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Lighting quality and human health problems in man-made environments

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A B S T R A C T

In this paper, the features and types of lighting in different environments have been reviewed to highlight their effects on the biological human body. Secondly, strategies for domesticating healthy daylight in buildings and design of light sources have been graphically presented to define their critical zones. Next, the mechanism of body organs against light considered in different environments with different values. Finally, the rate of antidepressants consumption and average hours of sunlight per year in the most populous cities of twenty-one countries presented that shows an inverse relationship between antidepressants consumption and average hours of sunlight. Inappropriate lighting may harm physiological systems such as the visual, the nervous and the endocrine, the pineal, and the pituitary systems, as well as cardiac activity and skin conductance. It is noticeable that each problem creates or increases stress and depression. Natural daylight produces serotonin which is called the happiness hormone. Therefore, the rate of depression among residents of southern blocks, who absorb more daylight, is less than other blocks in winter. The most effective factor to obtain daylight and its pertinent quality is appropriate orientation. On the other hand, indoor lighting quality defines the level of visual comfort, which is measured and evaluated under the Relative Visual (RV) Performance model.

1. Introduction

The importance of lighting conditions is on the verge of gaining more recognition as the impacts of appropriate lighting practices on individual`s emotions and performance, are well-emphasized in the environment, architecture, urban design, hygienic and medical literature. Vast amounts of resources are allocated to designing spaces that appreciate the right choice of lighting conditions in interior spaces. There is little to no scientific evidence that would suggest the validity of these claims, however. In spite of the extensive amount of literature written about lighting, the drawn conclusions on color and light influences provide heterogeneous results. Subjective methods are used in the conduct of research on the effects of light on individuals that would make the studies speculative at best.

This research is framed around the notion of a demand for replicable research in finding the emotional effects of light and color on individuals. In doing so, physiological and psychological qualitative methods are used to safeguard objectivity, replicability, and reproducibility. The problems this paper attempts to tackle are more specifically related to health problems caused by building design as well as its lighting quality which are in disaccord with human body response to artificial and natural light. Proper lighting is at the heart of an appropriate spatial design, which is to avoid insufficient light at one end, and disproportionate lighting at the end of the spectrum. The latter increases health risks risen from exposure

to excessive light is the central concern of this paper. Principal questions of interest are as follow:

• What is the light, and how does it effect on the human health?

• What are the health problems related to the lighting quality of the building?

• How the organs get influenced by lighting?

• What are the building techniques to use of appropriate light?

2.1. Light Definition and Lightning Strategies in Man-Made Environments

Light is electromagnetic radiation within a certain portion of the electromagnetic spectrum which is visible to the human eyes and is responsible for the sense of sight [4]. Visible light wavelengths range from 400 to 700 nanometers (Figure1) [10].

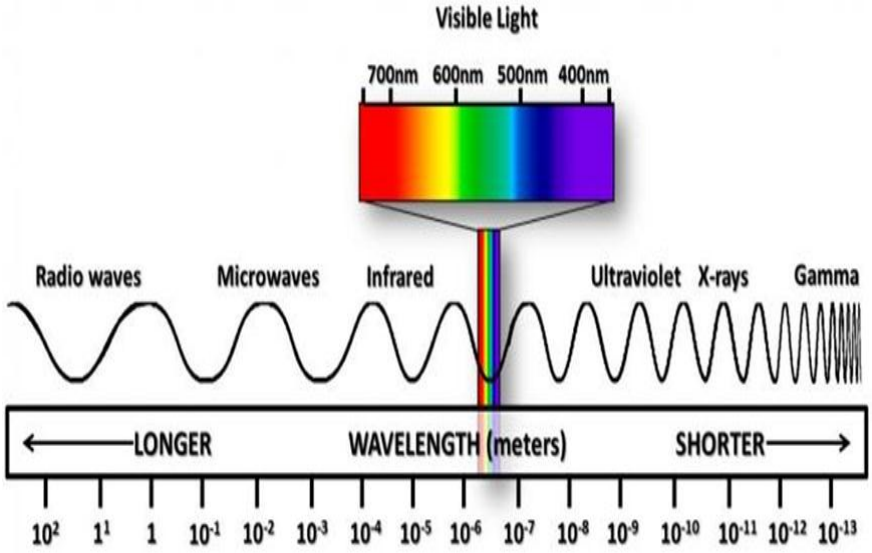

Figure 1. Electromagnetic Spectrum

Materials and Methods

2.1.1. Domesticating Light in Building

Lighting or illumination are to domesticate light, means to use light deliberately for practical and/or aesthetic reasons. Visual comfort is an important component in space quality to note in either usage [18]. Interior and exterior lighting of buildings of either natural or artificial, from sunlight and electric powers respectively (Chart1). The source, types, and equipment of light are presented in chart 1.

