EFFECT OF DAYLIGHT ON STUDENTS' BEHAVIOR IN LIBRARIES

MOHAMED ELIBIADI

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EFFECT OF DAYLIGHT ON STUDENTS' BEHAVIOR IN LIBRARIES

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Submitted by **Mohamed ELIBIADI**

Approval of the Graduate School of Natural and Applied Sciences, Çankaya University

Prof. Dr. Can ÇOĞUN
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Asst. Prof. Dr. İpek MEMİKOĞLU
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Prof. Dr. Gülser ÇELEBİ
Supervisor

Examination Date : 14.09.2017

Examining Committee Members

Prof. Dr. Gülser ÇELEBİ	(Çankaya Univ.)	
Assoc. Prof. Dr. İdil AYÇAM	(Gazi Univ.)	
Asst. Prof. Dr. Papatya Nur DÖKMECİ YÖRÜKOĞLU	(Çankaya Univ.)	

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Name, Last Name : Mohamed ELIBIADI

Signature :

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ABSTRACT

EFFEC OF DAY LIGHT ON STUDENTS BEHAVIOR IN LIBRARIES

ELIBIADI, Mohamed

M.S., Interior Architecture Department

Supervisor: Prof. Dr. Gülser ÇELEBİ

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Natural lighting is one of the most tried concepts in architecture due to the several psychological and physiological benefits of its utilization on space occupants. Therefore, several studies have shown its positive impacts and superiority to artificial lighting. Moreover, using natural lighting allow owners and facility managers to save up to 40% of the energy used in their buildings. In this research, the perception and impacts of natural lighting is assessed at the library of Çankaya university in Ankara, Turkey. The library has a skylight that allows natural lighting to enter the library during day hours. Through a review of the literature, lighting perception indicators and illuminance measurement techniques are compiled in order to perform a subjective and objective measurement of the lighting in the case space. The library is divided by the researcher into four main zones; A, B, C and D. The findings of the objective illuminance measurement show that cloudy weather reduces the illuminance in the library by 23.1%, while several inadequate illuminances were found in many cases especially in zones A and D. The subjective perception by 120 library users distributed throughout different day periods shows that the lighting perception indicators differed between the different zones.

At the end of the study, correlation testing between the subjective perceptions and objective illuminance measurements was performed, which indicated a weak to medium correlation between the two variables.

Keywords: Lighting in Architecture, Natural Lighting, Behavior, Health, Libraries

ÖZ

GÜNIŞIĞININ KÜTÜPHANELERDEKİ ÖĞRENCİLERİN DAVRANIŞLARI ÜZERİNDEKİ ETKİSİ

ELIBIADI, Mohamed
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Doğal ışığın mekânı kullananlar üzerinde psikolojik ve fizyolojik etkileri bulunmaktadır. Bu nedenle, binalarda doğal ışık kullanımı mimarlıkta irdelenmesi gereken olgulardan birisidir. Doğal ışığın pozitif etkilerini ve yapay aydınlatmaya karşı üstünlüğünü gösteren pek çok araştırmalar yapılmıştır. Kütüphanelerde doğal aydınlatmanın kullanıcı üzerindeki etkisi konusunda yeterli sayıda araştırmanın olmadığı, özellikle Türkiye özelinde kütüphane aydınlatmasına ilişkin çalışmaların bulunmadığı saptanmıştır. Bu araştırmada, doğal ışığın algılanması ve etkileri Ankara Çankaya Üniversitesi kütüphanesi özelinde irdelenmiştir. Kütüphanede gündüz saatlerinde doğal ışığın kütüphaneye girmesini sağlayan tavan penceresi kütüphanenin daha fazla ışık alabilmesini sağlamaktadır. Literatür taraması ile başlayan çalışmada, örnek mekândaki aydınlatmanın öznel ve nesnel olarak ölçümü yapılmıştır. Bu bağlamda, anket ve aydınlatma ölçüm teknikleri birlikte kullanılmıştır. Kütüphane dört zona ayrılmıştır: A, B, C ve D. Ölçüm açık ve bulutlu havada ayrı ayrı yapılmış ve bulutlu havada kütüphanedeki ışık seviyesinin %23,1 oranında azaldığı görülmüştür. Açık havada özellikle A ve D kısımlarında yetersiz aydınlatma düzeyi olduğu tespit edilmiştir. Günün farklı zamanlarına dağılmış 120 kütüphane kullanıcısının sübjektif

algılaması için anket tekniği de kullanılmıştır. Kullanıcının tercih ettiği alanlar saptanarak aydınlık algılama göstergelerinin önemi vurgulanmıştır. Çalışmanın sonunda, sübjektif algılama ve nesnel aydınlatma ölçümleri arasında korelasyon testi yapılmış ve bunun sonucunda iki değişken arasında zayıf ile orta derece bir korelasyon olduğu görülmüştür.

Anahtar Kelimeler: Mimarlıkta Aydınlatma, Doğal Aydınlatma, Davranış, Sağlık, Kütüphaneler

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I would like to thank my parents for their support and believe in me and I hope to return some of the many blessing God gave me through them

I would like also to dedicate this work to my wife and daughters

A special thanks to my advisor Prof. Dr. Gülser Çelebi, for her continuous advice, recommendation and support to perfect this research.

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1. INTRODUCTION

1.1 Problem Statement

As lighting forms more than 40% of the educational and commercial spaces energy consumptions, using the natural lighting is becoming popular in architectural design (CHPS, 2002). Moreover, studies show that a well-designed lighting strategy in spaces could impose many positive impacts on the performance and health status of the space occupants (Mead, 2008) (Mirrahimi, Ibrahim, & Surat, 2012) (van der Rhee, de Vries, Coomans, van der Velde, & Coebergh, 2016). Furthermore, libraries are essential parts of the educational institution, where students perform their after-class activities including reading, writing, resources' seeking, research activities and group studying. Thus, adequate and healthy lighting strategy using natural lighting is considered beneficial. Moreover, several studies have shown enhancement in the interior space and functionality of libraries by introducing well-designed natural lighting into them (Eneref Institute, 2009) (Chua & Flores-Bernardo, 2004).However, although many studies have examined the impact of lighting and natural lighting in different contexts, there is few studies in the literature correlating quantitative and qualitative measurements in the library contexts.

1.2 Purpose, Significance and Methodology

The aim of this study is to evaluate the adequacy and effects of daylighting in the library building at Çankaya University on the students' satisfaction, comfort and behavior. Furthermore, the importance of this research emerges from the following:

1. The proven positive impacts of the natural lighting on the health and performance of the space users (Mead, 2008) (van der Rhee, de Vries, Coomans,

van der Velde, & Coebergh, 2016) (Yacan, 2014) (Mirrahimi, Ibrahim, & Surat, 2012).

2. The importance of the library spaces to empower the performance of the students as an essential part of the academic institution.
3. Availability of few studies that correlate the quantitative and qualitative parameters in measuring the impacts of the lighting on the students' comfort and behavior.

Therefore, this research adopts a dual methodology for assessment as shown in Figure 1.1 below.

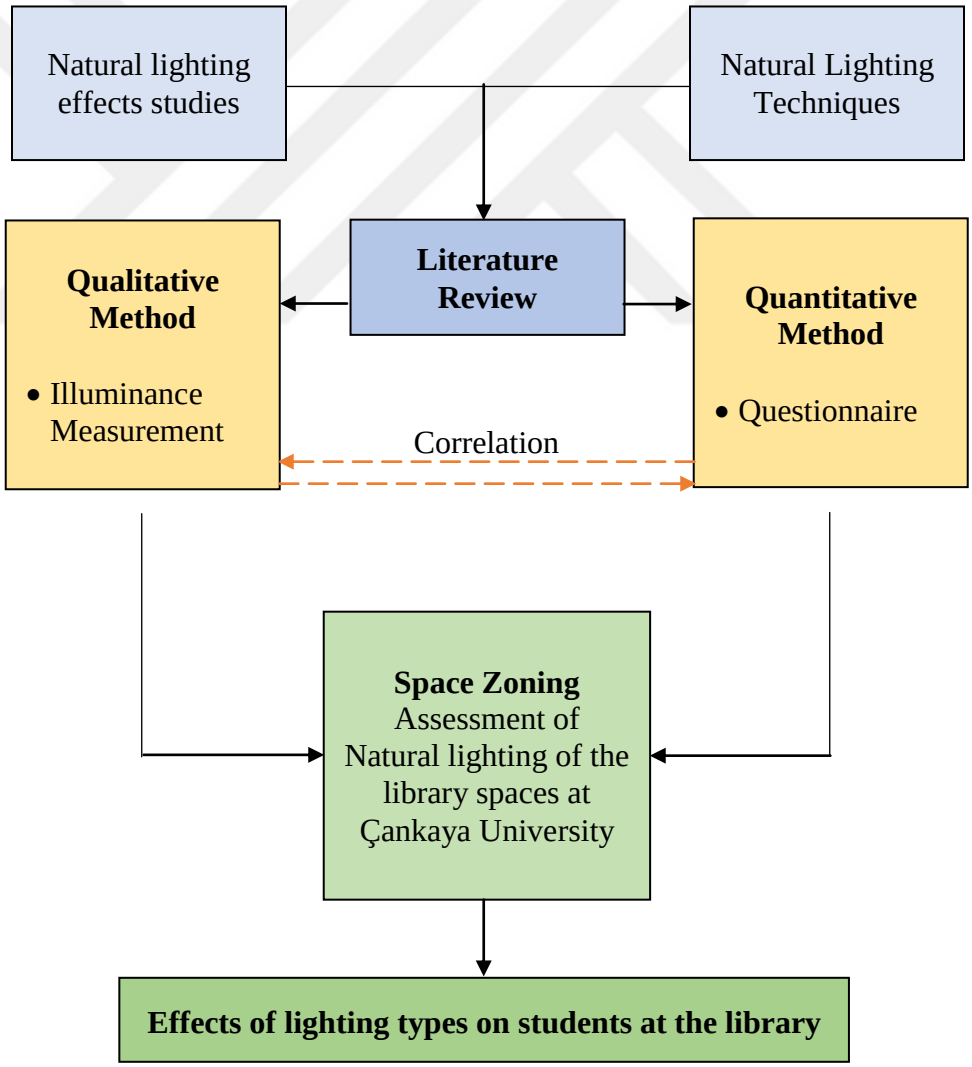

Figure 1.1: Research methodology chart

1.3 Study Structure

This study is a comprehensive assessment of the natural lighting impacts on the students' behavior, satisfaction and comfort. Therefore, the thesis is divided into five main chapters to cover the theoretical and practical studies. Furthermore, this chapter have introduced the problem, which the study is looking to contribute to its solution, the study significance, main aim, and a summary of the methodology used in order to achieve the research objectives.

Moreover, the second chapter reviews the literature for theoretical information about lighting in general and the natural lighting effects on the human psychology and physiology. Other parameters are also studied such as performance and academic achievement changes according to lighting type. Subsequently, methodologies and results of previous studies are reviewed in order to build comparable aspects and ways to carry out this research. Finally, lighting requirements in the library is studied, along with previous research results. The research mainly depended on lighting specifications, journals and previous studies that investigated the subject in similar or different interior settings.

The third chapter introduces the hypotheses of the research, the methods used, and the case space characteristics. Furthermore, the design of the study tools, questionnaire and measurements, are narrated to establish the templates which the research is carried through. The end of the third chapter looks into the sample and the analysis methods and parameters in order to test the reliability of the study.

At the fourth, the findings of the research are narrated, analyzed and discussed in order to understand the outcomes of the study and establish the correlations between the natural lighting, the students' behavior and comfort, and the illuminance measurements at the different zones of the library according to their functionality. Finally, in the fifth chapter, the researcher provides his recommendations and final conclusions on the study outcomes, and lay down exploration opportunities for future research.

2. LITERATURE REVIEW

In order to build the necessary knowledge on the natural lighting and its requirements in the libraries, the researcher have reviewed several resources in order to provide the following information:

1. Lighting types (Natural/ Artificial), difference, similarities and utilization.
2. Available natural lighting, specifically in the geographic area of the case study.
3. Impact of lighting on the psychological and physiological aspect of the human.
4. Architectural assembles that support providing the maximum benefit of natural lighting into the interior spaces.
5. Lighting measurement through direct illuminance and perception.
6. Studies that investigated lighting in library settings.

2.1 Lighting in Architecture

Since one of the most important factors to be considered in design is the comfort of the space occupants, lighting is one of the most important factors to be considered while designing a building due its proven impacts on the occupants' health and behavior (Samani & Samani, 2012). There are two main types of lighting which are used in internal spaces; artificial and natural lighting. While the natural lighting is known to be generated from the direct or indirect sun radiation, artificial lighting has been the common source of illumination since the invention of the lamp in 1879 by Tomas Edison (HoL, 2013). However, the common drive behind the research to use the natural lighting is the high energy consumption of artificial lighting, which could reach to 35% of the total generated energy (Konis, 2013) (Sandanasamy, Govindarajane, & Sundararajan, 2013). Furthermore, to be able to understand the impacts of lighting in interior architecture, it is significant to study the different types of lighting and the different lighting effects and spectrums that they generate in an internal space.

2.1.1 Artificial Lighting

There are several artificial lighting sources that differ in their technical aspects. Nonetheless, for the benefit of this research, the artificial lighting sources are presented in terms of wattage and impact on the coloring in a space in Table 2.1 below (Phillips, 2004).

