among lighting engineers. It would be very intriguing to evaluate the opinion of architects, employers, employees or health and safety experts in this matter. The opinion among scientist reads like this: "*Present-day recommendations, formed principally from visual performance criteria, vary somewhat from one jurisdiction to another. These recommendations are based on consensus among committee members, and are notorious for their weak link to published research."* [15]

Finally, the European Commission has ruled that health and safety regulations in Europe are not subject to interpretation by standards. The outcome is that the European standard on lighting (EN 12464-1) had to be amended with the statement "*This European Standard does not specify lighting requirements with respect to the safety and health of workers at work and has not been prepared in the field of application of Article 137 of the EC treaty, although the lighting requirements, as specified in this standard, usually fulfil safety needs.*" [16]

Not quite easy to understand, though, that the almost identical ISO 8995:2002 states "*The recommended values are considered to represent a reasonable balance, having regard to the requirements for safe, healthy and efficient work performance.*" [17]

The role daylight plays in the most recent standards, i.e. EN 12464-1 and ISO 8995, is minimal and consists of some statements and descriptions. The only requirement in relation to it is "*Glare from daylight shall be avoided*" (for air traffic control towers). A search in the IESNA Lighting Handbook on the implications of daylighting for humans has shown that "Daylighting and Human Factors" is worth half a page of 1002 pages, and two thirds of this section deals with glare from daylight and blinds and shades.

2.2 Study: Light and Health

During the second half of the 1970s, numerous implications on the utilization of computers in office environments were studied in a project funded by the German Ministry of Labour and Social Affairs [18]. In the course of this project, the visual problems of users and their relationship to lighting, visual objects and the visual environments were studied among many other aspects. One of the most unexpected outcomes of this study was the extremely low acceptance of lighting. Using a questionnaire developed for the evaluation of pleasantness of lighting and disturbances caused by it [19], the overall acceptance was between 0% in some environments and 20 % in others, whereas visitors of football stadiums in Germany accepted the floodlighting there with a rate between 70% and 90%. Since the subjective evaluation of lighting is always correlated with the difficulty of visual tasks, the result can be interpreted in different ways. One possibility is to claim that working with computers includes very demanding visual tasks and therefore the usual lighting is not adequate.

As a consequence of this idea, new types of luminaires were developed with a cut-off angle by 50º, and all user organizations were recommended to use these in order to avoid reflexions on visual displays. In addition, they should not use desk lamps because they would create a luminance imbalance in the field of vision. Most ergonomists also recommended locating visual displays far away from windows. And the first field study on vision and lighting of VDT workplaces suggested to darken the workrooms and to lower the level of illumination [20]. Realizing all recommendations would end with windowless rooms with dark walls and an illumination level of about 100 lx.

Since we knew the potential outcome of such measures, all Telecoms of the world have been operating such rooms for their directory assistance services with almost all inmates hating their environment, such measures have not been recommended as a result of the study [18]. Many field studies performed during this research had demonstrated that the users would love to work as near as the window even having a high level of visual load. Since the preferred behaviour of workers is not necessarily the best for their health and safety, a larger study on the impact of lighting on users of office rooms was performed [21]. Published under the title "Light and Health" in 1990, this study has demonstrated the importance of daylight for all people working in offices. Luminaires developed for avoiding visual problems of computer users proved to cause more health complaints than all other types of luminaires [22]. Since this study is well documented [23] both in English and German, only the most important outcome is to be mentioned here. First, regardless of the type of work the subjects performed those working in the vicinity of windows experienced the lowest level of health impairments. Secondly, the kinds of health impairments associated with lighting were not limited to vision, e.g. asthenopia, but included also symptoms like dizziness or fatigue. Environmental factors like noise, dry air or too high or to low temperatures were correlated with health impairments and the type of lighting (natural lighting or artificial lighting).