2.1.2. Natural Lightning Strategies

In this part, three strategies of domesticating natural daylight such as; skylight strategy, windows, and envelops, and atria have been reviewed (Figure2). Sometimes skylight windows are installed for top lightning to achieve optimal illumination [2]. Essential light amount can evenly pierce through skylights in single-story, or the highest floor of a multi-story building [5]. But, side lighting is a technique most suitable for the south face of the building in the northern hemisphere because it allows direct sunlight to illuminate the interior the most hours [19]. Glass windows or transparent building envelopes is used in this scenario to achieve optimal lighting in addition to providing a better outside view.However, the open spaces within buildings that were traditionally used for growing plants and greens have been enhanced and named Atria [16]. Modern Atrium is a large open space located within buildings that let light enter through a glass roof or wall for the purpose of lightning as well as ventilation [9].

Although atria provide light for adjacent working spaces, the amount is generally meager and does not yield satisfactory lightning very far from the initial location. In successive stories, hard to reach areas as well as rooms adjoining the atrium require re-lamping of high light fixtures. The biological model of light is limited to an energy as matter consistently. The electromagnetic energy passes between molecules as electrons thought as Particles biologically (Figure3) [3].

Obviously, the body needs the energy to act. On the other hand, electromagnetic energy is the basic physical form of energies that Albert Einstein presented his famous relation as follows,

$$E=m.c^2 \quad (1)$$

Subsequently, $m=E/c^2$ that illustrates any type of matter in its purest form which is ultimately

electromagnetic energy. Electromagnetic energy is considered as important stimuli of hormones. In terms of electromagnetic form of energy, Max Planck presented Einstein`s famous formula as follows,

$$E\ (j) = h.c\ /\ \lambda \qquad (2)$$

It presents frequency with a wavelength which is the base of electromagnetic energy. Regarding the Planck`s relation of matter and energy that makes the Einstein`s famous formula more understandable in architectural, medical and lighting fields. Planck`s relation made it possible to understand the range visible spectrums and their effect on human body.

Therefore, uncontrolled amounts of light can affect people psychologically and/or harm their bodies physiologically by alerting various human organisms. In this regard, possible diseases/cures as direct effect are as given in (Chart 2).

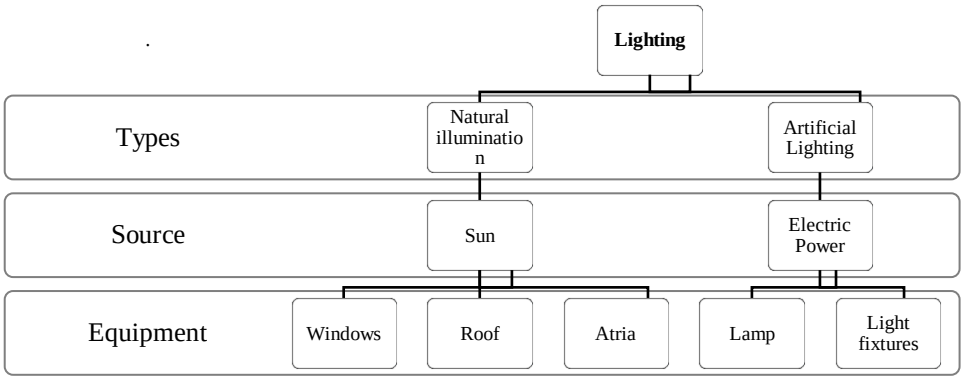

Chart 1: Domesticating Lightning in Building

Figure 2. Natural Lightning Strategie

2.2. Physiological Effects of Light

Physiological effects of light include harms to human body systems such as visual, nervous and endocrine systems as well as cardiac activity.