Table 2.1: Artificial lighting sources (Phillips, 2004) (Bagher, 2016)

Lamp	Type	Wattage (W)	Color Temperature (K)	Lighting level rating (out of 100)
Incandescent	Tungsten Filament	15 to 500	2700	99
	HV Tungsten Halogen	25 to 2000	2800 to 3100	99
	LV Tungsten Halogen	5 to 150	2800 to 3100	99
High intensity discharge	Low pressure sodium	18 to 180	N/A	N/A
Fluorescent Tubes	Cold Cathode	23 to 40	2800 to 5000	55 to 90
	Halo phosphate (T8 & T12)	15 to 125	3000 to 6500	50
	Triphosphorous (T5 & T8)	4 to 80	2700 to 6500	85 to 98
Compact fluorescent twin-based	Triphosphorous	5 to 80	2700 to 5400	85 to 98
Compact twin-based integral ballast	Triphosphorous	3 to 23	2700	85
Induction (Fluorescent)	Triphosphorous	55 to 150	2700 to 4000	85
High intensity discharge	High pressure sodium	50 to 1000	1900 to 2300	23 to 60
	High pressure mercury	50 to 1000	3300 to 4200	31 to 57
	Metal halide (Quartz)	35 to 2000	3000 to 6000	60 to 93
	Metal halide (Ceramic)	20 to 250	3000 to 4200	80 to 92

As seen from the table above, the different artificial lighting sources differ in their energy consumption, and effect of color temperature which is important for the visual comfort of the occupants. Therefore, it can be well observed that the artificial lighting can deliver the required illumination according to the functionality of the space.

Furthermore, the study is mainly focused on natural lighting to deliver the same comfort with the best effect on the occupants' physiological and psychological conditions. Nonetheless, it is also acknowledged that natural lighting may not be sufficient to provide the full lighting need of the space due to its absence in the night time or due to the variable weather conditions (Turlej, 2011).

2.1.2 Natural Lighting

When it comes to natural lighting, the main source of this commodity is the sun direct or indirect light. The direct light is referred to the direct sunlight which is directed to a segment of the earth during the day time, while the indirect light referred to the reflection of the sunlight on the moon during the night time (Turlej, 2011).

However, since the moon light is inconsistent, weak and unreliable, the main focus in any study that involves natural lighting is mainly drawn to the direct lighting of the sun.

Furthermore, the natural lighting radiation can achieve the best quality of lighting which is provided by the artificial lighting which is 1370 W per square meter as shown in Figure 2.1 below.

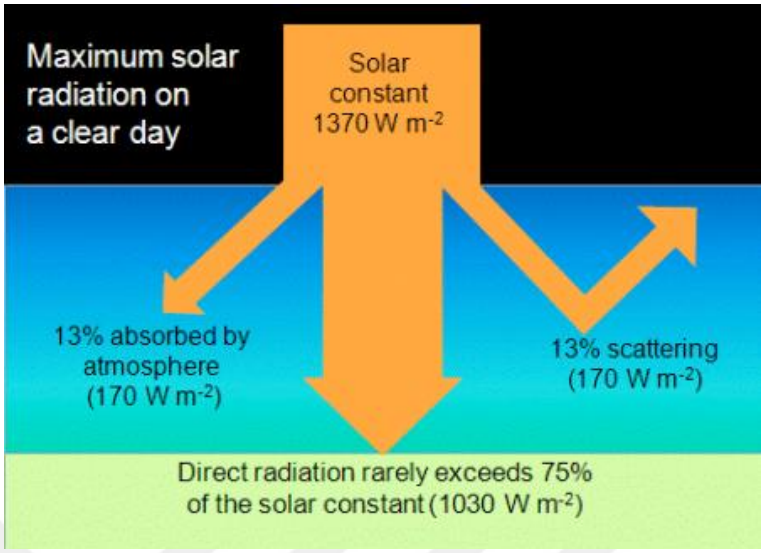

Figure 2.1: Maximum solar radiation at earth's surface (Burgess, 2009)

However, the direct sun light is mainly absorbed by the atmosphere and scattered, which makes it lose 26% of its energy under ideal weather conditions and assuming readings near the earth's equator, which makes the net radiation of the sun to reach 1030 W. These readings make the sunlight a reliable lighting source especially under clear weather conditions (Burgess, 2009).

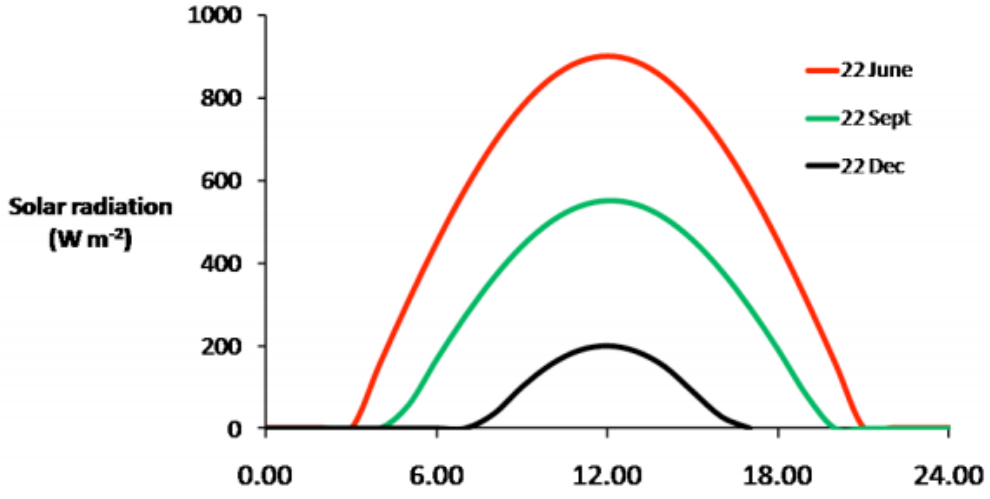

Figure 2.2: Solar radiation in 24 hours during different seasons at 52 deg. North (Burgess, 2009)

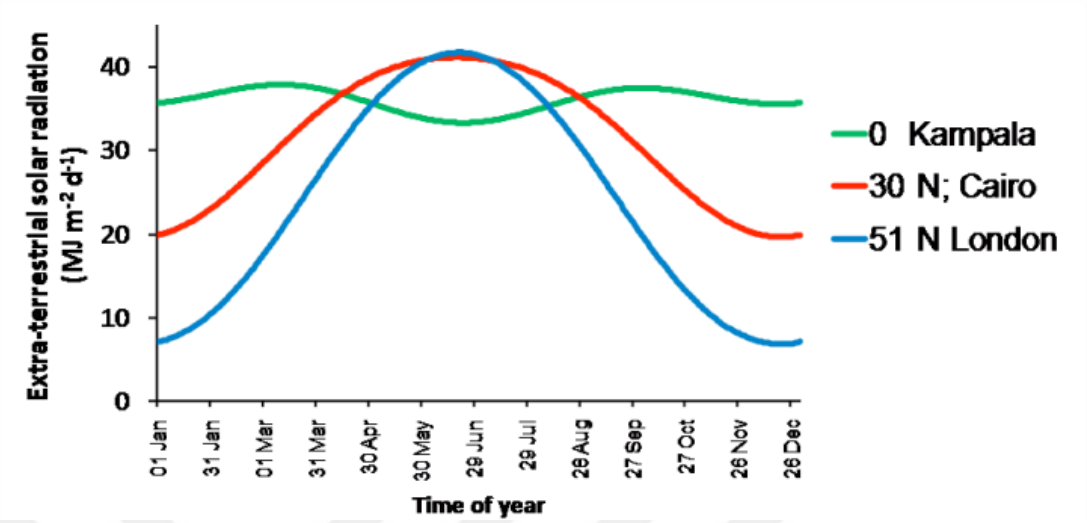

Figure 2.3: Sun radiation differences according to the season and geographic location (Burgess, 2009)

Moreover, the first factor that affects the resultant radiation reaching the earth surface is the several seasons that pass over a certain area on earth. Whereas, the geographic location also plays a role in determining the lighting intensity from the sun to the earth. Figures 2.2 and 2.3 show the difference in sun radiation according to the season and geographic location.

The source of the sunlight can be divided into three main ways, which are the direct, diffused and reflected sunlight arrays. The direct sunlight array is a straight delivery from the sun to any area on earth.

Furthermore, the diffused array is the sunlight which is affected by the environmental and the weather conditions. Lastly, the reflected array is delivered after its reflection on another surface on the earth surface (Vecan, 2011). Figure 2.4 below shows an illustration of the three types of sunlight reaching the earth surface.

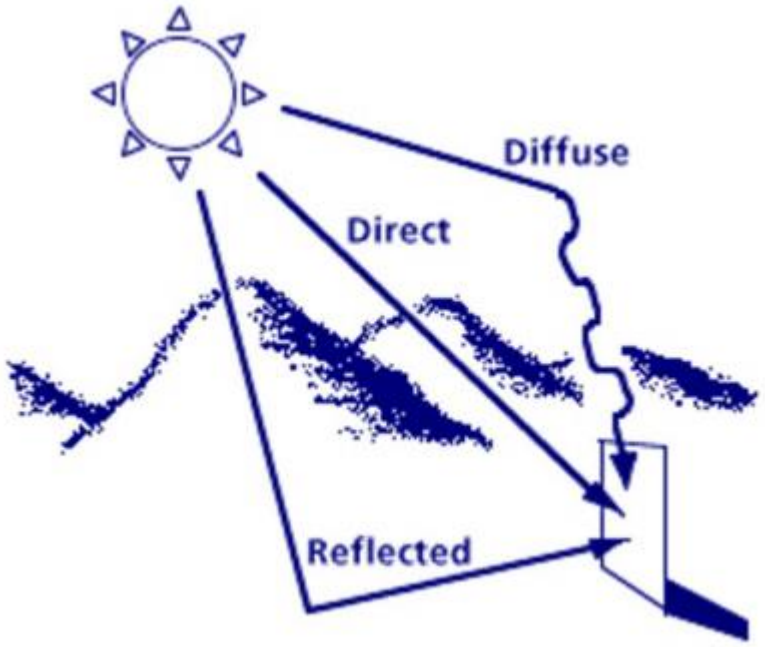

Figure 2.4: Types of sun arrays delivered to the earth (Vecan, 2011)

In Turkey's case, the intensity of the light differs mainly based on the season and the weather conditions. Table 2.2 below illustrate the wattage of the sun radiation in Turkey in a square meter in every month.

Table 2.2: Sun radiation in Turkey throughout the year. Adopted from (Vecan, 2011)

Month	Average Sun Radiation in the month (W)	Average Sunshine Duration per day (Hours)
January	69.56	3.3
February	94.15	4.12
March	129.91	5.32
April	169.76	6.57
May	206.80	8.81
June	234.38	10.83
July	235.73	11.77
August	212.90	11.06
September	171.22	9.33
October	120.83	6.90
November	84.47	5.23
December	63	3.32
Yearly Average	**149.46**	**7.2**

The above table shows that the yearly average of sun light radiation and average sunshine hours are at acceptable limits in Turkey, which allows the architects to utilize them into achieving better natural lighting in their designed buildings. Moreover, the importance of using natural lighting in achieving visual comfort and positive health impacts on the space occupants in evident in many studies, which can be reviewed in the following sections of this literature review.

2.2 Effects of lighting on Occupants

There are many studies that tested and elaborated on the impact of natural lighting in different spaces including residential, commercial and learning environments. Therefore, it is significant to study the results on these researches in order to form an

expected set of outcomes for this study. From previous studies, natural lighting has proven positive implications on the productivity, behavior and other operating aspects such as cost and emission reductions (Sandanasamy, Govindarajane, & Sundararajan, 2013).

2.2.1 Daylight and Human Health

From a medical perspective of the positive effects of daylight on the human body, a research shows that the Ultraviolet radiation provided by the sunlight has the ability to boot up the human body's production for Vitamin D, which is vital for the bone structure. However, the lack of sunlight exposure results in to more than 3 billion diseases and deficiencies annually, which can be solved by exposing the body to around 15 minutes during the middle of the day (Mead, 2008).

Although it is important to understand the balance between the needed and maximum sunlight exposure, many skin diseases can be treated and avoided using the correct amount of sunlight, such as psoriasis, eczema, vitiligo and acne. Moreover, the natural sun light is essential to simulate the circadian system, which is essential for the daily rhythm of a person, as well as the metabolism functions of his or her body. These physiological operations are proven through medical studies to:

1. Reduce probabilities for breast and prostate cancers.
2. Reduce the risk of weight gain and diabetes.
3. Enhance the sleeping rhythm of the body (van der Rhee, de Vries, Coomans, van der Velde, & Coebergh, 2016).

On phycological effects of the daylight, a study was made with 1233 participants in Germany, the absence of sunlight was found to have a direct negative effect on negative mood, while it had a direct relation with the tiredness feeling with a correlation factor of 0.65 (Denissen, Butalid, Penke, & van Aken, 2008). Furthermore, the sunlight was also found to have an impact on the social and cognitive skills of student through a study performed on kindergarten students. The results of the study showed that students who are exposed to the sunlight in the classroom environment had a better social and

cognitive skills than those who have limited sunlight exposure (Yacan, 2014). Table 2.3 below shows improved and reduced health implications that are affected by the daylight exposure.

