Journal of Solar Energy Research (JSER)

Journal homepage: www.jser.ut.ac.ir

Analyses of Daylighting Effects on Human Health in Buildings

Osman[a],M., Ghaffarzadeh[b,*],M., Sirous[c],Z., Khatibi[d],M., Azami[a],A.

[a]*Department of Architecture, Eastern Mediterranean University (EMU), North Cyprus.*
[b]*Department of Architecture, Jolfa International Branch, Islamic Azad University, Jolfa, Iran.* **E-Mail: Mortaza.ghaffarzadeh@yahoo.com*
[c]*Department of Architecture, Science and Research Branch, Islamic Azad University, Urmia, Iran.*
[d]*Department of Electronic Engineering, Science and Research Branch, Islamic Azad University, Urmia, Iran.*

ARTICLE INFO

Received: 29 October 2016
Received in revised form: 17 February 2017
Accepted: 19 February 2017

Keywords:
Daylighting; Human Health; Sick Building; Strategies

A B S T R A C T

Even though human beings feel cheerful and happy when living and working under artificial light, but science have proved that feeling healthy, happiness and well-being is dependent on daylighting conditions in the working & living. One of the major reasons behind it refers to spreading of diseases like bone diseases, rickets, heart failure disease, cancer and stress. Nowadays, inappropriate utilization of daylighting in buildings' interior spaces resulted encountering sick syndrome for building users. However, the quality of any architectural space designed is measured by the healthy factor of those buildings, that is to say what extend the space adapts daylight in its design process. Presently, there are many softwares available for architects which could be used to analyse building adaptation with daylighting strategies affect the healthy issues outcomes in the built environment. The research finding indicates that daylight has a great impact in human health, psychology, productivity and well- being.

1. Introduction

Utilization of daylight as a main source of illumination in building has been documented in literature, since long years back. With the advent of electricity use for lighting, the attention of architects has shifted to and fro, in using electricity, however in some instances emphasising the possibilities to create a conducive and appropriate visual efficiency in interior environment, irrespective of the condition of outdoor environment. Architects and Engineer design requirements of some certain spaces recommends suitability of natural materials that are not harmful or cause hazard to the build environment [1]. Now days, buildings are made in unhygienic external environment using artificial materials that manufactured through complicated manufacturing processes to meet human being or users dynamics complex requirements, functions and aspirations. However, it is important that users anticipated functions must highly be considered. These complicated connection between man his shelter and its outer environment to the greater extend have its impact on the primary use and function of buildings: to provide a hygienic environment to its users for them to feel at well being. The quest for healthy building motivated researcher from western Europe to develop research a bout what is now called building biology, however this research was initiated to recognise the relationship that link the buildings, its users and surrounding environment [2]. Even though, natural light is incorporated in to buildings as means for energy efficiency, its psychological and physiological effect shouldn't be undermined, however, incorporating natural light have the advantage of posting productivity, decreasing fatigue, eyestrain and also reducing absenteeism in work [3].When daylight is appropriately design would definitely help in reducing buildings running cost which includes, lighting, cooling load, and productivity, etc. For architectural design to be regarded good, daylight design should be considered right in preliminary design stages, this would however, be much better than to incorporate daylight techniques in an already accomplished design.

1.1. Statement of the problem

Now days one of the reasons for buildings to be unhealthy, attributes to their inadequacy of utilizing daylight which in turns resulted in to tremendous health problems for its users,

for instances, rickets , bone , heart diseases, cancer , stress, etc. The quality of any space design to great extend depends on the resulted outcome of medical care, therefore, architectural design would be considered worthy aspect of healing process.

1.2. Aim of the Research

This research entails to examine the impact of daylight on human health, and proffer solutions through optimizing daylight to eliminate health problems related to the lack of solar energy inside buildings.

2. Daylighting

Daylighting is the main source of energy, considered as a renewable because is readily available and impossible for it to seize to exist in the near future. More over due to tendency of day light to change space users psychological feeling from bad mood to good, influences architect to try as much as they could to allow natural lighting penetration to any building project they design [4]. The objective of a good day lighting is not only to fulfil lighting requirement that are adequate for performance of certain visual task, but rather to keep comfortable and conducive atmosphere.