2.2.1. The Role of Lighting in Performance of Nervous, Visual and Endocrine Systems

Neurons are responsible for carrying electrical messages, also called impulses, throughout the body. The nervous system consists of the brain, spinal cord, nerves and sense organs. The Endocrine System signals other cells and asks them to behave in various certain ways by releasing hormones into the blood. This form of communication is diffused in a slow manner but remains to be widespread. The pathways of two eye-brain are given by a simplified diagram as given in figure 4. In these visual and non-visual pathways, the optic nerve converts the light to neural signals which are received by the eye, [4]. Where; (POT = Primary optic tract), (RHT = retinohypothalamic tract), (LGN/IGL = Lateral geniculate nucleus/ Intergeniculate leaflet), (SCN = Suprachiasmatic nucleus of the hypothalamus), (PVN = Paraventricular nucleus of the hypothalamus), (IMLCC = intermediolateral cell column of the spinal cord), (SCG = Superior

cervical ganglion), (CRH = Corticotropic releasing hormone), (ACTH = adrenocorticotropic hormone).

It should not be forgotten that the human visual system is an integral part of the central nervous system (Figure 5). This system not only provides organisms with the ability of processing visual detail but also empowers the formation of several non-image photo responses to function [13].

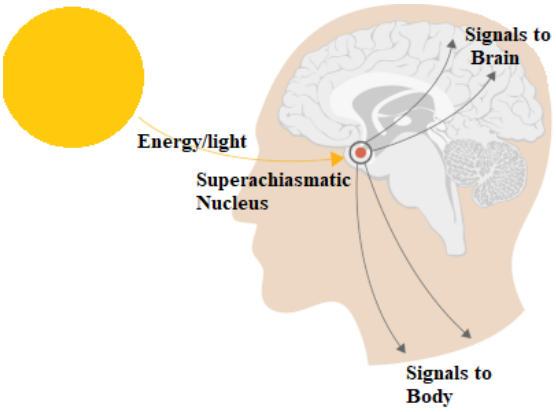

Figure 3. Light and signals

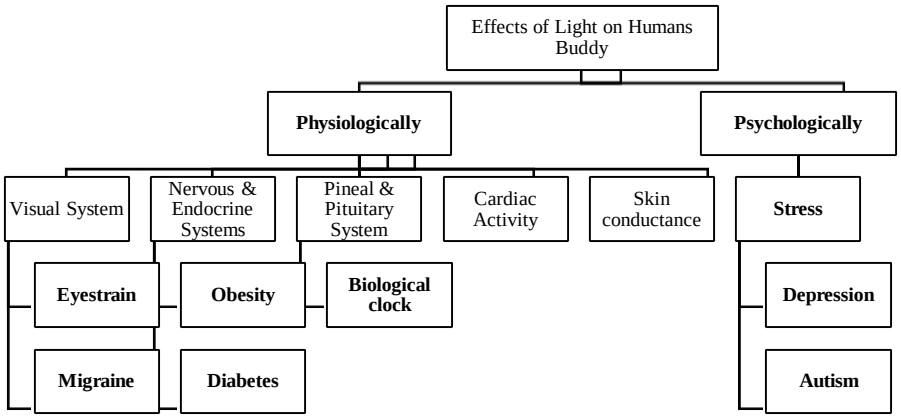

Chart 2. Effects of Light on Humans Buddy

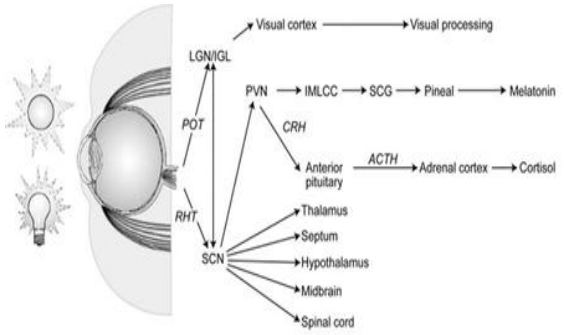

Figure 4. Simplified schematic diagram of two eye-brain pathways, [4]