Table 2.3: Health implication of sunlight (Mirrahimi, Ibrahim, & Surat, 2012)

Improved			**Reduced**	
Physiological	**Psychological**	**Learning**	**Physiological**	**Psychological**
Vitamin D	Mood	Problem solving	Headaches	Depression
Visual System	Happiness	Test performance	Cancer	Tiredness
Calcium metabolism	Commitment to work		Stomach aches	Seasonal disorder
Bone structure	Sleeping		Blood pressure	Stress
Circadian system			Infections	Sense of security

2.2.2 Daylight, Performance and the Human Body

In a research in the banking sector, the connection between the employees' productivity and the several interior design factors were studies in order to establish the relation between them. Using Pearson's correlation, it was found that lighting quality directly affects the productivity of the employees with a factor 0.720, which is the highest factor among all studied elements; Furniture, Noise, Lighting, Temperature, Air quality and Spatial arrangement. In the same case study, the findings regarding the lighting quality were as the following:

1. Exposure to natural lighting is an essential factor to perform the routine daily activities.
2. Failing to provide natural lighting into a productive space leads to occupants facing difficulty in completing their task and drive their focus towards the targeted work (Hameed & Amjad, 2009).

In a study by the United States Department of Energy, a comprehensive study was performed in order to assess the benefits and impacts of natural lighting on the human productivity. This results into a new definition for the impact of lighting on performance by introducing the term "visual performance", which means the effect of lighting on the visual system within the human body.

The impacts of the sunlight on the human body systems and performance is narrated by the study as the following:

> *Physically and physiologically, daylight is just one more light source. How daylight influences visual performance depends on how it is delivered. Either good task performance or poor task performance can be expected depending on the amount of daylight delivered and whether glare, shadows or veiling reflections are produced*. (Boyce, Hunter, & Howlett, 2003)

However, the sunlight is vital to the operations of circadian system, which influences directly and indirectly the performance of the human body and subsequently the performance in work and learning. Therefore, the study states:

> *Exposure to daylight outdoors is usually the major factor in determining the phase of the circadian rhythm. Daylight outdoors delivers a high illuminance at the eye that is better matched to the spectral sensitivity of the circadian system than most electric light sources*. (Boyce, Hunter, & Howlett, 2003)

Furthermore, in studying the influence of daylight on the students specifically, a study in California shows that students who are exposed to sunlight demonstrate a learning ability that is 25% faster than those with less exposure, which is a result of analyzing the test scores of 2100 students. Subsequently, the overall performance of the students was noticed to improve up to 20% with daylight exposure (Mirrahimi, Ibrahim, & Surat, 2012). On a more engineering-oriented study, another study compared the changes on test score for schools' students with different design systems. The results of the study show that classrooms with skylights and more windows area supported students achieving 7% to 26% better test scores compared to the students whom their classrooms have less of that feature. Moreover, it was concluded that diffused light has better impacts on students' performance than direct sunlight, which can imply adverse effects (Heschong, 2002).

Moreover, studies have shown that the daylight is superior to the artificial lighting sources in achieving better alertness of the human body, which is a result of the synchronization between the circadian system (λ = 480 nm) and the daylighting (λ ranging between 450 and 530 nm). Thus, this translates into illuminance values range between 180 to 210 lux during the different periods of the day. Figure 2.6 below shows an example from a study comparing the natural lighting (Coded as D55, D65 and D75) to the artificial lighting sources (other shown codes), their impact on the alertness of circadian system, and the closeness of natural lighting in achieving comfort more than artificial lighting. Nonetheless, it is stated that the artificial lighting should target an illuminance value of 360 lux in order to achieve the same comfort provided by natural lighting (Pechacek, Andersen, & Lockley, 2008).

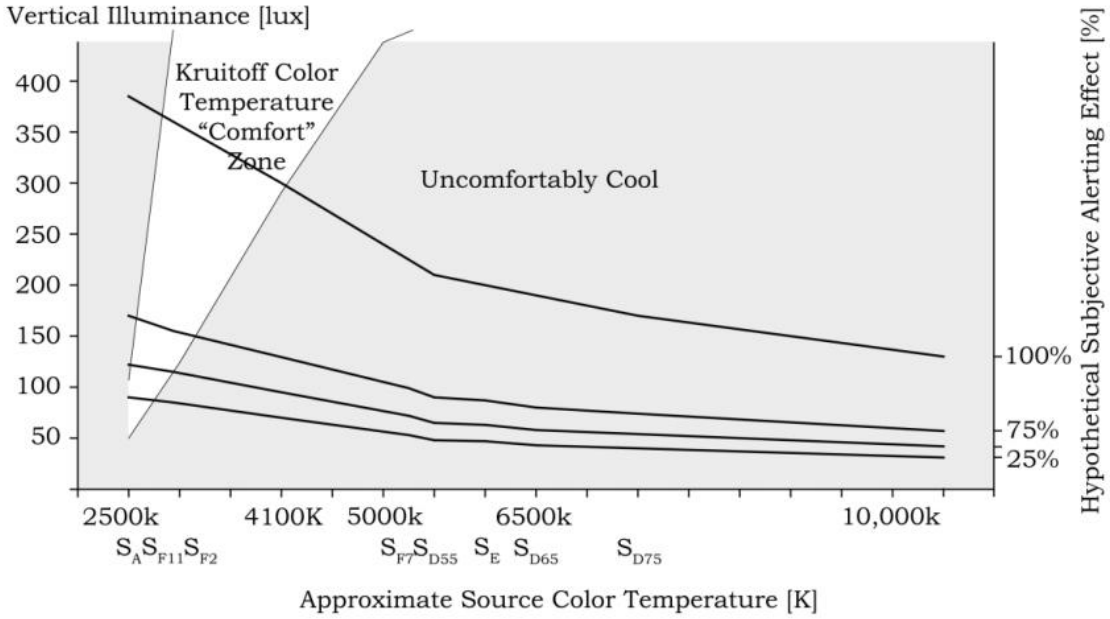

Figure 2.5: Natural lighting superiority in achieving the circadian system's alertness (Pechacek, Andersen, & Lockley, 2008)

2.3 Daylight Architectural Assemblies

There are many assemblies that can be adopted to allow more exposure of sunlight in internal spaces. Traditionally, windows are the common way to convey sunlight into the space.

However, direct sunlight may increase the heat in the space, turning it into a green house and subsequently result into unfavorable impacts on human body systems and performance (Abdelatia, Marenne, & Semidor, 2010). During the design of a daylight empowerment system, there are three main factors to consider:

1. The health of the space users.
2. Architectural standards.
3. Economic factors.

Figure 2.6 below shows the daylighting system selection strategy that should be followed during the design.

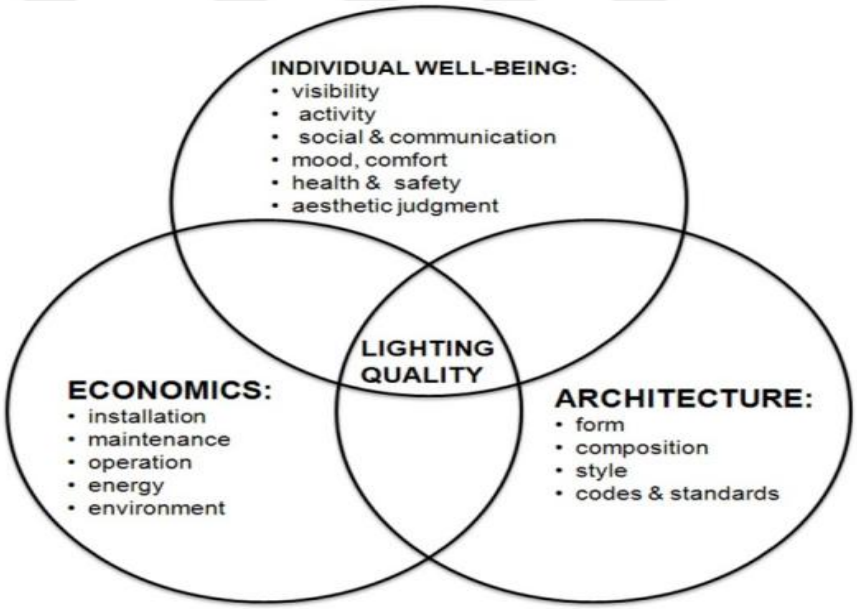

Figure 2.6: Daylighting systems selection strategy (Abdelatia, Marenne, & Semidor, 2010)

Moreover, as it would not be realistic to only consider using the daylight into the design of any space, Figure 2.8 below shows the acceptable level of lighting that shall be targeted by an architect throughout the day and night hours.

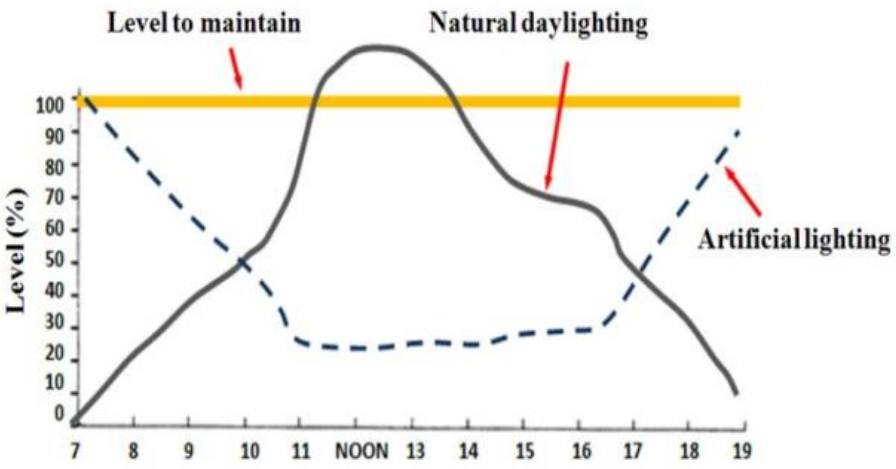

Figure 2.7: Daylighting and artificial lighting combination strategy (Abdelatia, Marenne, & Semidor, 2010)

Furthermore, the focus in architectural assemblies regarding the introduction of sunlight into any space is to provide ambient diffused light in order to utilize the advantages of the natural lighting, while eliminating the negative and adverse effects. Therefore, windows, skylights and atrium designs focus on directing the sunlight to provide that effect. Figures 2.8 and 2.9 below illustrate the favorable assemblies that could be used in each case as examples.

solar gain and glare.

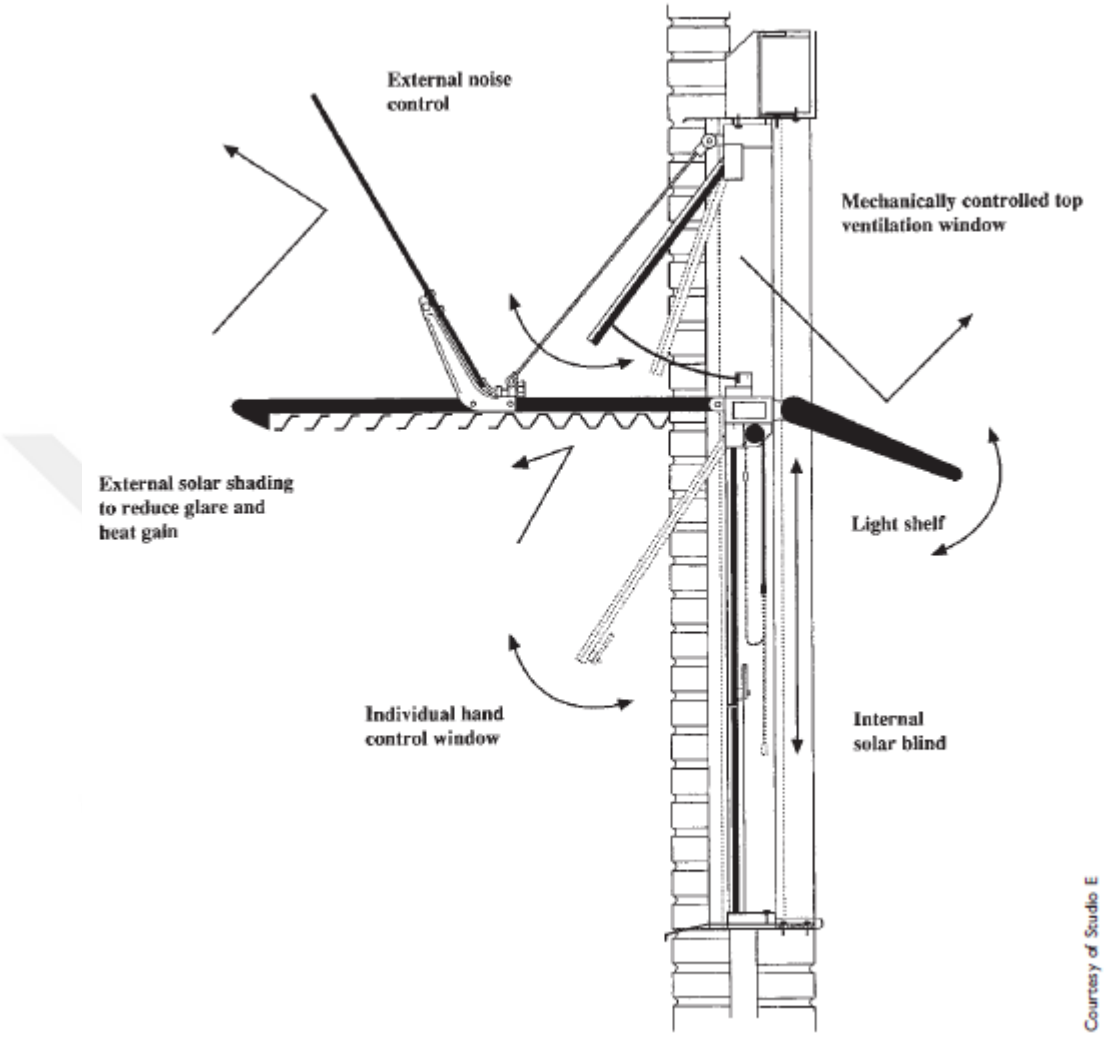

Figure 2.8: Sunlight control system for windows (Phillips, 2004)

