

# The Significance Of Lightening Determining Interior Environmental Quality

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**Abstract:** The purpose of the study is to present the significance of the lightening for an individuals' perception, attitudes, feelings, behavior, and achievement. The research deals with daylighting and controlled daylight, as well as artificial light. It highlights the correlation between light and human needs. The study presents a wide theoretical review on the topic that offers suggestions and recommendations. The findings of the study deal with the particular environment: the classroom and demonstrates the samples of lightening design. The study shows the significance of lightening determining the interior environmental quality and it has a huge contribution to school and classroom design.

**Index Terms:** lightning, daylight, controlled light, artificial light, classroom setting.

## 1 INTRODUCTION

Many experts have been discussing the importance of lighting and the impacts it has on space environments and people who are space consumers. Lighting as a particular space is very demanding for the reason it has the total impression of space. When it comes to an enjoyable environment, it is also essential for productive acting within the area. There are various reasons an individual chooses to spend time at a particular place. It is due to work, study, entertainment, living... In order to prove its justification and the purpose of the space, we need to apply the lighting solution, in other words, lightning design. Many experts directly involved in the process of lighting are interior designers, architects, landscape architects, and external designers. A relatively new profession that is much related to the lighting is a lighting designer. Since the lighting stands for the aesthetic which is known as the art of lightening, this art requires huge knowledge about technology and visual arts. There must be a balance achieved for the sake of people, security, and the atmosphere. The term lighting, on one hand, has a physical dimension as energy, but on the other hand, these dimensions create the response of humans towards the environment. From the physical point of view, lighting is a spectrum of electromagnetic waves with all physical sizes: speed, frequency, wavelength, energy value etc. However, for many subjective points of view, lighting is the tool for information collection. In terms of architecture, the subjectivity attitude is more important. There has been a lot of research done on lightening. Research focuses on the application of the lighting and the factors that demand a particular sample. The conducted research is also related to tech quality and visibility in people's environment. The main components of lightening are space, luminaries, and color appearance; integration of daylighting and control, glare, light distribution within the space, the luminance of room surfaces, shadows, highlights, modeling of faces/objects, allowed flexibility and required illumination for a particular task. Many criteria are essential points for lighting designers such as the amount of illumination. Firstly, designers follow a unique procedure in terms of programming and schematic design. The steps in such a procedure are visual task, general lightening or ambient lightning and visual interest. The visual task can be described as an ability to walk safely all along the corridor. General lightening can be presented as a lightening system in order to circulate safely within a particular space and visual interest makes all these lightening tools more magic and appropriate for a human eye. Imagine a restaurant without a visual element, it would seem so cheap and not attractive. Yet we should not forget that we need lightening for a nice

atmosphere with our spouse, lightening for menu reading and lightening to find the doorway out. However, there is still a question posed. Does lighting in the restaurant bother the guests? Is the psychological response positive? In what way lightening affects people's behavior? Do clients enjoy it? For all of these reasons, lightening designers are meant to consider the consumers' behavior while using the space. It is believed that lightening in great extends shapes consumers' behavior: space consumers need to have an orientation in the space which is reached by horizontal and vertical junctions. It means that safe navigation is reached when horizontal meets vertical. In case when the junction of horizontal and vertical elements are the same in terms of hue and value, a problem pops out for the reason visual abilities are limited due to the specular surface.