2.1. Glare

Glare as the name implies is a visual discomfort that occurs to occupants of a space as a result of excessive day light. In order to enhance day lightings for office building designer should pay attention to furniture design, their location, reflectivity of wall surfaces so as to evenly distribute day light , also portioning walls facing the south façade should be short to allow daylight pass deep. When our workplace is located at a distance from south elevation, it would be possible to control daylight with smaller shading devices.

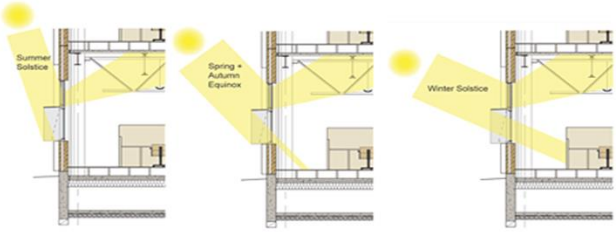

Figure 1. Daylight control [5]

2.2. Visual Comfort

Visual comfort is normally comprehended in terms of illumination level, that to say quality of light, surrounded environment and its influences on features such as space design [6] Visual comfort is not merely allowing daylight pass through space to illuminate it, in order for space occupant to perform their various visual task, but rather to design windows that allowing daylight entry to provide illumination needed for various visual task for the users.

Figure 2. The tolerance of viewers for visual discomfort coming from daylighting tends to be higher than that from electric light sources [7]

Table 1. Modifying factors for the general illuminance values [8]

X 0.8	X1	X1.2
Age < 35 years	Age 35-55 years	Age >55 years
Activity unimportant	Activity important	Activity critical and unusual
Low difficulty	Normal difficulty	High difficulty

Table 2. Lighting and Task [8]

Visual code	Luminance (cd/m^2)	Horizontal Illuminance (lux)
Human face hardly visible	1	20
Face fully visible	10-20	200
Optimum for normal work	100-400	2000
Surface with reflection > 0.2 well lit	>1000	>20000

2.3. Daylighting control

Utilizing shading element is essential to protect occupants from any visual discomfort (glare) that might happen to them, most especially in hot and humid climatic areas [9]. One of the most common challenges facing daylight design now days is glare, due to the fact that most modern building design now days utilized large glass opening and in some instances the entire facade may be glazed.

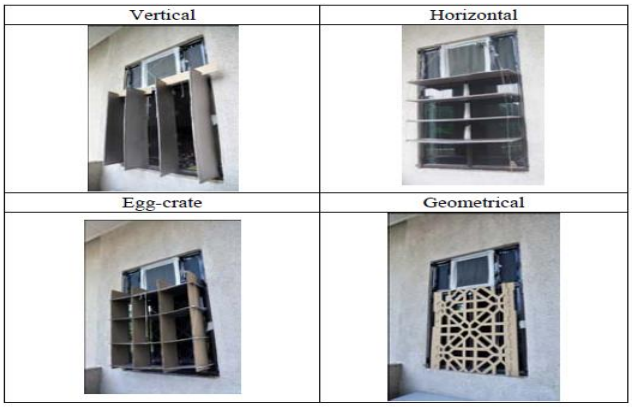

Figure 3. Different types of shading devices [10]

Even though they provide shading element but still they are more or less for aesthetic purposes rather than functional instead they contributed in blocking ambient daylight from penetrating the buildings interiors [10].

2.4. Desired luminance and luminance levels

The quantity of light recommended for human beings to attain adequate vision, depends on factors of age and reflectance of the task. People whose age is 65 for instances need a double quantity of light required by 20 years old, moreover old people tendency of experiencing glare is higher than young people.

Table 3. Recommended illumination level for people according to their age [11]

Area or activity	Under 25	25-65	Over 65
Passageways	2	4	8
Conversation	2.5	5	10
Grooming	15	30	60
Reading/Study	25	50	100
Kitchen Counter	37.5	75	150
Hobbies	50	100	200

For older people to have good visual efficiency, doesn't depend only on strength of light, but it should be appropriately shield [11].