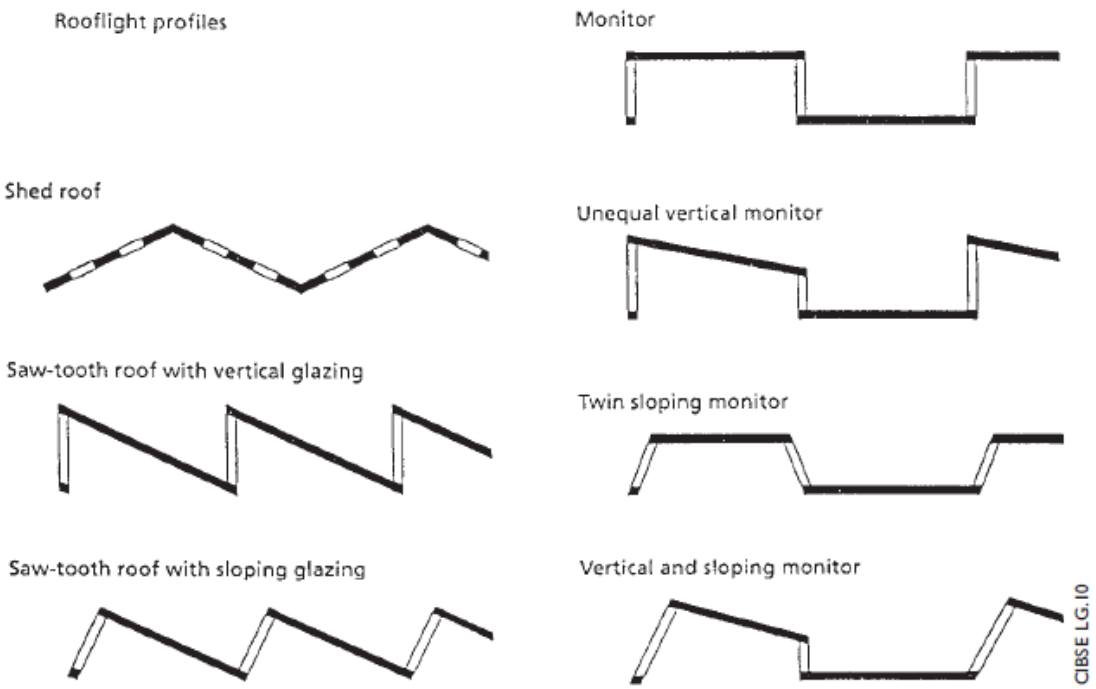

Figure 2.9: Roof lighting profiles to empower diffused lighting and eliminate direct arrays (Phillips, 2004): Black profiles are blocked and while profiles are glass.

Both designs in Figures 2.9 and 2.10 are common techniques or a combination of them, which achieve the following:

1. Providing a diffused sun lighting.
2. Exclusion of mechanical systems, which consumes energy using ventilation.
3. Providing adequate insulation of excessive heat.
4. Control the sunlight arrays and eliminate glare and direct arrays (Phillips, 2004).

2.4 Lighting Objective and Perception Measurements

The purpose of this section is to explore the measurement methods for lighting in different spaces. Therefore, through the literature, three main methodologies were observed including:

1. Direct mechanical measurement of lighting intensity
2. Measurement of human body reaction to lighting using heart rate and skin conductance
3. Measurement of human perception on lighting effect using a questionnaire methodology

The direct measurement of lighting intensity, also known as illuminance accompanied by its unit lux, is often used a way to ensure adequate lighting in any space. Hence, there are two main procedures to measure illuminance (OSHBLD, 2008):

1. General illuminance measurement: which measures the lighting in a room to ensure adequate lighting is provided throughout the space.
2. Task illuminance measurement: which is a specific measurement of an area to ensure that the lighting level supports the functionality of that area.

Both procedures use a device called the lux-meter, The general illuminance measurement is performed by dividing the space area into smaller squares according to the total area, taking measurement at each center of square, and averaging all readings to obtain the average illuminance of the space. Moreover, this method is beneficial to ensure that the lighting is distributed evenly throughout the space. Nonetheless, task illuminance measurement is performed on top of the area, where visibility is tested, which applies to horizontal and vertical planes. For instance, if the illuminance is measured for library bookshelves, the measurement should be taken vertically on the sides of the books and it should be ensured that no obstacles, even the person who is taking the measurement, are affecting the sensors' reading (OSHBLD, 2008).

Furthermore, other studies measured the impact of the lighting on the human body through the measurement of the body's reaction to different lighting colors and types. In a study that involved 15 university students, the researcher measured the impact of the lighting on the heart rate and the skin conductance of the participants.

The results of the study indicate that the participants have had a more normalized heart rate under white and natural lightings, as well as higher skin conductance under natural lighting, which indicates a better emotional and psychological state (Abbas, 2006). Figure 2.10 shows the superiority of natural lighting in achieving skin conductance over other types and colors of lighting.

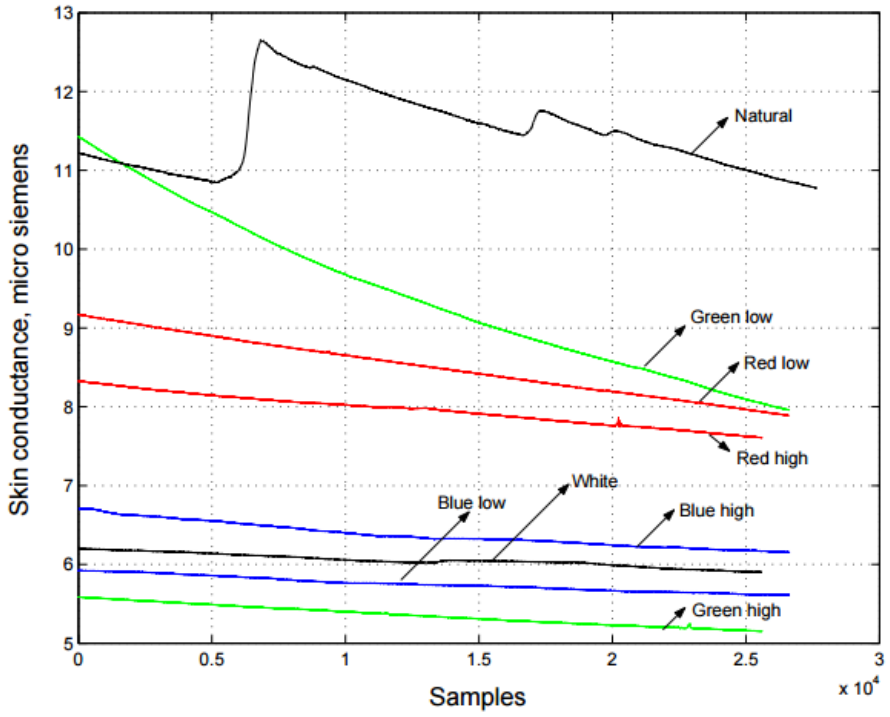

Figure 2.10: Natural lighting achieving better skin conductance indicating better psychological state (Abbas, 2006)

On using the questionnaire methodology in evaluating the impact of the lighting on the space users, there are several studies that tested different lighting aspects and analyzed the perception of the participants to them.

In a Turkish study, which examined lighting illuminance within an experimental setting, the researchers constructed a room with no windows and arranged lighting into three ways; uniform, cove, and wall wash. The participants of the experiment were 100 university students, who were introduced individually to each room lighting

arrangement (Durak, Olgunturk, Yener, Guvenc, & Gurcinar, 2007). For the purpose of this research two aspects of this study are reviewed:

1. The parameters used in the questionnaire questions
2. The uniform lighting illuminance effect.

Therefore, six parameters were included in the questionnaire questions:

1. Clarity
2. Spaciousness
3. Relaxation
4. Privacy
5. Pleasantness
6. Order

Moreover, two illuminance levels were implemented; 320 and 500 lux. During the experiment the participants were given the liberty to choose the lighting arrangement and illuminance in order to assign a parameter to each situation (Durak, Olgunturk, Yener, Guvenc, & Gurcinar, 2007).

A summary of the results of the study in regard to the tested parameters and illuminances are shown in Table 2.4 below.

Table 2.4: Summary results of the (Durak, Olgunturk, Yener, Guvenc, & Gurcinar, 2007) study

Parameters	Uniform	Cove	Wall Wash	500 lux	320 lux
Clarity	●		●	●	
Spaciousness			●	●	
Relaxation		●			●
Privacy		●			●
Pleasantness		●	●	●	●
Order			●	●	

It can be concluded from the above results that the uniform lighting profile, wall wash lighting profile and high illuminance characters are mainly associated with clarity,

spaciousness, pleasantness and order, while cove lighting profile and low illuminance are associated with relaxation and privacy. Therefore, two points are suggested based on this study:

1. The lighting profiles and types, and the illuminance can vary according to the space functionality.
2. The chosen parameters, e.g. for libraries, can be chosen according to the designated spaces and the functionality of each space.

Furthermore, in a Korean study on lighting intensity in a classroom setting, the researchers installed six LED fixtures in accordance with the national specification of lighting illuminance in classroom spaces, which specifies a range between 300 and 600 lux. Moreover, the study initially measured the general illuminance of the lighting in the classroom space by dividing the 8 m x 6.5 m area into 300 squares and taking the measurement at the center of each square as shown in Figure 2.13 below (Eo & Choi, 2014).

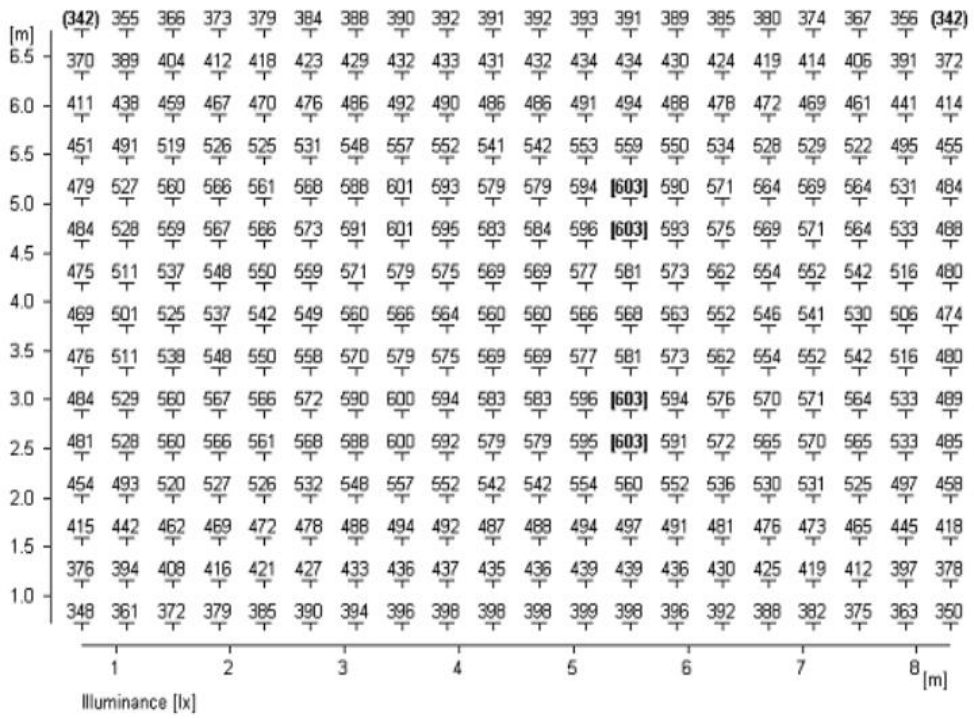

Figure 2.11: General illuminance measurement at the case study space (Eo & Choi, 2014)

Thus, the minimum illuminance measurement was 342 lux and the maximum illuminance measurement was 603 lux, with an average of 499 lux. Moreover, a questionnaire methodology was adopted in the survey were participants evaluated the following parameters on a five-point satisfaction Likert scale (Eo & Choi, 2014):

1. Brightness
2. Psychological stability
3. Effectiveness
4. Supporting learning outcomes
5. Supporting learning needs
6. Positive emotions

The results of the study show that the LED lighting with illuminance within the specified standards have had a positive impact on all the studied parameters ranging between 25% to 30% (Eo & Choi, 2014). Moreover, other medical oriented studies have used general parameters of the lighting such as quantity and quality, while studying the eye disorders of the participants, who took a questionnaire that was used to correlate both factors (Zamanian, Daneshmandi, Mazidi, Nejad, & Haghayegh, 2014).

2.5 Lighting in Libraries

When studying lighting strategies in the library environment, there are two different considerations based on the functionality of the space. Therefore, the bookcases' aisles and the study or reading areas should be considered during the design of the lighting. Nonetheless, the experts on the subject focus mainly on two main points (Malman, 2005) (CHPS, 2002):

1. Even or uniform lighting distribution throughout the space.
2. Avoidance of glare in natural and artificial lighting usages.

Furthermore, studies show that using daylighting in libraries by implementing effective designs increased the students' performance up to 26%, while inefficient designs had adverse effects on performance. Thus, there are several benefits to using natural lighting in the library space, beside academic performance (CHPS, 2002):

1. Energy saving: while schools spend 40% of their electric consumption on lighting.
2. Lighting quality: natural lighting provides a high-quality lighting that can be used as task lighting.
3. Positive health impacts: daylighting helps relaxing eye muscles for reading tasks, reducing stress, and regularizing the hormone pattern, which increase the focusing ability.