### 1.2. Background of the study

There were only two types of lighting in the historical period from the history of mankind until the 18th century. Having the daylight as a primary element and main light source, the human added a flame as a second one, during the period of Stone Age. Many paintings in history, placed in caves, are made in the absence of natural light. So to work on them and to see them, the artificial light is required. However, in everyday use, sunlight is the main light source. Whole buildings and the spaces inside the buildings were made according to the natural light. Even the dimensions of the interior spaces were determined by the quality of natural light and air quality. When it comes to natural light, some factors should be taken into consideration while research. These factors are the natural light condition in different weather conditions and the glare-reducing of daylight (Hamon, 1948). The place of the building also determined the form of lighting. Buildings in areas with cool climate used to have big and high openings, in order to catch the sun and daylight. The shadows, glare, and sunshine occur in the spaces with big windows, but in places with the cool climate, these effects can be neglected. On the other hand, the buildings in the areas with the hot climate, have small openings placed in the lower part of the walls, in order not to penetrate huge amount of sun into the rooms. The light in that period was also used for aesthetic purposes. The falling sunlight, except for lighting purpose, was also used to create and influence the perceptual psychology in a sense of aesthetic, emphasizing the three-dimensionality of the columns and decorations. When it comes to lighting in the period until the 18th century, the artificial light, in comparison to the natural daylight was very weak and poor. The daylight

was lighting whole space, while the light of a candle was pointed and always limited to one certain environment. In order to have a well-lightened space in the absence of daylight, there was a need for plenty of candles that were generally expensive and used only for important gatherings. Thus, architecture and lighting were generally related to natural light until the last decades of the 18th century. In comparison with candle and gas lamps, recognized as a very weak light source, in the first part of the 19th century by creating the voltage between two carbon electrodes, an extremely bright arc could be produced (Ganslandt&Hofmann, 1992). In the first part of the 20th century, until World War II, the open-air classroom system was spread. The characteristic of this kind of classroom was that one whole side of a classroom was opened towards the outside garden. Ventilation was very good in these types of classrooms; also the light penetration of the daylight was maximized. But, as mentioned, in the 1980s the artificial light was involved in classroom lighting. By developing different types of artificial lighting and air ventilation, the window size was decreased during the time. Teachers complained about big sized windows claiming that the attention of students is decreased.

## 2 LIGHT AND HUMAN NEEDS

For an indoor environment, light is important not only as a tool to see or to collect the information from the environment but lighting is also important as a mechanism as well as its quality either. Wurtman states that, in order to control the body functions, the lighting, besides water and food, is the most important input in the environment (Wurtman, 1975). Light enables visual performance (Grangaard, 1995). According to Czeisler et al, human evolution was influenced by light. The internal clock inside the human body was developed according to light/dark day mechanism (Czeisler et al, 1999). So, the main body processes are influenced by light, such as sleeping and alertness (Takasu, et al., 2006). An architect needs to know the mechanism of transportation of objective dimensions into a subjective experience, in order to use this information to create the space. The literature review shows that the information which is presented visually is received faster than the information received through communication, which represents the importance of visual information absorption. Human being has a special system through which the objective dimensions of light refract making the picture of reality, with many subjective dimensions of every individual. "Light reflected on surfaces links the visual environment with human feelings, creating mood" (Steemers and Steane, 2004, p.179) The purpose of light is to provide vision through the eyes. There are cones and rods inside of the eye, called photoreceptor cells, which regulate the effect of seeing. When these cells get in touch with light, the chemical reaction with high complexity occurs. Electrical impulses are created in the nerve, which is a connection between these photoreceptors and the visual cortex in the brain. In the cortex, these impulses create the vision. Rod cells are active only in a decreased level of light and do not deal with color. The cones are active in the daytime when the level of light is decreased, and they usually deal with the formation of details, sharpness, and color. Eyes are the main receptors in the human body that can gather information from the environment. Light, in a way how it is spread, creates the conditions of a certain area that impacts the human perception. That is the reason why lighting design