3. Effects of Daylight on Human Health

3.1. Health and biology

The most apparent influence of daylight on man is to allow him to carry on his various visual tasks using his eyes. The eye contains photoreceptor cells named rods and cones, this photoreceptor cell functions is to regulate man's visual effects. This done when light strikes the photoreceptor cell series of reaction happen which in turn enable man to visualize objects. Researchers, narrated that the quantity, spectrum and distribution of light of light dictate the level of visual efficiency achieved [12]. Human internal clocks to great extend have influences on their emotions, however, mood disorder diseases such as depression, bipolar disorder and seasonal affective disorder (SAD) attributed to alteration that occurred to their circadian rhythms .Moreover, too much sleeping or less sleeping could also caused the previously mentioned diseases. The manner in which the body rhythms and mood relates to each other is complex issue, it might be probably attributed to the chemical serotonin fluctuation of the human brain in relation to light/dark cycle as the day reduced or elongated in seasons of the year [13]. When a room is appropriately lights it would have a very good psychological effect on the users, and reverse is the case when it is dark most of the time, its psychological draw back will definitely much.

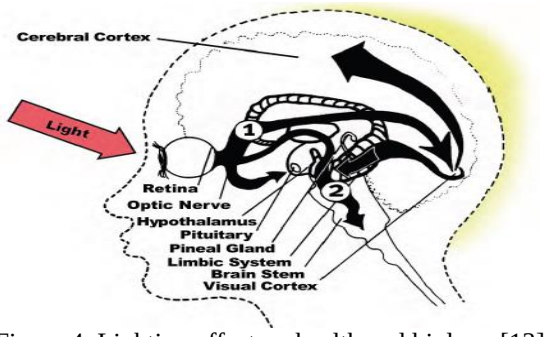

Figure 4. Lighting effect on health and biology [13]

3.1. 1. Cardiovascular diseases

When human being have deficiency in vitamin D, there is tendency for them to easily have problem with their cardiovascular system, which causes heart diseases, however, researchers suggested that this harmful effect can be readdressed if the body is supplied with vitamin D [14]. Researcher in the field of medicine advocated that hypovitaminosis D, is said to be common among patients who are having heart diseases such as hypertension even though hypertension might be attributed to genetic reasons, also vitamin D deficiency is one of the causes. According to transrnal and dialysis patient's experiences high blood pressure during winter more than in summer; this is attributed to their exposure to short daylight.

3.1. 2. Cancer, vitamin D deficiency & daylight

High UV radiation is one of the principal's reasons for skin cancer diseases; however, there are also other causes. The risk of being affected by this disease can be avoided with reducing exposure to UV in daylight radiations. It must be noted that research in the field of medicine advocates that, the body can gain vitamin D from the sun which in turn prevent, some other types of internal cancer, i.e. prostates, ovarian and breast cancer, hence, there are general agreement that vitamin D gain from sun have high tendency of prevention of types of internal cancer mentioned . The liability of death caused with skin cancer is less than those of internal body type [15]. The only way to make good use of daylight for it not to causes disease is to control it well, using appropriately sized and designed shading devices.

3.1. 3. Bone diseases

Human beings rely on sunlight to fulfil their needs for vitamin D, photons in solar radiation are conceived by skin and then converted to previtamin D3, which in turn transformed to vitamind3.When infant suffering from lack of vitamin D not only results in to rickets among them, but also resulted in to deteriorates osteoporosis for adult and causes serious painful bone disease osteoporosis [16].

3.2. Daylighting and psychology

Research proved that appropriate utilization of natural light reduces the occurrences of headaches and eyestrain. These illnesses mentioned are caused due to insufficient lightings levels, however, these illnesses could be reduced when lighting level is enhanced [17]. Human beings are influenced to greater extend by availability of daylight, however, human biorhythm is said to be built on, quantity and quality of natural light available throughout day and night. Research proved that in a situation where human beings work longer hours of the day under artificial light

without getting access to daylight, there is high tendency of him be affected with diseases. In winter season, central Europe experiences less quantity of daylighting, therefore, there is likeliness of people living here to have winter depression, which is known as (Seasonal Affective Disorder or SAD).

3.2.1. Stress

When workers work in windowless area, there is much tendency for them to experience much job stress compared to those having direct axis to windows and daylight [18]. Research conducted in 141 nurse in Turkey revealed that when nurse staff in a hospital were exposed to natural light for three hours daily they turn to experience less stress and feel happy with their work.