Moreover, there are basic principles in using the daylighting in the educational spaces, and specifically the libraries, which maximizes the benefits from it and minimizes any negative impacts, summarized as the following (CHPS, 2002):

1. Avoiding direct sunlight, as the sun is a very strong lighting source.
2. Providing diffused and uniform illumination
3. Avoiding glare
4. Supporting the natural lighting system with control mechanisms, which showed the ability for energy saving up to 40% in library spaces (Hackel & Schuetter, 2013).
5. Integrating the natural lighting with the artificial lighting system
6. Planning the lighting strategy according to the space layout and needs

In a study that examined the lighting and its impacts in a library environment, two main methodologies were adopted; a quantitative methodology through users' evaluation questionnaire, and qualitative methodology through illuminance measurement. In the quantitative part of the study, the researchers divided the time periods of the day into 3 main intervals (Thangaraj & Balaji, 2014):

1. Morning: 10.00 am to 11.00 am, where 47 students participated in the study.
2. Noon: 12.30 pm to 1.30 pm, where 62 students participated in the study.
3. Afternoon: 3.00 pm to 4.00 pm, where 57 students participated in the study.

The questionnaire asked the participants several questions about the impact of the lighting on their seating preference, time spent in library, optimizing daylight through changing the seating layout, lighting brightness, and glare from sun lighting. The results of the study show that lighting affects the students seating preferences and an increase of glare and brightness during the noon and afternoon periods caused by natural and artificial lighting. However, through the qualitative measurements of the illuminance showed different readings according to the area and period as shown in Table 2.5 below (Thangaraj & Balaji, 2014).

Table 2.5: Illuminance measurement according to zoning and period as per (Thangaraj & Balaji, 2014)

	Morning	**Noon**	**Afternoon**
Reading area – Academic zone	280 lux	370 lux	170 lux
Newspaper reading zone	350 lux	260 lux	220 lux
Desktops	80 lux	84 lux	82 lux

The above illuminance reading shows many inadequate lighting in seven out of the nine measurements taken, as the lighting illuminance for libraries should has a minimum of 300 lux, according to the study (Thangaraj & Balaji, 2014).

Nevertheless, the study did not show a sufficient correlation between the quantitative and qualitative parts of the study, which could have been beneficial to establish the impacts of lighting on the users.

On the special lighting illuminance requirements for library spaces, (Dean, 2005) provides minimum and average illuminances for the different library spaces in foot-candle, which are translated to lux for the consistency of this study, as shown in Table 2.6 below.

Table 2.6: Minimum and average illuminances for library spaces (Dean, 2005)

	Minimum illuminance (Lux)	**Average illuminance (Lux)**
Occupied book stacks	65	388
Unoccupied book stacks	54	81
Book repair	215	323
Cataloging	215	323
Reference desk	215	323
Computer zone	215	323
Multimedia	215	323
Reading (magazines)	215	323
Detailed reading	538	807

3. METHODOLOGY

This chapter provides a brief description of the case space used in this research, as well as the study tools used for the objective and subjective measurement of the lighting in the library. Moreover, the research design is narrated and the analysis strategy introduced.

3.1 Case Space Selection

The case study is conducted in the library of Çankaya University in Ankara. The library consists of two floors dedicated for different functions, mainly for study areas and book shelfing. For the benefit of the study, the area of the library is divided into four main areas; namely A, B, C and D. Table 3.1 shows the information of each section of the library, and the lighting type used in each one of them. Moreover, figures 3.1 and 3.2 shown the ground floor and first floor plans, respectively. Figure 3.3 provides as section in the library.

Figures 3.4, 3.5 and 3.6 provides different pictures of the case space.

Table 3.1: Area information for the library of Çankaya University

Area Code	Area Description	Function	Lighting Description
A	Area at the entrance of the library and the only area covered by the soffit of the first floor	Reception area and book shelves	Artificial lighting
B	East side oriented, ceiling and wall side covered by a skylight, mainly light and reflective surfaces	Study area and book shelves	Skylight natural lighting and artificial lighting
C	West side oriented, ceiling and wall side covered by a skylight, mainly light surfaces	Study area and book shelves	Skylight natural lighting and artificial lighting
D	Terrace style located in the second floor through a stair from the back side	Study area and book shelves	Artificial lighting and limited indirect natural lighting

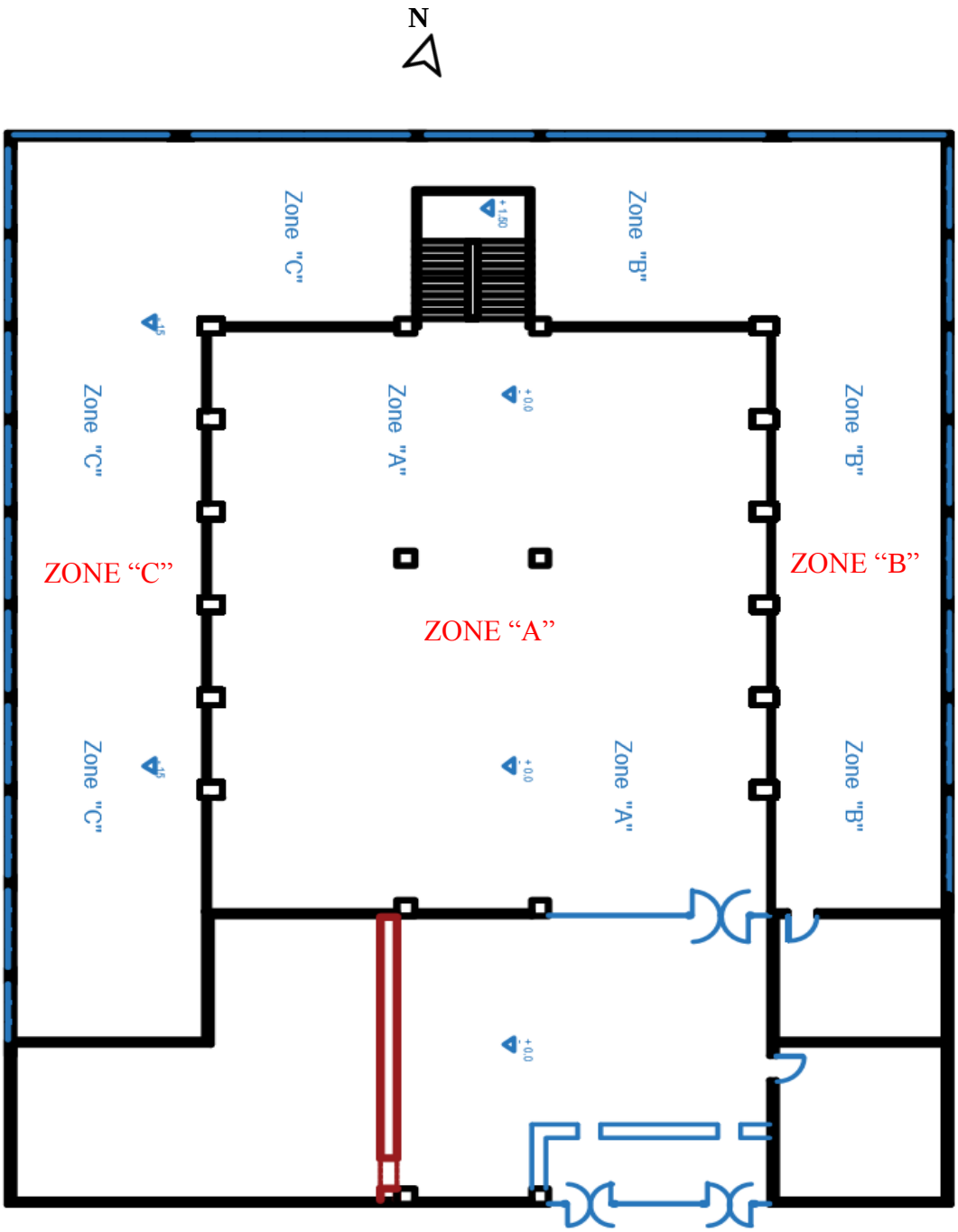

Figure 3.1: Ground Floor scheme

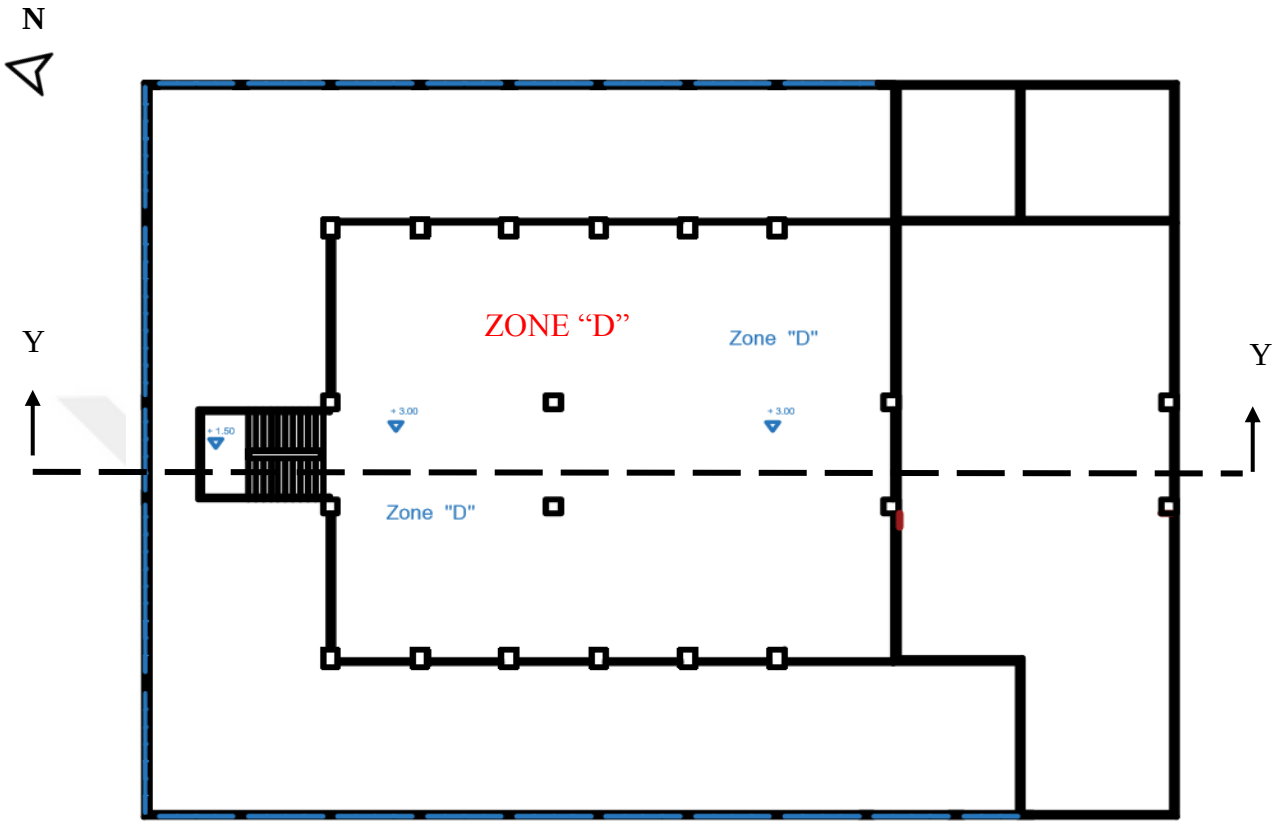

Figure 3.2: First floor scheme

Figure 3.3: A section in the library (Y-Y)

Figure 3.4: Zone B of the library supplied with a skylight assembly

Figure 3.5: Zone D at the second floor

Figure 3.6: Skylight at Zone C

Figure 3.7: Zone A at the First floor of the library

3.2 Study Questions

In order to achieve the main aim of this study and the set objective, the study questions are aligned to guide the research into the desired goal and facilitate a comprehensive research and study tools' design. Therefore, the study questions are as the following:

Q1: What are the lighting properties of the different areas of the case study library?

Q2: What are the illuminance values provided in the library space in different areas during the different day times and variations of weather?

Q3: How do the illuminance values and the lighting conditions influence the behavior of the students in the space?

Q4: How do the lighting conditions and types affect the usage of the students from the library?

Q5: What is the correlation between the lighting conditions and the space clarity and spaciousness?

Q6: What is the correlation between the lighting conditions and the stress levels of the students?

3.3 Questionnaire Design

The questionnaire built for this research is composed from 23 questions, distributed into three main sections:

1. Demographics and Library use.
2. Area Lighting Evaluation
3. Library Overall lighting evaluation

The questionnaire form is provided as Appendix A in this thesis for referencing.

3.3.1 Demographics and Library Use

This section contains seven questions, with the aim to collect information about the study participants and the conditions accompanying their evaluation of the lighting conditions in the library. The questions included in this section are as the following:

1. Gender: participants provide their gender information from two choices; male and female.
2. Age: an open-end question for participant's age to be provided in years.
3. Time, then survey is taken: participants are asked to indicate the time period, when they are taking the questionnaire from five choices; 9:00 to 10:00, 10:00 to 12:00, 12:00 to 14:00, 14:00 to 16:00, and after 16:00 (Thangaraj & Balaji, 2014).
4. Area, where this survey is taken: participants are asked to indicate the area they are sitting in at the time of taking this questionnaire from the previously identified areas; A, B, C and D.
5. Weekly library use: the questionnaire requests the participants to indicate the frequency of visiting the library from three choices: Less than 3 times per week, almost every day, and More than once per day.
6. Time of visit: the questionnaire requests the participants to indicate the time period, when they visit the library the most from five choices; early morning, late morning, noon, afternoon, and evening.
7. Areas usage preference: the participants are requested to arrange areas A, B, C and D according to their preference of usage when visiting the library.