plays a crucial role in creating the environment. Successful lighting design means well-being, effective work and safety movement in the space (Ganslandt&Hofmann, 1992). That's why an individual must be taken into consideration while designing the light. "How designers exploit the conclusions of behavioral research will give a unique identity to the buildings they design, based on their awareness of, intuition for and sensitivity to the future users" (Steemers and Steane, 2004, p.192). The transport of information from the environment is not as important as the interpretation of information and the creation of visual impressions. Some of the researchers claim that the spatial aspect of perception is innate, but also the perception is also determined by the earlier experience (Ganslandt&Hofmann, 1992). When one object is seen once, it will be perceived very easily in the future, neglecting the value of object complexity. As a result, there is a very big importance of innate and experience factors both in creating perception. The role of an innate component is to gather and to organize the information, while the role of the experience component is to interpret the environment. Light also plays a huge role in the evocation of emotions. Light can be used for bringing the aesthetic pleasure to space, creating a different atmosphere, which will affect the emotions. The feel of well-being has a great correlation with light. Many studies show that "light does not only serve to render spatial bodies three-dimensional. It is an excellent means for controlling our perception on a psychological level" (Ganslandt&Hofmann, 1992, p.13). If the lighting in the inner space is improved, also the wellbeing and comfort of humans will be increased, because of the biological need for being well informed about the environment. One of the feelings, which is placed in consciousness, is the feeling of safety. Humans need to know the orientation, position, the correlation with the environment, and the possible situations soon, in order to give a qualitative response. Blood pressure, brain activity and biorhythm are affected by lighting. So, humans' behavior is determined by the knowledge about the mentioned information. The absence of natural light influences the production of the hormone cortisol, and also the abilities of students are also decreased (Kuller and Lindsten, 1992). Light impacts the hormones, especially the production of cortisol and melatonin (Berson, 2002). The light of one internal environment is determined by human physiological and psychological needs, which will represent the visual comfort. In order to learn it all requirements are fulfilled, we need to know some specific information:

- Lighting level,
- Uniformity of lighting,
- Distribution of brightness,
- Limitation of glare,
- The climate of light color,
- Economy,
- Aesthetics (Hadrovic, 1996).

### 2.1. Lightening in a particular environment: classroom

When the lighting is not designed properly, it produces discomfort, overheating of the room, it interferes with the ventilation and air quality, and the energy use is increased. Opposite to that, properly designed lighting will not include glare, it will produce comfort, balance, sufficient amount of light. And also, as mentioned, the sight to the outside of the building is provided. Since lightning is one of the most important factors for working and studying the condition, Hadrovic (1996) in his studies uses the term "the climate of

light color" which is considered as the psychological relation of human to light. The level of illumination is determined by room purpose and it is regulated with regulation as minimum average illuminance. We classify the color of light as warm, white and daylight (Hadrovic, 1996). Visual acuity depends on the brightness of the observed objects. The visual acuity is proportional to the brightness. The minimum brightness for communicating (facial recognition) is 10 lx (vertical lightening) and 20 lx (horizontal lightening) that makes the glossiness of 1 cd/m<sup>2</sup>. The minimum brightness for workrooms is 100 lx (vertical lightening) and 200 lx (horizontal lightening) that makes the glossiness of 20 cd/m<sup>2</sup> (Hadrovic, 1996) Having in mind that lighting has a very huge impact on human mood, vision and achievement, the impact of lighting in classroom environments cannot be neglected. Many studies were done in order to improve the concentration and motivation of the students in the classroom. The result of many studies showed that the correlation between lighting and individuals' behavior/achievement surely exists. Hammond (2000), states that the light impacts the eye tracking, focusing and strabismus. Hammond in the same study claims that problems affecting eyes can cause behavioral problems (Hammond, 2000). The mood and cognition of a human can be affected by lighting, Veitch and McColl (2001) state that lighting has these implications: Better performance in an academic environment, Better life quality and the feeling of well-being (Veitch&McColl, 2001). For example, the electric lighting was not available in school classrooms during the time, and only the natural lighting was used. In order to sufficiently use natural light, the school buildings were designed accordingly. The main rule in design about natural light is that light should come from the left side of a student (Hamlin, 1910). "The importance of orientation in a building must be considered at the outset when the architect is planning the location of the building on the site, the aim being to ensure the maximum availability of useful natural light and sunlight to the interior" (Phillips, 2004, p.25). Phillips also confirms that if the daylight comes to the classroom only from one side, the sunlight should reach the working desks from the left. "Contemporary research and thought regarding lighting in classrooms has largely focused on the need for performance-based standards that accurately represent both illumination and visual comfort metrics" (Baker, 2012, p.22).