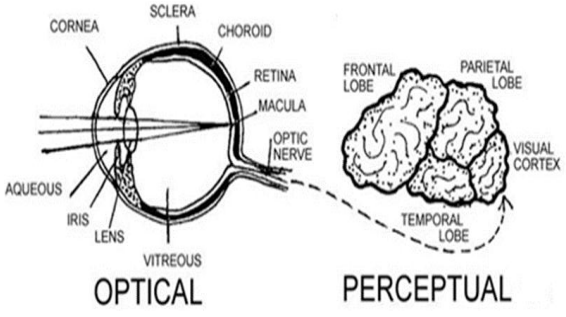

Figure 5. Human Visual System (Benavides. C, 1996)

2.2. Light Value in Different Environments & Relative Visual Performance (RVP)

Light value varies in different natural and man-made environments. In spite of indoor lighting importance, the following graph shows how much fewer light inhabitants receive, indoors versus outdoors (Lux is a standard unit of light flow), (Table 1).

On the other hand, RVP is the speed and accuracy of processing visual information often known as visual response time. In order to

understand human response to the visual environment, a valid computational model is required [16].

Table 1: How much fewer light inhabitants receive, indoors versus outdoors

Light type	**Light value**
Candlelight at 20 cm	10-15 Lux
Light of Street	10-20 Lux
Lighting of a normal living room	100 Lux
Light of office fluorescent	300-500 Lux
Halogen type of lamp	750 Lux
Sunlight (1 hour before sunset)	1000 Lux
Cloudy sky of daylight	5000 Lux
Clear sky of daylight	10,000 Lux
Bright, (sunlight)	> 20,000 Lux

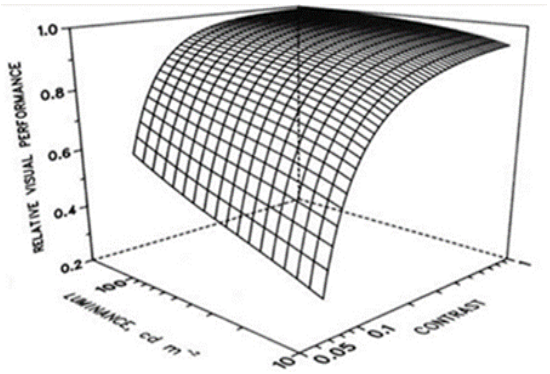

Figure 6. The Model of Relative Visual Performance or RVP, [12]

Figure 6 shows a three-dimensional surface plot of RVP values for 10-point typewritten characters (averaging 4.8 microsporidians in solid angular size) varying in luminance contrast (i.e., having different ink lightness) and against a background varying in luminance (i.e., under different light levels)

2.3. The Role of Lighting in Biological Clock Performance

The primary circadian “clock" in mammals is located in the suprachiasmatic nucleus (or nuclei) (SCN), a pair of distinct groups of cells located in the hypothalamus [21]. Mammals with (SCN) damage eradicates length and timing of sleep, and a complete destruction of the SCN results in the outright absence of a regular sleep-wake rhythm according to the daylight diffusion as given in Figure 7.

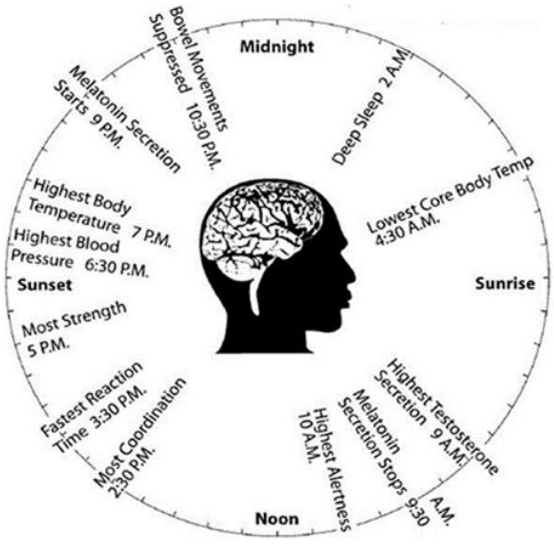

Figure 7. Biological Clock [12]

2.4. Lighting Symptom of Building and Appropriate Healthy Lighting

Both daylighting and electric lighting can cause eyestrain symptoms such as sore eyes, blurred vision, and headaches. In order to evade these issues, changing the direction and radiation angle of the light, luminous intensity and light height are to name but a few solutions (Figure 8).