Later, several intervention studies were performed demonstrating that improved lighting conditions reduce adverse health symptoms substantially. Since the impact was considered too strong to be caused through avoiding adverse effects on vision it was suggested that the real cause was likely to be direct impact on physiological processes. One of the studies on which this assumption based was [24]: "*Küller (Küller, 1987) has shown that the balance of hormones is influenced by the total amount of light and that the quality of the artificial light is also of some importance. He concludes "daylight entering the eye controls or affects many of the highly complex endocrine and autonomic processes that take place in the human body." Light and the visual environment also affect the daily and yearly rhythm of vital functions.*" The second important basis for the assumption was the research by Aschoff on external events triggering body functions, the so-called zeitgebers: *"… the most important result of this research was the isolation of the light-dark-rhythm of the sunlight as the most important "zeitgeber" ("zeitgeber"; Aschoff et al., 1982). The "zeitgeber" is a "clock" which provides the organism with the most important impulses. It triggers a mechanism synchronizing vital functions of the organism with the external event(s).*" [25] (cited from [21]).

Thus, one of the major outcomes of the study “Light and Health” was that most detrimental effects of artificial lighting is caused by disturbances of the natural rhythms caused by its constancy in lighting level and colour (spectrum). This means that an evenly distributed lighting remaining the same throughout the day as required e.g. by the German Workplace Ordinance was not a solution for health and safety problems of workers, but one of the main reasons.

2.3 Studies on the impact of light and lighting on humans

While preparing the report on “Light and Health”, we found a rich literature related to the impact of lighting on humans. Unfortunately, the number of field studies with appropriate methods was small. A research on possible reasons for the lack of valid studies yielded the result that a very early experience is the likely cause. In a series of experiments, Elton Mayo [26] and others tried to improve the productivity of workers by better lighting in the time period between 1924 and 1932 in a factory with the name Hawthorne Works. Researchers found that productivity almost always increased after a change in illumination but later returned to normal levels. The productivity was increased both for workers with better lighting and the control group without. It seemed as if the workers tried harder when the lights went dim, just because they knew that they were in an experiment. This lead to the idea of the *Hawthorne Effect*, that people will behave differently when they are being watched. Although these studies are still being subject to controversies among scientists and practitioners, at least the myth of the Hawthorne Effect has remained a trauma for all researchers.

There are still a variety of publications related to this subject, impact of lighting on humans. An important proportion of them, those on the influence of daylight and artificial light on diurnal and seasonal variations in humans, have been compiled by Rikard Küller [27] in a report with 1100 entries and a basic list of 120 key words. The bibliography deals with the impact of light, both natural and artificial, upon the biological clock. [28]

The year of the publication of the above-mentioned report, 2001, has witnessed one of the most important events in the history of lighting, the discovery of a new light receptor in the retina. This event has lead to an explosion of ideas on non-visual effects of light, e.g. photobiological effects, circadian rhythms, health implications, light therapy, night-shift work. After reviewing the emerging literature until 2005, the editor-in-chief of the Lighting Handbook, Rea, has stated that we need not only new ways for lighting, but also for measuring and assessing light [29]. In his words “*the amount of light, its spectral composition, spatial distribution, timing and duration needed for vision is so different from that needed for circadian functioning, that generalizations about “good lighting” will have to be assessed by two very different sets of criteria in the future.*” The conclusion he has drawn from his evaluation of the literature is: “*It is my belief that a new system of photometry for the circadian system should be developed, and that until we do, we will be unable to lay any claim to “good lighting” with regard to human health.*” More literature around this development can be found in [30] and [31].

While lighting technology and photometry are likely to set off for new shores, and will encounter many false dawns, the natural source of light, the sun and the day, has returned to the focus of interest, first by those who try to path the way to new methods for energy saving, and later by those interested in healthy lighting. An evaluation of the prospects for healthy daylighting can be found at [32]. As a result of this development, at least in European health and safety legislation, daylight is the primary source for the lighting of work areas by law. [33] Although this Directive of the EU was to apply in 1992, Germany has needed another 12 years to adopt it. In return the perhaps most important aspect associated with daylighting, the view out, has been deleted from legislation.