## 2.2. Suggestions and recommendations

All the results of the research made in the last couple of decades gave a huge contribution to school and classroom design. According to Phillips (2004), in order to have a good building design, there should be a holistic approach: The position of the building - use the opportunity to have the best orientation where ever the environment allows. Sun path and the position of surrounding buildings need to be included in the design. The function of the building will determine the dimensions of the rooms, height, width and length. Room depth and room height have crucial importance, which will affect the overall room performance and building cost. Size of the windows and their position on the external walls. Elimination of glare, the control of heat transfer and the provided outside view are the things that should be taken into consideration, as well as to provide the light for proper visual activities. This segment of decisions in the design process is the most important for architects since the positions of windows will define the exterior outlook of the building.

Prepared windows specification is important, with included parts about glass used, transmission value etc. This will help in the design of other disciplines included in the building system, such as ventilation, sound fade, and energy conversion. The system of control is very important, such as control of sunlight, glare etc. The control of artificial and daylight in general in order to have energy savings (Phillips, 2004). The orientation of the building and the windows' characteristics in the classroom is much more needed during the day than during the night. The orientation is required at the beginning of the design process. The purpose is to provide the best accessibility of natural light to the interior. There are many cases where several limitations in the environment occur. But even then, the best availability of daylight must be provided. It is much easier to set a building on flat terrain without surrounding buildings, where the maximum of daylight could be used. On the contrary, designing a building in an already constructed environment could be challenging. Openings and their size are related to the daylight design. Logically, if the window is bigger, the daylight presence is equally bigger. The height of the window has importance, thus the increased height of the openings will provide better penetration of daylight into a room. In case, the window is positioned more to the top, the effect of glare will be avoided. Kuller and Lindsten (1992), as doctors of medicine, claim that there is a biological need for openings in closed space. They claim that classroom without windows should not be used permanently. Despite being a factor of distraction, the students should enjoy gazing through the window. It is easier to focus on the lecture in the presence of window gazing. Windows are the tool for bringing the natural environment from outside to the interior. So, the task of the window is to make the relationship between a student and the environment. This relation is impossible with high positioned windows (Alexander et al. 1977). Tanner and Lackney (2006), claim that windows which provide the view to outside life, positively affect the students' productivity. They also claim that students need to have an unobstructed view of outside life. In the absence of glare, it would be good to use every opportunity to put away the curtains and posters, to provide a view to outside. According to these authors, students should also be able to have outdoor views to gardens, mountains and sky, which does not need to be from the place of their sitting. The students should have a view expending at least 15 meters outside the building. Having a green area or trees around will increase the positive impact of outdoor view to students. Dealing with the same themes, Alexander et al say: "It is important to make the best use of a view by ensuring that it is taken from places of transition and not straight on. Furthermore, views should not necessarily be visible from the places where people sit" (Alexander et al., 1977, p. 643). The same claim that view should extend to at least 15 meters, have Nair and Fielding, for resting the students' eyes (Nair&Fielding, 2005) "People require changing stimuli to remain sensitive and alert. For example, gazing out the window at distant objects provides relief for the muscles of the eye. And the constantly changing nature of daylight satisfies our biological and psychological needs for change—a view of the sky provides information about the time of day, which helps maintain our biological cycles, and the varying light intensity as a cloud passes in front of the sun provides respite or stimulation, which helps reduce monotony" (Gordon, 2003, p.51).

### 3 DAYLIGHTENING AND CONTROLLED DAYLIGHT

Sun has been the main source of light for many centuries. Almost all horizontal and vertical plans, openings, compositional principles, are made according to the sun path. The main deficiency of the sun is its periodicity because, during the day, its intensity can be increased or decreased.