3.3.2 Area Lighting Evaluation

The aim of this section of the questionnaire is to evaluate the lighting in a specific area of the library and link it to the results of the research as part of the analysis and discussion part. Thus, this part provides eight statements, which need to be rated by the participants on an even Likert agreement scale

of; I totally agree, I agree, I slightly agree, I slightly disagree, I disagree, and I totally disagree. The statements rated in this part are:

- The lighting provided in the area is suitable for visual clarity.
- The lighting provided in the area makes the place more spacious.
- The lighting provided in the area increases the relaxation and reduces stress.
- The lighting provided in the area increases the privacy.
- The lighting provided in the area is uniform and even.
- The lighting provided in the area gives a pleasant feeling.
- The lighting provided in the area is sufficient for the tasks performed.
- The lighting provided in the area gives a positive feeling.

3.3.3 Library Overall Lighting Evaluation

The aim of this section of the questionnaire is to evaluate the lighting in the library as a whole and link it to the results of the research as part of the analysis and discussion part. Thus, this part provides eight statements, which need to be rated by the participants on an even Likert agreement scale of; I totally agree, I agree, I slightly agree, I slightly disagree, I disagree, and I totally disagree. The statements rated in this part are:

- The lighting provided in the area is suitable for visual clarity.
- The lighting provided in the area makes the place more spacious.
- The lighting provided in the area increases the relaxation and reduces stress.
- The lighting provided in the area increases the privacy.
- The lighting provided in the area is uniform and even.
- The lighting provided in the area gives a pleasant feeling.
- The lighting provided in the area is sufficient for the tasks performed.
- The lighting provided in the area gives a positive feeling.

3.4 Data Collection and Analysis

In addition to qualitative data collected via the questionnaire, quantitative illuminance measurements are collected in the different library areas. Furthermore, the measurements are taken in conjunction with the date, time and weather conditions in order to ensure the incorporation of all necessary data. Table 3.2 shows the table that is used for the lux measurement data collection. Moreover, Figure 3.7 provides a picture of CEM Model 8820 used in the lux measurement.

Table 3.2: Illuminance Measurement collection table

Zone	A	B	C	D
Date				
Time				
Weather Condition				
Illuminance 1				
Illuminance 2				
Illuminance 3				
Illuminance 4				
Illuminance 5				

Figure 3.8: CEM Model 8820

In the subjective evaluation, the participants' sample collected is 120 questionnaires. Thereafter, quantitative and qualitative data are entered into IBM SPSS Statistics for analysis and correlations calculations. Different correlation techniques such as one-way ANOVA and t-test, and correlation tests are used where applicable in order to answer to the study questions and drive the final conclusions from the study. Cronbach's alpha for the lighting perception is 0.914 and for the measurements 0.988, which are considered as acceptable for the reliability of the study.

4. RESULTS AND DISCUSSION

In this chapter, the results of the case study are presented in descriptive and analytical models. The main objective is to establish the necessary correlations between the subjective and objective measures, as well as discussing the results.

4.1 Findings

Since the research includes subjective and objective measurements of the lighting quality and lighting perception in the case space, this section presents the findings in each section of the study separately. Furthermore, these data are discussed accordingly and prepared for further analysis and discussion in section 4.2.

4.1.1 Illuminance Measurements

The readings from the illuminance meter were designed to be taken during different time periods and different weather conditions, in order to collect the most representing data possible. Moreover, the data were collected during the whole month of July, which has the highest sun radiation in Turkey according to (Vecan, 2011). Therefore, the data shall present the best natural lighting performance.

Table 4.1 shows the average illuminance readings taken on task surfaces in the different zones at the case space library, also illustrated in figure 4.1.

Table 4.1: Average illuminance measurements in the case space in lux

Zones	**Weather condition**	**Time Periods and Average Lux** (Thangaraj & Balaji, 2014)				
		9:00 – 10:00	**10:00 – 12:00**	**12:00 – 14:00**	**14:00 – 16:00**	**After 16:00**
Zone A	Clear	202	543	396	247	202
	Cloudy	187	325	210	184	167
Zone B	Clear	1780	2567	2213	1004	638
	Cloudy	1281	2102	1764	651	421
Zone C	Clear	844	1344	1603	1029	813
	Cloudy	704	1130	1273	946	693
Zone D	Clear	111	286	241	183	44
	Cloudy	103	233	158	100	41

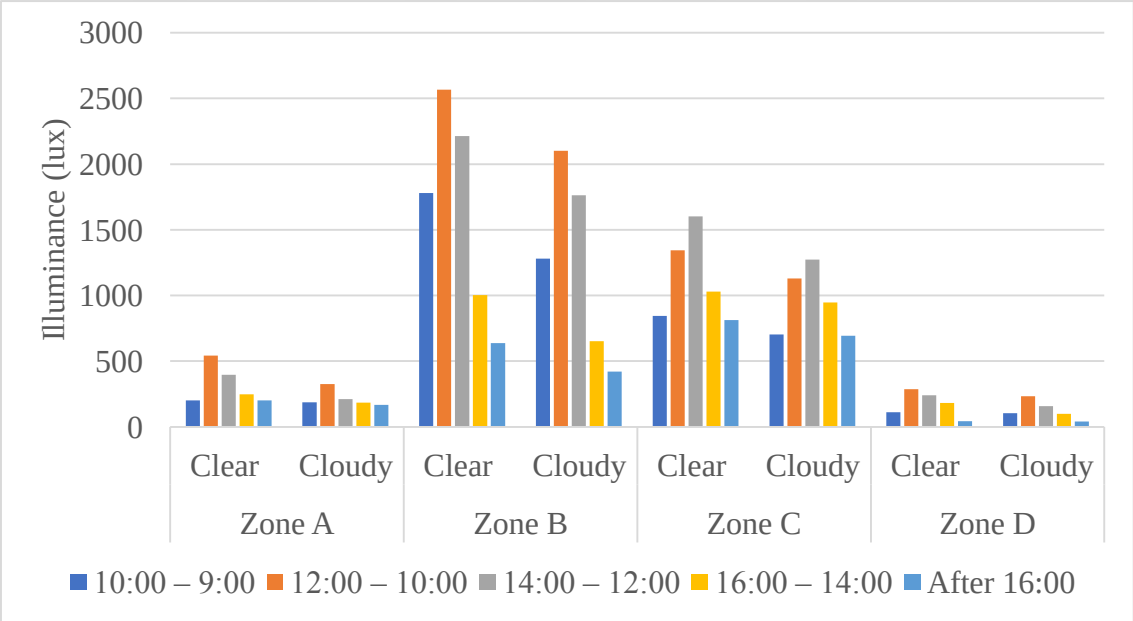

Figure 4.1: An illustration of average illuminance measurements in the case space

As per the measurements presented in the above table, the average difference in illuminance measurements between the clear and cloudy weather conditions are 27.5%, 27.1%, 15.2% and 22.5% for zones A, B, C and D, respectively, where the readings from the clear weather condition are always higher than the readings from the cloudy weather condition. The average illuminance in the library in the clear weather condition is 23.1% higher than the readings from the cloudy weather condition. Therefore, it is evident that natural lighting is effectively contributing in the lighting of the case space.

Furthermore, the illuminance measurements in Zones B and C are always higher than Zones A and D, as the skylight assembly allows natural lighting to enrich the lighting condition in the first two zones. As zone A is oriented towards the East direction, the illuminance values are higher during the morning time periods. However, during the evening time periods the illuminance in Zone C becomes the highest, as it is oriented towards the West.

According to (Dean, 2005), the lighting in the library for reading tasks shall have a minimum of 215 lux and an average of 323 lux, while the areas that detailed reading is required shall have a minimum of 538 lux and an average illuminance of 807 lux. Zone A is the area where the reception and periodicals are located. Thus, the reading tasks data are considered. According the abovementioned minimum and average lux level, Zone A satisfies both conditions during the three middle time periods between 10:00 and 16:00 in clear weather conditions, which is mainly driven by the brief natural lighting passing through the library skylight. During the cloudy weather conditions, the illuminance in Zone A drops below the minimum required lux level in most of the time periods.

Zones B, C and D are assessed against the minimum and average illuminance requirements for the detailed reading tasks. Zones B and C, where the skylight is located, satisfy the minimum lighting requirement during all time periods, with a drop below the required illuminance level during the last period after 16:00. Nonetheless, the readings from Zone D fails to satisfy both requirements, even for the reading tasks requirements which are lower than the detailed reading tasks requirements.

Based on the above results, it can be suggested that zones A and D shall be supported with additional artificial lighting with different extends. Moreover, Zone D can be further supported by natural lighting through installation of reflectors from the skylights available above Zones B and C.

4.1.2 Questionnaire Results

The design of the questionnaire ensures obtaining the required data in order to establish a complete analysis and discussion between the objective and subjective parts of the research. Furthermore, the questionnaire is divided into several parts, which are:

1. Demographic data
2. Library usage data
3. Zone lighting perception evaluation
4. Library lighting perception evaluation

Out of the 120 participants in the questionnaire, 60.83% were males and 39.17% are females, as shown in Figure 4.2.

Moreover, Figure 4.3 shows a histogram of the ages of the participants, where the average age is 29.12. Figure 4.4 shows the time periods the participants have taken the questionnaire.

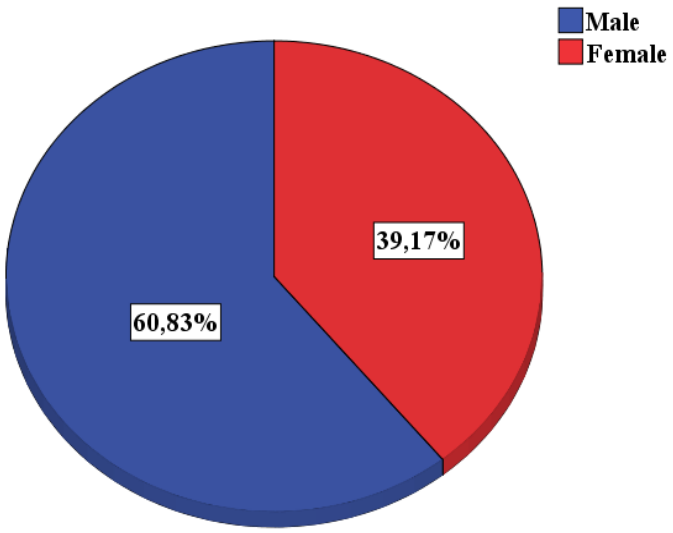

Figure 4.2: Gender of questionnaire participants

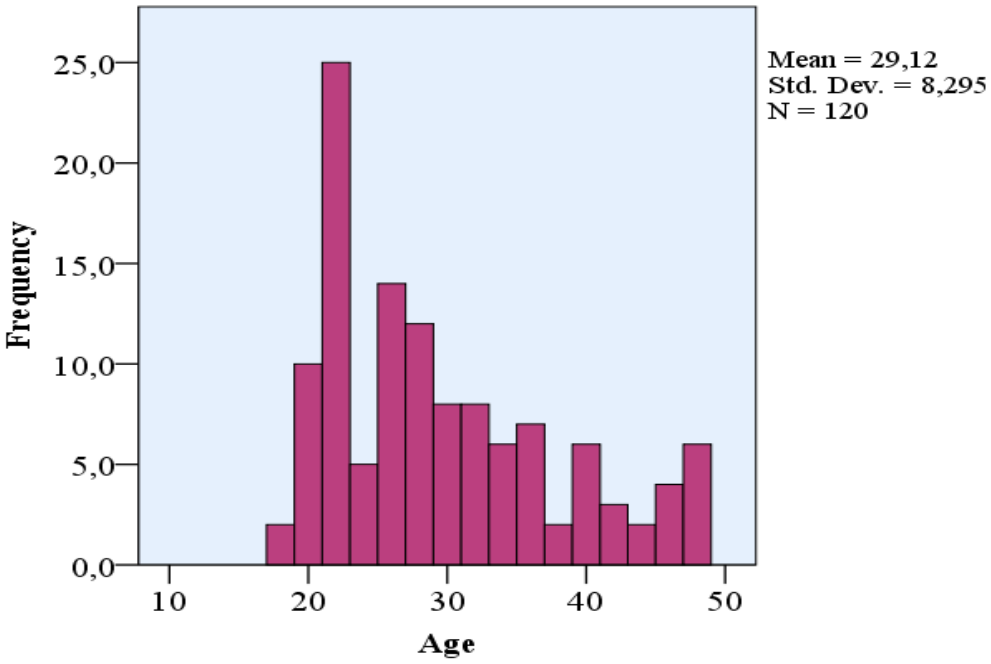

Figure 4.3: Participants' age histogram

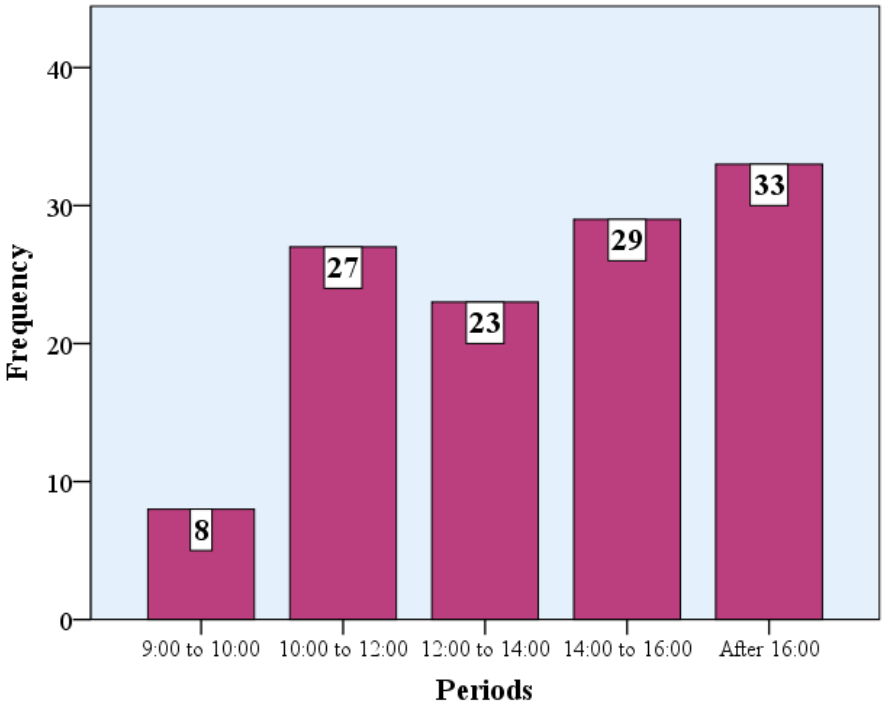

Figure 4.4: Time of taking the questionnaire by the participants

The majority of the participants are of the age between 20 and 30, as the questionnaire is performed in a university library. The time periods where the surveys were taken could be a close presentation of the usage pattern of the library during the different day hours. The above data are further used in order to establish the different tests and correlations with the lighting perception data.