Of course, daylight in interiors is not “natural” light, and energy saving is not necessarily beneficial for humans at work. To judge the future prospects, it is therefore important to review literature for studies that deal with effects of daylight beyond aspects like pleasantness or self-reported health.

3. Impact of daylight in interiors

3.1 Overall findings

In a literature study on the impact of daylight, the agency National Renewable Energy Laboratory of the United States government has stated: “*With properly installed and maintained daylighting systems, natural light has proved to be beneficial for the health, productivity, and safety of building occupants. Natural light helps maintain good health and can cure some medical ailments. The pleasant environment created by natural light decreases stress levels for office workers. Productivity increases with the improved health of workers, and with better productivity comes financial benefits for employers. Students also perform better with natural light. Across the nation, studies have shown students in daylit rooms achieve higher test scores than students in windowless or poorly lit classrooms.“* [34]

Further findings of the study, for which 92 publications have been studied and 106 further papers considered, read like a compilation of success stories. Daylighting also benefits retail stores because

of more even light that provides better colour rendering. Customers stay in stores longer and employees can identify items faster with better lighting. In health care facilities, natural light improves patient recovery rates and allows for proper vision for the elderly in assisted living facilities. Hospital staff also benefit from the natural light because of the amiable environment. Patients will be more at ease when staff is in a better mood, and the staff will be calmer when patients have improved recovery. Productivity increases in industrial environments because of improved colour rendering and the better quality of light provided by natural light. Also, safety is increased with better lighting conditions.

3.2 Daylighting in Schools

Further back in the 1980s, a variety of studies performed in schools demonstrated that the spectrum of the light utilized in school rooms could influence not only the mood of the students but also their medical history like the dental health or even body growth. These studies were either performed using daylit rooms as controls or artificial light with different spectra. Later, a series of studies were performed to demonstrate the impact of daylight also on learning and absenteeism.

In one of the earliest studies [35], elementary school students who spent two years working under high-pressure sodium vapour lamps had poorer records of achievement and attendance, plus far slower rates of growth and development, than those whose classrooms had full-spectrum fluorescent lamps with ultraviolet supplements. In a study of over 325 fourth graders, Hathaway et al. found that students who studied under the bright, daylight-like light of fluorescent lamps were absent less often and achieved higher scores on aptitude tests than those working under the sodium vapour lamps. The "bright-light" kids also grew more quickly, had far fewer cavities, and began menstruating much earlier.

A two-year Swedish study published in the same year [36] on health and behaviour of children in classrooms with and without windows with 88 children with an age of 8 to 9 years, significant influences of daylight on behaviour and physiology were demonstrated. The children were situated in four classrooms differing in respect to the access to natural daylight and artificial fluorescent light. The results indicated the existence of a systematic seasonal variation with more stress hormones in summer than in winter. The children situated in the one classroom lacking both natural daylight and fluorescent daylight tubes demonstrated a marked deviation from this pattern. High levels of morning cortisol were associated with sociability, while moderate or low levels seemed to promote individual concentration. Annual body growth was smallest for the children with the highest levels of morning cortisol. Possibly, the production of cortisol had some influence on sick leave.

In the USA, a series of daylight studies were performed by the Heschong Mehone Group, including [37] two on schools. For these studies, data from 21.000 students in three districts were evaluated. Controlling for all other influences, the researchers found that students with the most daylighting in their classrooms progressed 20% faster on math tests and 26% on reading tests in one year than those with the least. Similarly, students in classrooms with the largest window areas were found to progress 15% faster in math and 23% faster in reading than those with the least. And students that had a well-designed skylight in their room, one that diffused the daylight throughout the room and which allowed teachers to control the amount of daylight entering the room, also improved 19-20% faster than those students without a skylight. Such figures may not mean much for those not acquainted with learning. Perhaps the comparison of the impact of daylight and of parameters like ethnicity, gender and social status is more convincing: The impact of lighting was more powerful than these highly relevant demographic variables.