Figure 5. Sunlight brought into an underground office 30 meters below ground on the campus of the University of Minnesota [19]

Allowing daylight penetration to building is very necessary, but unfortunately most of health care now days permit less quantity of daylight to interiors. Moreover, occurrences of medical errors' among nurse staff happens most often in middle of winter than summer, however, the research postulates strong tie between availability/absence of daylight and medical errors, but didn't clearly stated weather it is as a result of psychological or stress.

3.2.2. Daylighting and mood

In areas that lighting is unnoticeably used for instances offices occupant's mood might change due to change or fluctuation in light even if this light is not clearly visible. Researcher in the field of environmental psychology suggested that slight alteration in lighting can in turn make changes in human mood of the users of building [20] The tendency of people having depressive disorder diseases have tremendously increased in recent years, as people reliance on artificial light to grater extend have increased, most especially among urban areas dwellers and night shift workers because of their exposure to excessive artificial light in the night may be one of the factors that said to be contributed to depressive mood disorder among vulnerable persons. Using artificially lighted environment, however causes disorder to human biological clock, which affects human biological rhythms, and could therefore negatively affect his mood. No matter how good the quality of artificial is, but still remain the most favourable to majority of people, because under it they feel at well being.

3.2.3. Daylighting, window and the therapeutic environment

Nemours research have documented the merits of providing daylight and windows in health care facilities as, reducing pain, medication/cost and reduce hospital study duration for bipolar patient. When windows for wards are positioned in a manner to provide natural views for patients of surgical wards, there is high tendency for them to heal faster than those in wards that have no access to natural views [21]. The quantity of daylight needed for human health is one of the hottest issues of research that still controversial. Till now the specific quantity of day light human need is not yet accurately determined.

4. Perception of Light in Architecture

Visual comfort in interior spaces to great extend depends upon the quantity and quality of light passing through them and the space characteristics. When architect using colours they should be conscious with the behaviours of colour with light, for the fact that each colour has reflectance coefficient which affect its reflectivity when exposed to light. An other factors that affect visual comfort of interior space users are their psychological and physiological backgrounds, all these are said to be connected with their sight [22].

It must be noted that most architects now days fail in the issue of not considering natural light in their design. Interestingly most ancient grand masters of design of Greek, Roman, and had considered daylight design in their design at conceptual stage, this one thing that made their design to be great and sustainable till today.

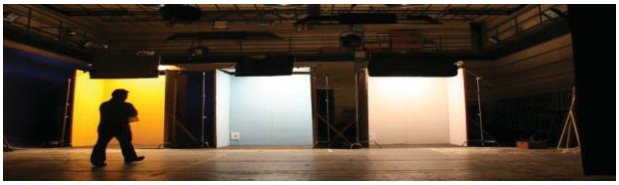

Figure 6. Light behaviour with different colours A, B, C. [22]

Very few architects, however, are sensitive enough to imagine and design in their mind the light being planned for these spaces. The shape and proportions of a building are important for its natural lighting, depending on the location of the opening. As a rule, irregular or elongated spaces with light entering at the end have a rather irregular light distribution (Figure 7).

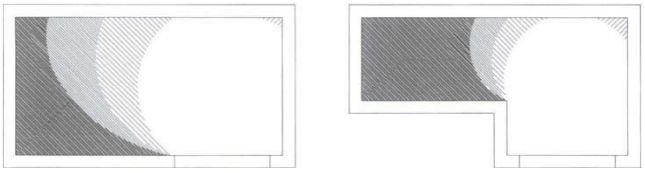

Figure 7. Relationship between shape and light distribution [23]

It should be taken into account that the lateral entry of light into a space causes a rapid decrease in light (i.e., illuminance) the further we are from the opening, due to the premises easily being badly lit, even if the total amount of light present is sufficient. The entry of zenithal light, on the other hand, tends to be more suitable (Figure 8).

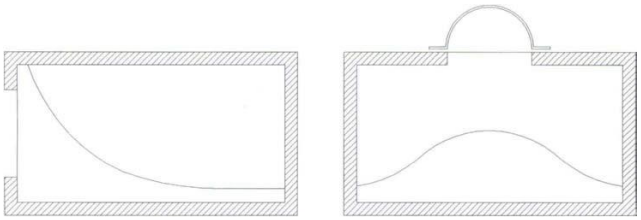

Figure 8. Relationship between shape and light distribution [23]

Finally, differences in the floor level have repercussions on both lighting and the view. If the floor drops towards the middle, the light distribution improves but the view is reduced, and vice versa (Figure 9) [23].