Moreover, the particiants of the questionnaire are distributed evenly among the four zones of the library in order to obtain an equal assessment for all the zones within the library. As shown in Figure 4.5, 56.66% of the participants visit the library on a daily basis, which shows the importance the usage pattern of the library. This is also evident through Figure 4.6, where the highest visit numbers occur in the late morning and afternoon periods, where 25% and 34.17% of the participants use the library during there time periods, respectively.

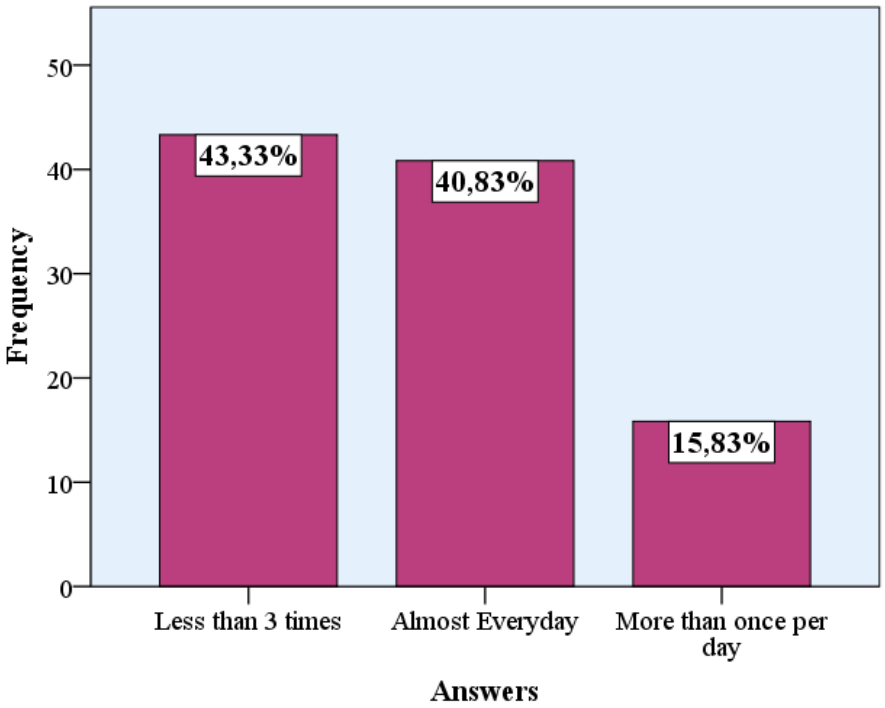

Figure 4.5: Library usage frequency

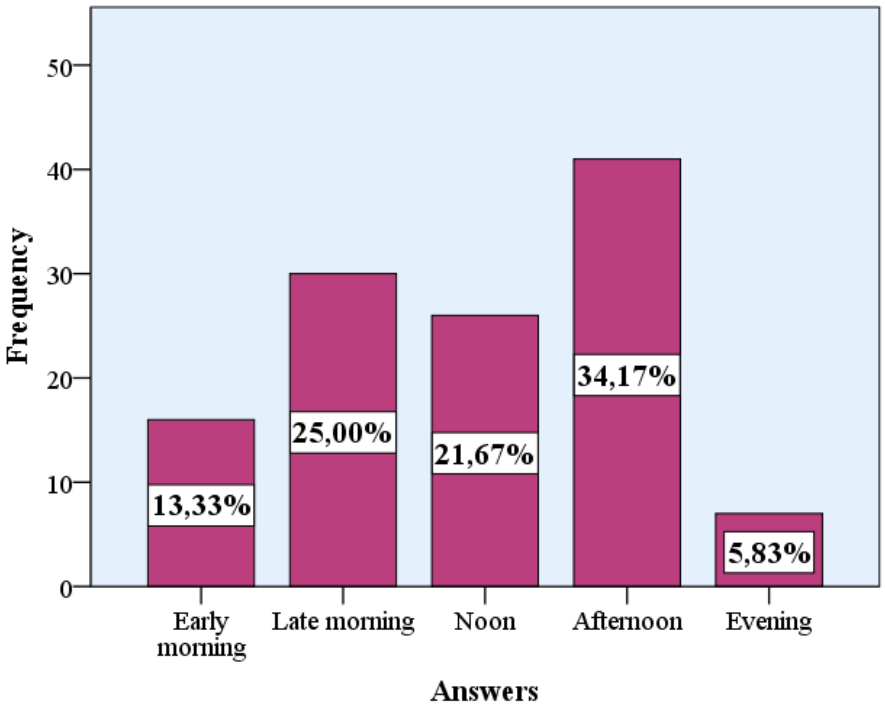

Figure 4.6: Preferred time periods for library usage

Furthermore, the participants are asked to rank their preference of the library zones when visiting the facility. The ranking resluts are shown in Table 4.2. The survey particpants ranked the zones from the most preferred to the least preferred as C, B, A, then D. The first two ranked zones have the skylight assembly, which provides the natural lighting through it that is not provided in zones A and D.

These results indicate that library users prefer the zones where natural lighting is provided.

Table 4.2: Library Zones preference ranking

	First Rank (%)	Second Rank (%)	Third Rank (%)	Fourth Rank (%)	Mean Score	Percentage Score (%)
Zone A	21.7	15.0	26.7	36.7	2.22	55.50
Zone B	26.7	38.3	26.7	8.3	2.83	70.75
Zone C	33.3	32.5	25.0	9.2	2.90	72.50
Zone D	18.3	14.2	21.7	45.8	2.05	51.25

Subsequently, the participants evaluated the lighting according to eight lighting perception indicators compiled from the literature through (Durak, Olgunturk, Yener, Guvenc, & Gurcinar, 2007) and (Eo & Choi, 2014), which are:

1. Suitability for visual clarity
2. Effect on space spaciousness
3. Relaxation effect and stress reduction
4. Increase of privacy
5. Uniformity
6. Pleasantness
7. Suffeciency for performed tasks
8. Positive effect

The evaluation is made in two levels; the zone where the questionnaire is taken and an overall assessment of the library lighting. In zone A, Figures 4.7 to 4.14, the participants indicated that the lighting provided in the area is suitable for visual clarity and suffecient for the performed tasks. The majority of the participants agreed that the lighting increases the space spaciouness, reduces stress, provided uniformly and has a positive and pleasant effects. However, the answers regarding the increase of privacy were not absolute. Therefore, the privacy effect is not dominant in zone A.