By the way, there are no German studies on daylighting of schools. The reasons are that the studies in the USA and Canada were triggered by attempts to build windowless and even underground schools while in Germany windowless schools built in the 1970s caused such an uproar among children and parents that they have been either rebuilt soon or even dismantled.

In general, it has been demonstrated that light influences mood, sociability, body growth, dental health and learning performance of school children. And daylight positively!

3.2 Daylighting in Offices

While the study “Light and Health” has been performed in a country where worshipping the sun once had even a political dimension and at least the visual contact with the outside has been part of the health and safety legislation, in other countries like the USA similar studies might result differently. In such countries, in many areas, people need to protect themselves against the sun, and in many areas it is almost impossible to work without air conditioning and appropriate measures against solar radiation. Surprisingly, there is a large variety of studies related to office work and productivity performed in the USA reporting even more positive effects than “Light and Health”. For example, the preference for daylight in different studies reviewed in the course of an extensive literature review has been much higher (e.g. “Daylight better than electric lighting” for psychological comfort 88% vs. 3%; for office ap-

pearance 79% vs. 0% (!), for general health 73% vs. 3%, for visual health 73% vs.. 9%, for colour appearance 70% vs. 9% etc.).

Also studies on work performance suggest that daylighting improves productivity. Field surveys in a large number of offices, using the same evaluation methodology, have identified two important factors for high levels of satisfaction with the environment and for a high level of self-rated productivity. [38] For all three routes by which lighting conditions can influence the performance of individuals (through the visual system, the circadian system and the perceptual system), many studies exist that demonstrate positive effects of daylight. The missing proof for the productivity itself can be explained by a fact that reaches far beyond the "Hawthorne Effect". This is the lack of a definition for office productivity. In addition, there is also not even a description of "quality" for the outcome of office work. Without measuring quality, it is not possible to measure productivity. Or one ends with absolutely useless measures like LOC (lines of code) for the productivity of programmers.

3.3 Daylighting in Retail Space

Probably the most convincing evidence that daylight can have a positive influence on sales is a study of sales in a retail chain operating 108 stores, two-thirds with diffusing skylights [39], [40]. The authors name many possible reasons for the effect they have measured. However, they do not state whether the effect is due to changes in visibility of merchandise, changes in store appearance, or changes in architecture.

4. Conclusions and outlook

Daylight is back. It is healthy, pleasant and helps energy saving. Physiologically, daylight is an (the most?) effective stimulant to the human visual system and the human circadian system. Daylight reduces the incidence of health problems caused by the rapid fluctuations in light output typical of electric lighting with discharge lamps. Daylighting of retail space can have a positive effect on sales. Psychologically, daylight and a view out are much desired regardless of the country where people live and the legislation in that country.

The dark side of the story is that humans have unlearned utilizing daylight in professional environments. The architect, once also the "lighting engineer", has lost much power to technical people concerning the design of the physical environment. Perhaps the most significant differences to the "pre-fluorescent-era" when natural lighting governed building design can be found in the world population (1950 = 2,52 billions; 2008 = 6,71 billions according to the UN report) and in how and where people live. While densely populated areas, cities, keep growing to "mega"-cities – in 2008 more then the half of humans were living in urban areas -, small towns, villages or islands throughout the world lose their population dramatically. Since most workplaces are located in areas where the population density is high, it is not easy to supply them with sufficient daylight. And, in difference to optimistic statements, daylight is not available at no cost in interiors.

We need to develop an entire technology for efficiently utilizing daylight. Although much can be learned from the past, building the future is not a simple and easy task. As can be seen from a page count of the Lighting Handbook, the people with the highest knowledge in light and lighting, the lighting engineers, are not well prepared for the task. And their cooperation with those who create built space, the architects, does not function as a synergy. Sometimes, the opposite may be true.

Even acknowledging all these concerns, the outlook for daylight is bright for many reasons.

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