The ideal light is about 35 to 50-foot candles. Lighting should be indirect and adequate. So, it should not be too much, because it may cause a glare, headache and eye fatigue. If there is a glare on eyes, the glare screens or adjustable blinds should be used at windows. Also, migraineurs are likely to be hypersensitive to visual instability. Migraine symptoms are heightened by fluctuations in light output from a light source over time, a large-area, high-contrast, and repetitive patterns over a space [8]. Anti-glare devices such as diffusers, reflectors, and reflectors are effective to control indoor lighting glare and illumination. The fraction of the light should be distributed toward the upper part of the walls and ceiling (Figure 9).

Traditional, light was a standard to approach of antidepressant treatment but recent researches propose it strongly equal to medications. However, sunlight penetration from different directs is not desirable. Its rate should be controlled incorporating with artificial lightning in different hours and also seasons. Unwanted sunlight, glare and extreme contrast of the light which cause uncomfortable visual conditions to highlight the importance of appropriate orientation of buildings. In this regard, altitude and azimuth of the sun which constantly define sun position depending on buildings attitude should be analyzed.

An appropriate orientation of buildings is the base of domesticating healthy sunlight. The long axis of buildings should be faced due north and south. As given in figure 10, the best daylighting is from south-facing windows which provides much rate of light in winter. Also, south facing windows can be protected from a direct beam that is harmful sunlight by use of fixed overhangs in summer.

Incorrect lighting causes the pineal gland to secrete hormones that have important endocrine functions such as Melatonin, lightening skin color, seasonal behaviors, and adverse effects on the human biological clock.

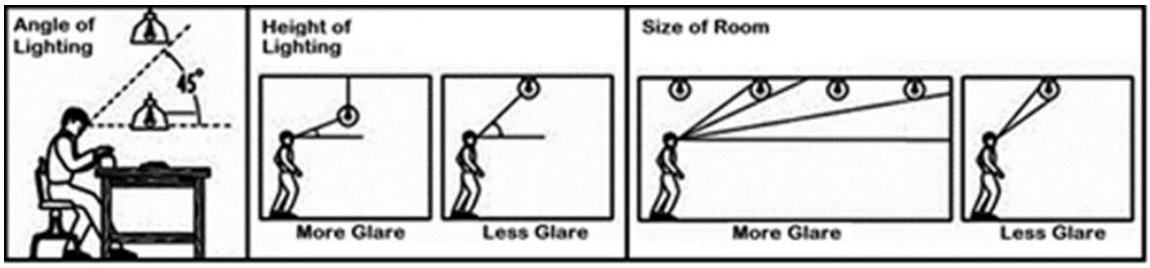

Figure 8. Effective Factors on Glaring, [6]

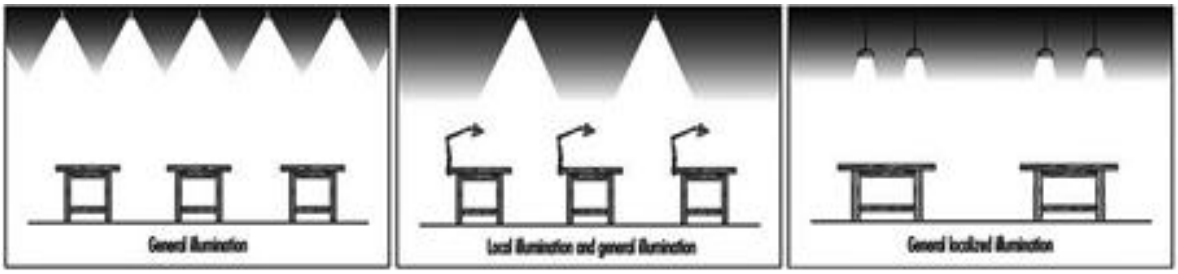

Figure 9. Lighting systems Glaring [6]