"Daylighting is an excellent light source for almost all interior spaces. It is best for offices, schools, and workspaces requiring a lot of light and for public spaces such as malls, airports, and institutions. Windows, skylights, and other forms of fenestration are used to bring daylight into the interiors of buildings. Daylight is highly desirable as a light source because people respond positively to it" (Karlen&Benya, 2004, p.31).

Upon his studies, Heschong et al. in 2002, states that educational buildings with a huge amount of daylight and with big-size windows and proper skylight have a noteworthy influence on students' performance and behavior. While controlling socioeconomic status (SES) over 21,000 students in California, Heschong Mahone Group (1999) ascertained that students with more daylight in the classroom achieved better results in mathematics for 20 percent and 26 percent in reading tests than the students having the lectures in the classroom with less daylight (Heschong Mahone Group, 1999). They also claim that students with bigger window areas were 15 % faster in math, while 23 % were faster in reading tests than students attending lectures in classrooms with smaller windows. In order to reach comfort, the light changes should be used, because the monotony results as fatigue, while the changes in the environment result as stimulation. Contrast that will occur in a short period, produces the instant comfort and well-being, but contrast which lasts will decrease the performance of the vision. As an example, if sudden sunlight ray hits the interior and if lasts just a couple of seconds, it will create a relief and well-being effect at that moment, but if that sunlight ray stays for a long time, it will produce stress and discomfort. Daylight, as a natural light source, has two components: sunlight and skylight. Sunlight is the direct light coming from the sun, and the skylight is the diffuse reflection of light in the atmosphere (Gordon, 2003). Sunlight, as a component of daylight, is not practical to be used in interiors, while the skylight is more appropriate for indoor natural lighting. If there is a presence of sunlight, careful control is needed, because the discomfort and poor visibility may occur. The sunlight creates a high contrast in the room, so the additional effort of the eyes is needed, which causes fatigue and visual disability. "The proper introduction of daylight into the interior is the simplest way to provide this change. The goal of daylight design is to provide visual variety with controlled brightness contrasts" (Gordon, 2003. p.51).

"Daylight does not cost-free, and factors such as the control of sunlight, heat gain and loss, the association of windows with ventilation and the question of whether the windows should open or the building be sealed, are all problems which need to be addressed; but these need to be equated with the human desire for association with the natural environment, as well as the possible savings in electricity and cost" (Phillips, 2004, p.20)

As we control the daylight, choosing just a skylight, avoiding

the sunlight, the radiant heating of the sun needs to be controlled. There are several ways how to control the radiant heat transfer, one of them is building orientation. The low moving winter sun can be caught in a purpose for heating, and the strong summer sun moving highly on the sky can be avoided with some additions on roof and facades. If the building is orientated towards the north, the light from the north is quite soft and cool, and if it is orientated to the south, light is more sharp and strong in a sense of radiant heat. However, no matter how the building is orientated, by quality daylight control, the same effect of lighting can be reached. When the daylight system is properly designed, the light is without glare, diffused and the light is provided from more directions, also in properly designed daylight systems there is sufficient level of light, there are proper devices for shading to avoid heat gains etc. Heschong Mahone (1999) reported the importance of controlling daylight in classrooms. They claim that well-controlled daylight, with a skylight that can be adjusted, which is diffused and with reduced glare, will contribute to a better and faster students' performance and achievement (Heschong Mahone, 1999).

#### 3.1. Suggestions and recommendation

The classroom with the diffused, uniform daylight provides the best performance of students. The daylight in the classroom should be in such a presence that the artificial light will remain turned off even on overcast days.

A solution for solar shading, according to Phillips:

External shading,

Internal shading,

Alternative glazing (Phillips, 2004).