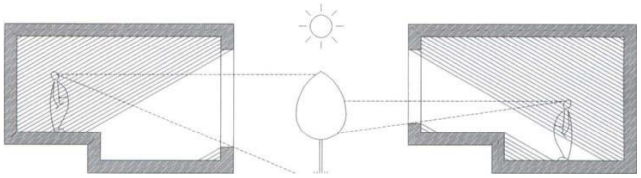

Figure 9. Variation of Light and views in stepped premises [23]

In new parliament building of Germany in Berlin, the central dome is used to project natural light to lower part through hundreds of mirrors forming the middle funnel as shows in figure 10 [24].

Figure 10. Light behaviour [24]

One of good example is Kimbell Art Museum is considered as of the most glorious buildings in the world, which is light-emitted by daylight. The designer, Louis Kahn chose the most modest level of daylight for ambient lighting in the building. For his quest to satisfy the biological needs by daylight in order to creates comfortable feeling for visitors [20].

Figure 11. Light Kimbell Art Museum (above-left), Gallery (above-right), Entrance Hall (venter-down)
Architect Louis Kahn used vines to soften the flow of daylight to interior (down) [25]

4.1. Daylighting Improvement in Buildings

Daylight provision depends on the building design: windows, internal reflectances and the type of glass. But the external environment is also important. Large obstructions outside reduce the amount of daylight entering a window. Consider a room with a wide continuous obstruction outside, like a terrace of houses or apartments. Working from the basis of the considerations in the above sections, we shall now attempt to analyse natural lighting systems, considering them as a complementary strategy to the general lighting design of buildings. Natural lighting systems are components or sets of components of a building the chief purpose of which is to improve the natural light of inhabitable spaces, optimizing the distribution of light in peripheral zones and attempting to bring as much natural light as possible into interior zones with no direct contact with the exterior. Among the components of natural lighting we make a distinction between pass-through components and conduction components. Conduction components are those which take natural light from the exterior towards interior zones of the building. They are frequently connected, forming continuous series. Pass-through components are devices designed to allow the passage of light from a given light environment to one located next to it. From this analysis, any combination or succession of pass-through and conduction components can be established, and we can interpret a building in lighting terms as a series of pass-through components placed between conduction components which connect them. In this way it is possible to schematize any complex system for the entry of natural light towards interior spaces. Pass-through components for natural light can be highly complex; so in order to analyses them we consider them as being composed

of a set of control elements through which light passes. These control elements which make up the pass-through components correct the light reaching them and send it on to the neighboring conduction component in a controlled way.

5. Conclusions

Daylighting is readily available in abundant, but its appropriate utilization involves some critical and costly measurements. However, proper usage of daylighting depends upon: building form; orientation; opening sizes; and obstacles surrounding buildings which might hinder their exposure to daylight. In areas characterized as being urban dense it is challenging to orient daylight deep inside the building, but in such areas architects should use their creative skills to use colours, form and texture to achieve balance between daylighting and artificial lighting.

Numerous researches carried out proved that daylight have great importance on: health, physiology, psychology, mood, and productivity of human beings. Daylight shouldn't be considered in the perspective of visibility only, but must rather be seen as a tool to enhance human health and well being. There is an urgent need for architects to consider proper utilization of daylighting in the first stages of their design process as an important part of their philosophy in architecture. Having considered all what mentioned above, the building would be healthy and support human health in order to achieve sustainable development through sustainable healthy buildings.

References

[1] Selkowitz, S., 1998, "The elusive challenge of daylighted buildings: A brief review 25 years later'' Proceedings of daylighted 98 Conference, Ottawa, Ministry of supply and services, Canada: Ottawa, ON.

[2] Balanli, A., Öztürk, A., 2006, Yapı Biyolojisi – Yakla¸sımlar. YTÜ Üniversite Yayın No: YTÜ.

[3] Boyce, P.R (2010) The impact of light in Buildings on Human Health: Indoor Built Enviroment.