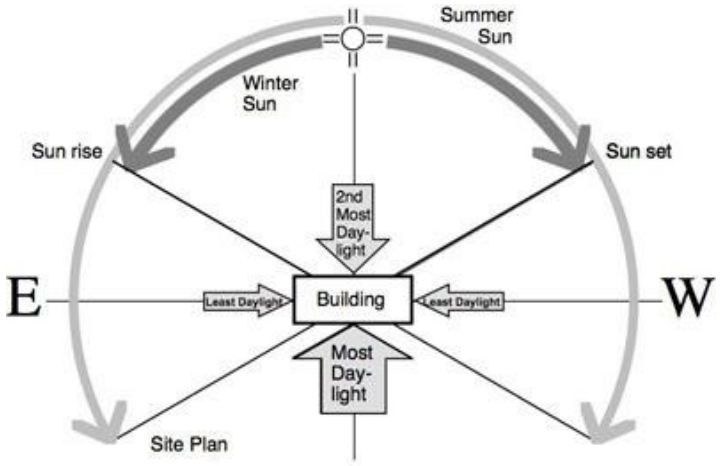

Figure 10. Aspectual and Seasonal Sunlight Penetration [20]

2.5. The Role of Light in Cardiac Activity and Heart Rate in Environments

There are a lot of hospital-based data about acute coronary syndrome (ACS) which its seasonal distribution illustrates the relationship between climatic parameters and occurrence of ACS [7]. According to a research that has been done by Chinese Academy of Medical Sciences, records of emergency medical service in Beijing highlights winter a critical period of ACS as given in (Chart3).

The most important factor of the chart which is related to indoor lighting is deducing the increased rate of diseases in winter. In other word, people prefer to spend more times in the buildings in winter to compare other seasons because of climatic problems. On the other hand, cardiac activity is strictly linked with the emotional state of an individual.

Psychologically disorders are indirectly caused by light intensity impacts human heart rate, which in turn affects skin and emotion [17]. Light and color intensities have a direct relationship with changes in heart rate in individuals. Some colors and their intensities cause greater variations in heart rate than others do. This is the same reasoning behind the preferred usage of cold and light colors such as blue and green in hospitals (Nadeen Abbas, 2006). Subsequently, providing appropriate lighting and color besides of ventilation is the base of indoor health in this case.

2.6. Psychological Effects of Natural Light

A number of factors in a constructed environment affect the psychological and emotional state of individuals. Light intensity and color are two crucial factors that may trouble individuals suffering from the disorders such as; autism, depression, and [16]. The amount and inconstancy of light provided by artificial and natural lighting may challenge ordinary daily activities for autistics. Even the dispersed clouds in the sky can affect an individual diagnosed with autism and should be managed by artificial lighting techniques.

Daylight causes producing serotonin, a hormone, which is associated with the perception of happiness [15]. In a study, rates of depression and suicide among residents of northern blocks were found to be higher than others, according to the influences of daylight on the human body [11]. Therefore, lighting must be controlled in these regions (Graph). It should not be forgotten that stress is an organism's response to a stressor such as an environmental condition [14]. Environmental effects on human stress can be managed with controlled lighting as well as appropriate use of colors. Also, average hours of sunlight is effective on antidepressants consumption of people. According to the data given in (Chart 4), 17 does per 1,000 people per day have consumed in Chile where the average number of sunny hours per year was 2,500. In opposing, in Iceland, people consume 106 antidepressants where the hours is half of Chile.

3. Results and Discussion

1- Light is electromagnetic radiation within a certain portion of the electromagnetic spectrum which is visible to the human eye.

2- The electromagnetic energy passes between molecules as electrons thought as particles biologically.

3- Natural light cause the greatest impact on SC and HR.

4- Light value differs in different environments and it should be controlled. Angle and distance of the light source, the size of the man-made environment are the effective factors on the lightning symptom of buildings.

5- Ultraviolet radiation seeping through fluorescent bulbs, in the long term, damage the skin and the eyes.

6- Southern aspect of buildings in the northern hemisphere is the healthiest daylight.

7- Chilean and Korean peoples consume antidepressants less than Iceland people because of average hours of sunlight.

4. Conclusions

The findings of this research demonstrate that some colors and light intensity have a greater impact on depression and stress than others.

The observations concluded from the study show that there is a correlation between mutual causes and their effects on physiological and psychological issues.

In retrospect, inappropriate lighting may harm physiological systems such as visual, nervous and endocrine, pineal and pituitary systems, as well as cardiac activity and skin conductance. As a result, each disorder mentioned above subsequently increases stress in the individual.