One of the very good solutions in daylighting is the use of exterior light shelves. Their purpose is to remove direct sunlight into the inner space (Innovative Design, 2004). When glare is reduced, the solar heat is also reduced. The good solution to avoid glare is the shelves that provide the rays reflect on shelves before entering the space (Hampton, 2010). Shelves can be used in interior spaces with 3m ceiling height, and as such will provide light for 6 meters in room depth (Innovative Design, 2004). During past decades, many schools were built using the recommendations from researches with enough amount of daylight. The glare was the main focus of Blackwell (1963), and the impact of glare on visual performance. He stands that the influence of the glare is evident no matter of quantity of the illumination (Blackwell, 1963). For the rooms that are not oriented to the south, or with no windows, then, the solution would be the roof monitors. The daylight and even sunlight could enter into space over roof monitors. The control of the sunlight is a complex procedure, so the sunlight could be avoided by baffles and diffused glass (Oldroyd, 2005). Oldroyd also states the roof monitors should only accept the daylight coming from the north. To avoid glare and to have effective lighting, the interior of the roof monitor should be covered with reflective surfaces (Oldroyd, 2005). Eighteen different types of lighting systems were the research focus of Sampson (1970) to maintain the contrast from each of them that impacts the ability to do specific tasks in the classroom. He concluded that brightness was not so much important for the no close visual work. But the brightness was important for a close visual work of students. Sampson also suggests that the brightness should be the same in every corner of the classroom and that the light sources should not

attract attention (Sampson, 1970).

#### 4 ARTIFICIAL LIGHT

The human condition is essentially determined by light. The environments with a different type of lighting, such as natural and controlled one, became the main issue for the students' achievement. The amount of daylight during the day depends on the time of the day, time of the year, weather, level of pollution etc. (Karlen&Benya, 2004). So, in case there is a lack of daylight, it is necessary to supplement natural light with artificial light. The term 'artificial light' considers every type of energy that is converted to light. The artificial light sources in the classroom include overhead indirect/direct fluorescent luminaires, incandescent accent luminaires, etc. The use of artificial and daylight as a combination, and what if artificial light match the daylight? Choosing artificial rather than natural light is the best choice, but such light may result in cool light effects at night. Color temperature and intensity of light illumination are the two important factors in artificial lighting. The intensity of light is measured with "Lux". The color of temperature is measured with Kelvin and represents the level of the light hue and varies in amounts between cool and warm. Cool temperature represents white and blue, while the warm temperature represents yellow and red. Knez (1995), investigating the effect of light on human performance, found the result that women had better performance in warm white lighting atmosphere, while men had better performance in cool white lighting. Because of different reacts, the mood among genders was differently affected, too (Knez, 1995). As mentioned, important factors for student performance are the room color and lighting, as well as lighting color. Studying the productivity of workers in the industry, Papadatos (1973) states that carefully chosen colors for interior increase the production of 5 to 10 percent and impact the atmosphere creating positive feelings.

"Forms of florescent lighting may affect some students and teachers negatively by causing mild seizures" (Tanner and Lackney, 2006, p. 270). According to Ott, cool white fluorescent lighting can positively impact students' behavior in classrooms, especially to students having learning disadvantages (Ott,1976). Ott, also claims that when radiation of lighting is decreased, behavior among students is improved.

#### 5 CONCLUSION

Careful consideration is needed for the appropriate lighting that creates the visual environment because the light despite being a tool for environmental data collection also creates a subjective attitude inside of the human. The sense of vision influences the students' ability to accept the visual stimuli creating a general impact on attitude, perception, feelings and behavior. The physiological consequence can be a result of the light that is not spread properly. The improper light design will cause discomfort, room overheating and will be in collision with air quality and ventilation. The properly designed lighting system will produce comfort with a sufficient amount of light without glare and light contrasts, where the sunlight is properly controlled and where the skylight is maximally exploited. As a conclusion, for a particular space, proper classroom lighting should provide a visual ambiance that the student absorb visual information efficiently and with no distraction and extra effort. Good and proper lighting creates a good environment that affects the students' performance.

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