[4] Johnsen, K, Watkins, R., 2010, Daylight in Buildings. ECBCS Annex 29/ SHC Task 21 Project Summary Report. Published by AECOM Ltd. On behalf of the international Energy Agency Energy Conservation in Buildings and Community Systems and Solar Heating and Cooling Programmes.

[5] Ander,D.G, 2014, Daylighting''.Updated by U.S. Department of Energy Federal Energy Management Program (FEMP).Available at: http://www.wbdg.org/resources/daylighting.php

[6] Maslach , C. and Jackson , S. 1996. Maslach Burnout Inventory. Palo Alto CA: Psychologist's Press .

[7] Hollwich, F., 1979, The Influence of Ocular Light Perception on etabolism in Man and in Animal, New York: Springer Verlag.

[8] López, J et al, 2012, Visual Comfort Assessment Based on perception in Transitional Spaces Between Inside and Outside : A Mediterranean Case Study. Architecture & Energy School of Architecture of Barcelona.

[9] Stewart, J.R., 1977, Solar Shading in Kuala Lumpur, Majalahg on Student Learning'' A report available at: http://sgo.sagepub.com/content/2/2/2158244012445585. (Accessed 4-05-2015)

[10] Kungolos, A, et al, 2009, Sustainable Development and Planning, Vol. 4 No.1. Southampton.

[11] Kuller, R. and Lindsten, C., 1992, Health and Behavior of Children in Classrooms with and without Windows, Journal of Environmental Psychology, Vol. 12, pp. 305-317,

[12] Van Bommel, W.J.M., 2006, Non-visual biological effect of lighting and the practical meaning for lighting for work. Applied Ergonomics, 37: 461-466.

[13] Walton, A.G, 2012, Your Body's Internal Clock and How It Affects Your Overall Health, Available at: http://www.theatlantic.com/health/archive/2012/03/your-bodys-internal-clock-and-how-it-affects-your-overall-health/254518/.

[14] Rostand , S.G., 1997, Ultraviolet light may contribute to geographic and racial blood pressure differences . Hypertension 30 , pp. 150-56.

[15] Grant , W.B. and Garland , C.F., 2006, The association of solar ultraviolet B (UVB) with reducing risk of cancer: multi factorial ecologic analysis of geographic variation in age–adjusted cancer mortality rates . Anticancer Research 26 , 2687 – 700 .

[16] Holick, M.F, 2004, Sunlight and vitamin D for bone health and prevention of autoimmune diseases, cancers, and cardiovascular disease. Journal American Society for Clinical Nutrition, pp 1678S– 88S.

[17] Franta, G.; Anstead, K., 1994, Daylighting Offers Great Opportunities, Window & Door Specifier-Design Lab, Spring; pp. 40-43.

[18] Heerwagen, J.H, and Wise, J.A., 1998, Green buildings benefits : differences in perceptions and experience across manufacturing shifts, Heating, piping Air.

[19] Isen , A.M. , Means , B., Patrick , R. , et al., 1982, Some factors influencing decision-making strategy and risk taking. In Clark , M. and Fiske, S. , eds , Affect and Cognition. Hillsdale NJ: Lawrence Erlbaum Associates, Inc.

[20] Schristian, S., 2003, Solar Architecture. (Strategies, Visions and Concepts). Publisher, Architecture Based. Boston, Berlin, Germany, pp. 60-62.

[21] Flynn, J.E., 1977, A study of subjective responses to low energy and nonuniform lighting systems. Lighting Design and Application, Vol. 7, No. 2, pp. 6 – 15.

[22] Zadeh, R.S, 2014, The Impact of Windows and Daylight on Acute-Care Nurses' Physiological, Psychological, and Behavioural Health. VENDOME GROUP LLC.

[23] Coch , L.H, et al, 2013, The perception of light affected by colour surfaces in indoor spaces''. Architecture & Energy. Barcelona School of Architecture.

[24] Guzowski, M., 2000, Daylighting for sustainable design. New York: Mc Graw-Hill.

[25] Sabzipour, M, et al, 2013, The Use of Daylight in Architecture with an Emphasis on Reducing Energy Consumption'' . Research Journal of Applied Sciences, Engineering and Technology Vol. 5, No. 11, pp. 3098-3104, 2013 ISSN: 2040-7459; e-ISSN: 2040-7467.