The research advocates that architects and designers of any type of space must consider the needs of their clients, accepting individual differences and predict user demands in the future

when incorporating lighting and color techniques for indoor-outdoor space designs.

Directions for future research: Unanticipated findings that were beyond the scope of this research are presented for the consideration of future researchers below:

The impacts and hazards of light and color on different age groups and genders.

Hazardous effects of long exposure to light and specific colors.

The possible relationship between light and color preferences of space users and perception of happiness.

Studying a relatively large sample of random participants for the aforementioned topics.

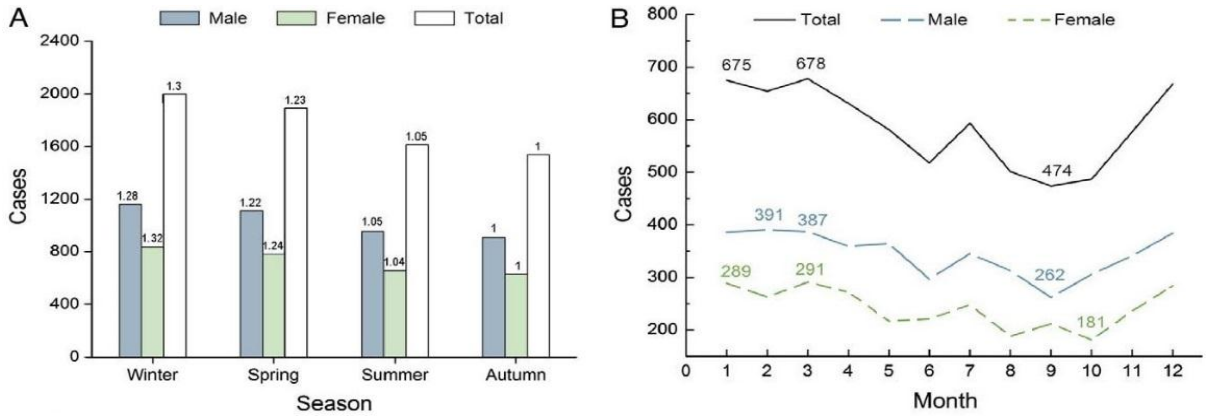

Chart 3; ACS of Beijing [7]

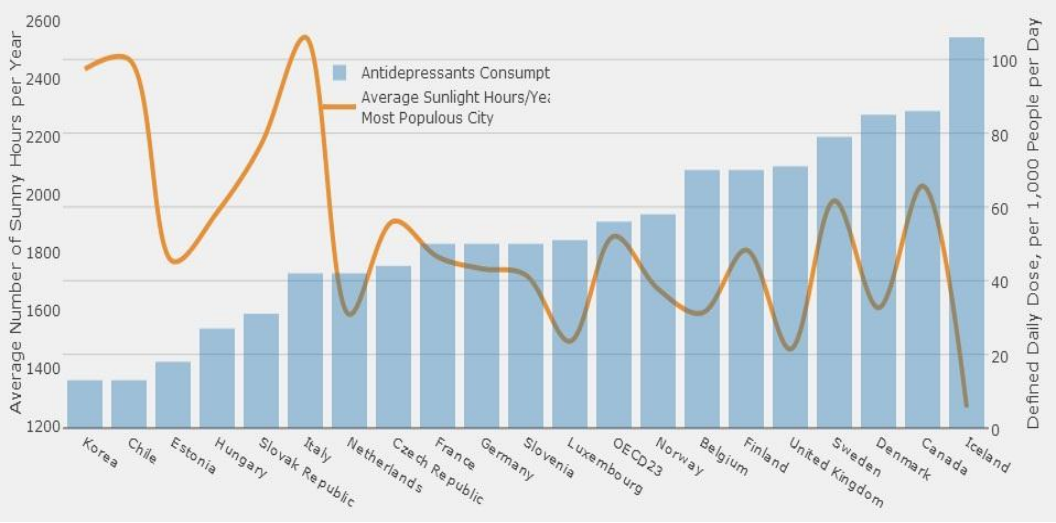

Chart4; Antidepressants Consumption & Average Hours of Sunlight per Year, Most Populous City in that Country (Plotly. A, 2015: OECD23)

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