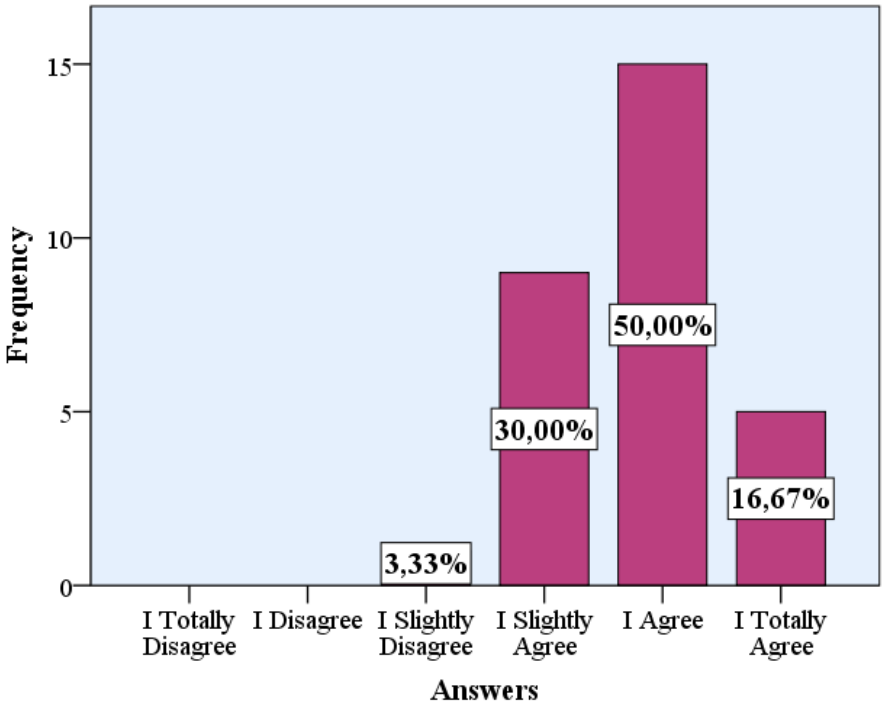

Figure 4.7: Zone A lighting suitable for visual clarity

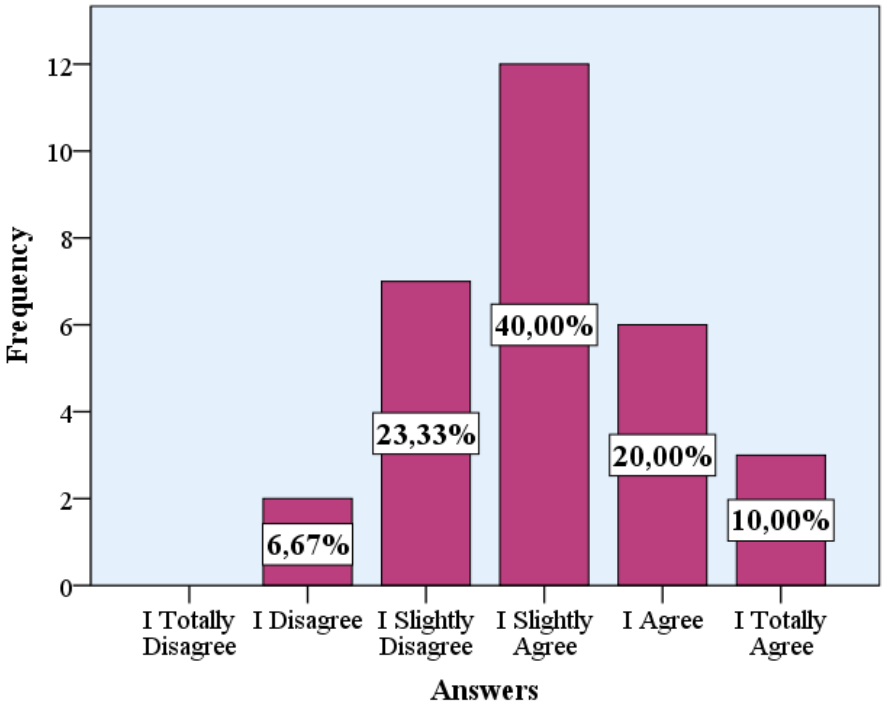

Figure 4.8: Zone A lighting increase space spaciousness

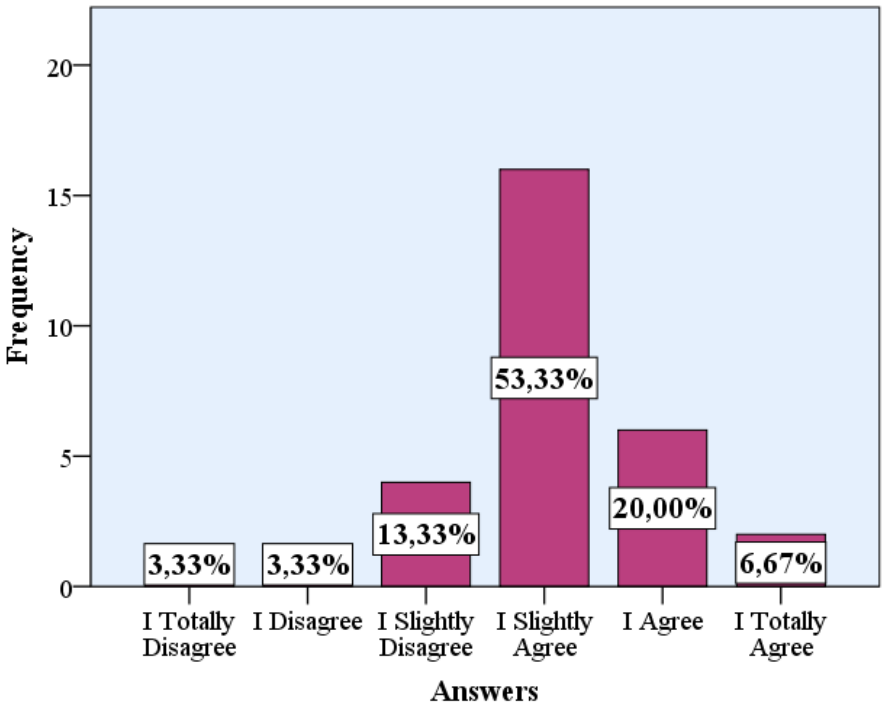

Figure 4.9: Zone A lighting relaxation effect and stress reduction

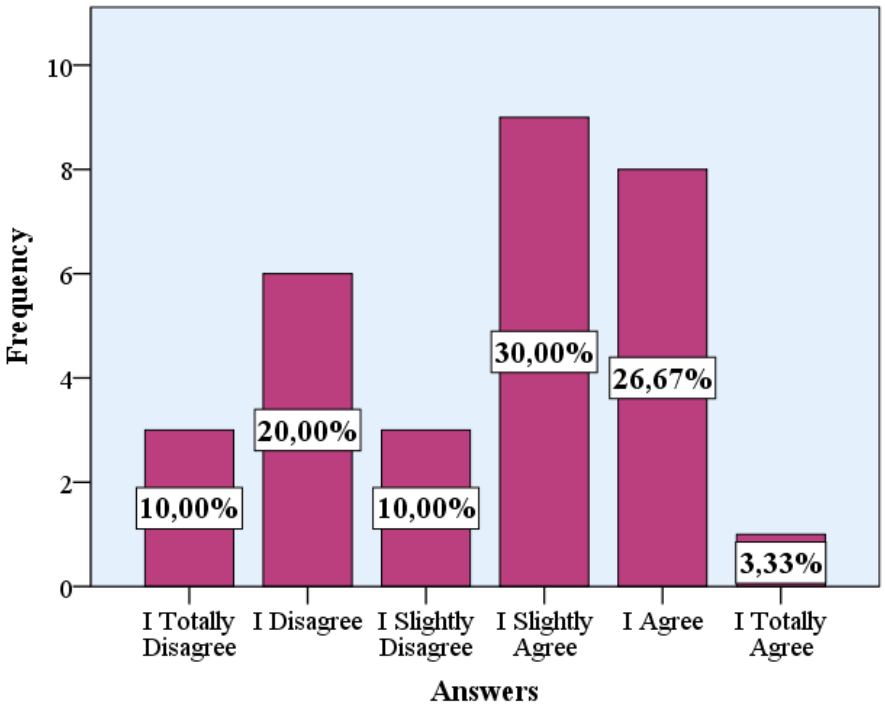

Figure 4.10: Zone A lighting increase privacy

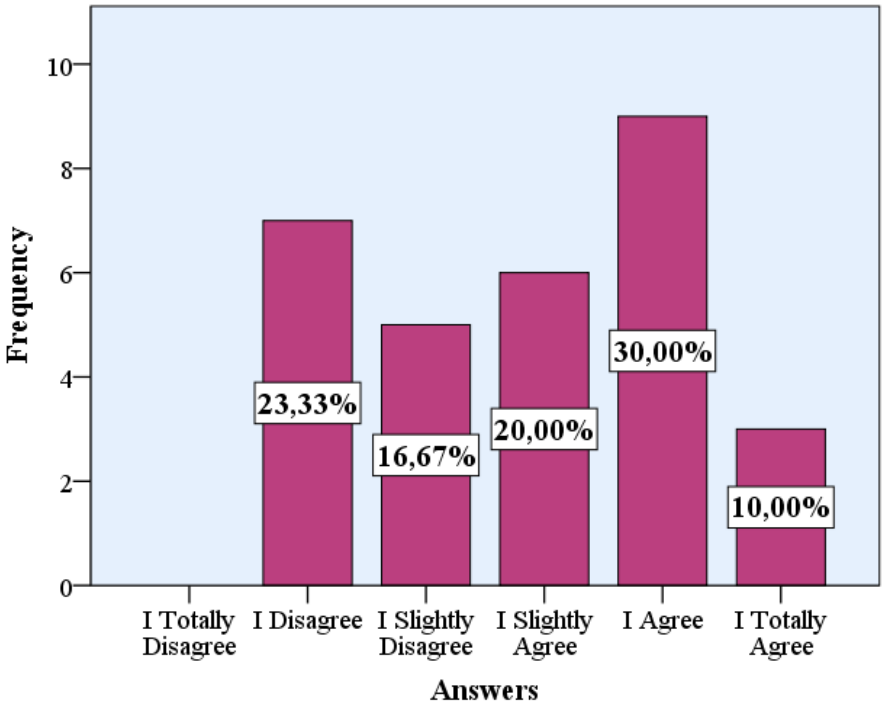

Figure 4.11: Zone A lighting provided uniformly and evenly

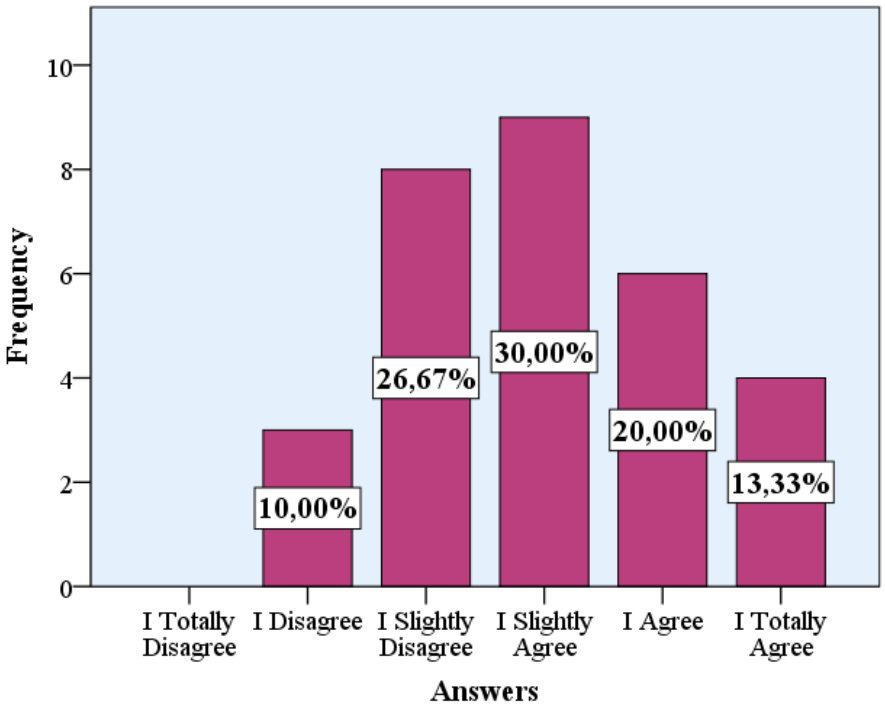

Figure 4.12: Zone A lighting increase pleasantness

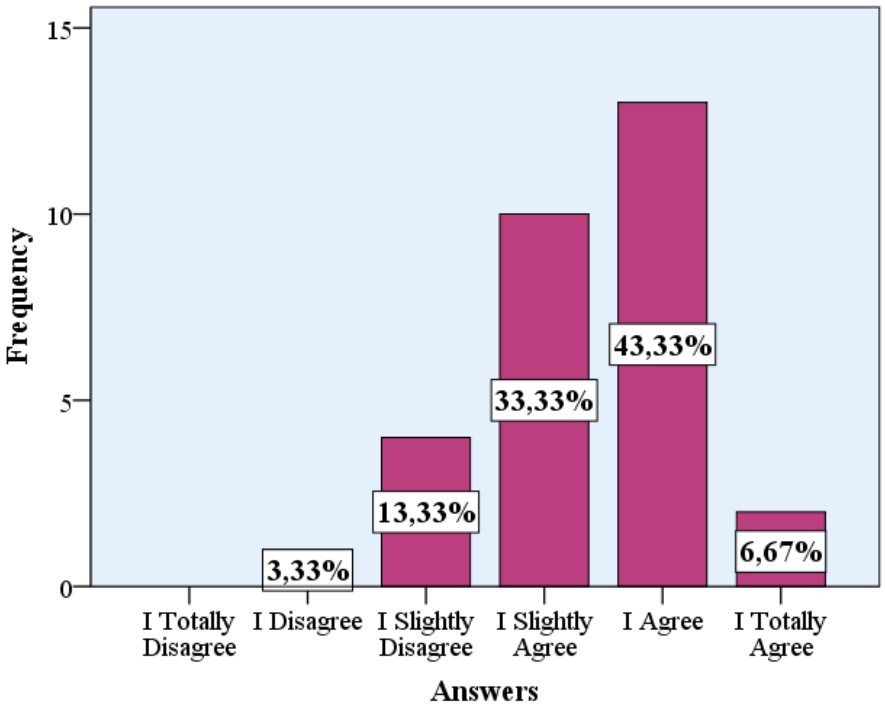

Figure 4.13: Zone A lighting suffecient for performed tasks

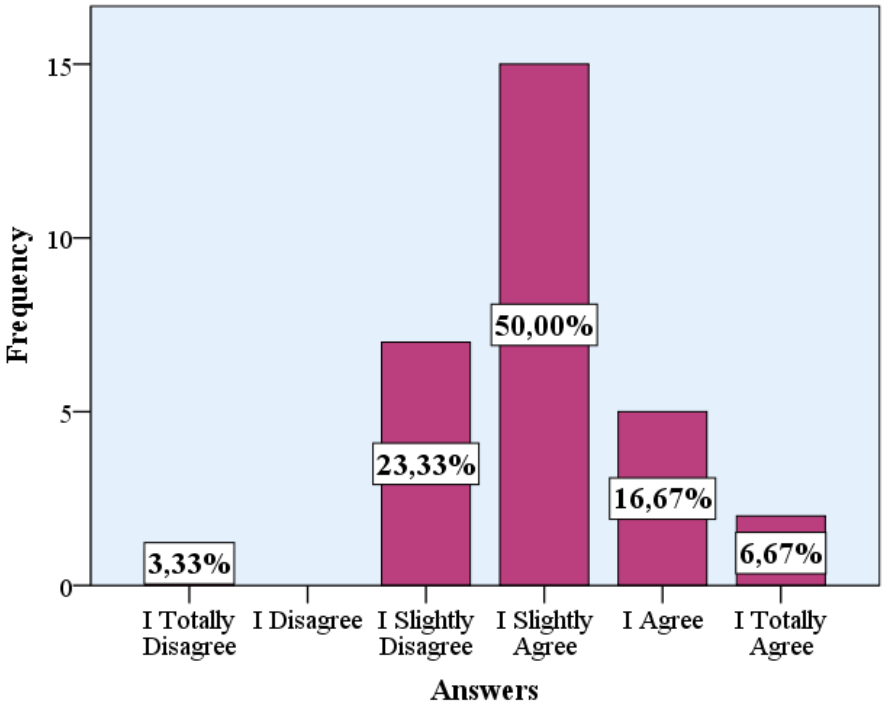

Figure 4.14: Zone A lighting has a positive effect

In Zone B, Figures 4.15 to 4.22, the participants rated positively the majority of the perception indicators. However, similar to zone A, the privacy aspect was rated uniformly, which indicates that the lighting illuminance and type does not increase this factor.

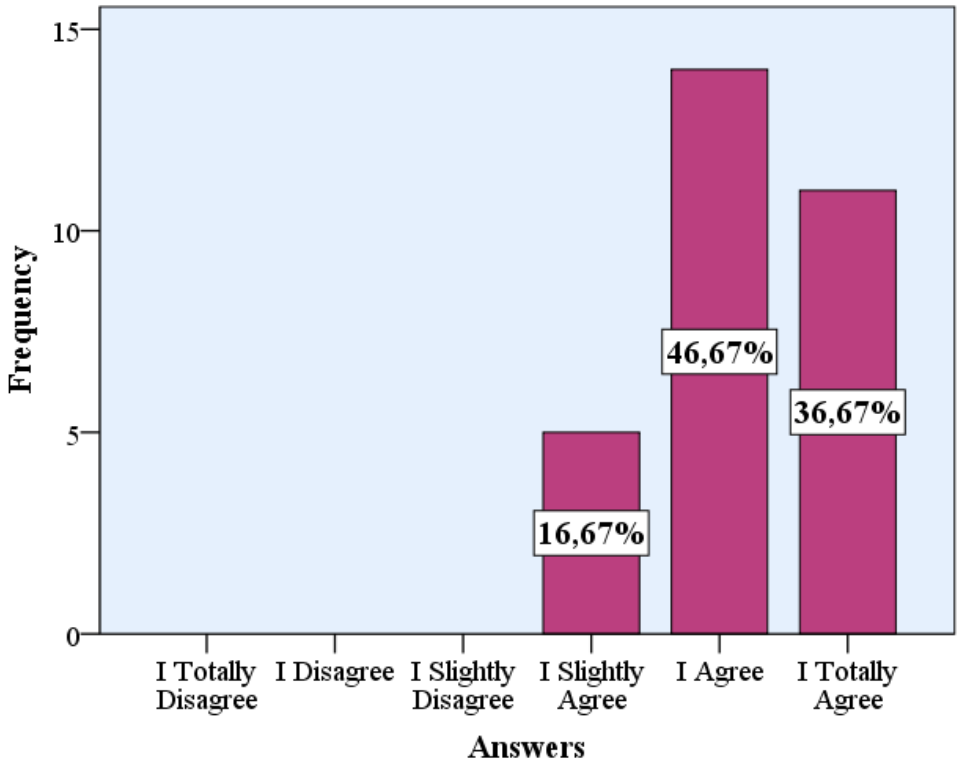

Figure 4.15: Zone B lighting suitable for visual clarity

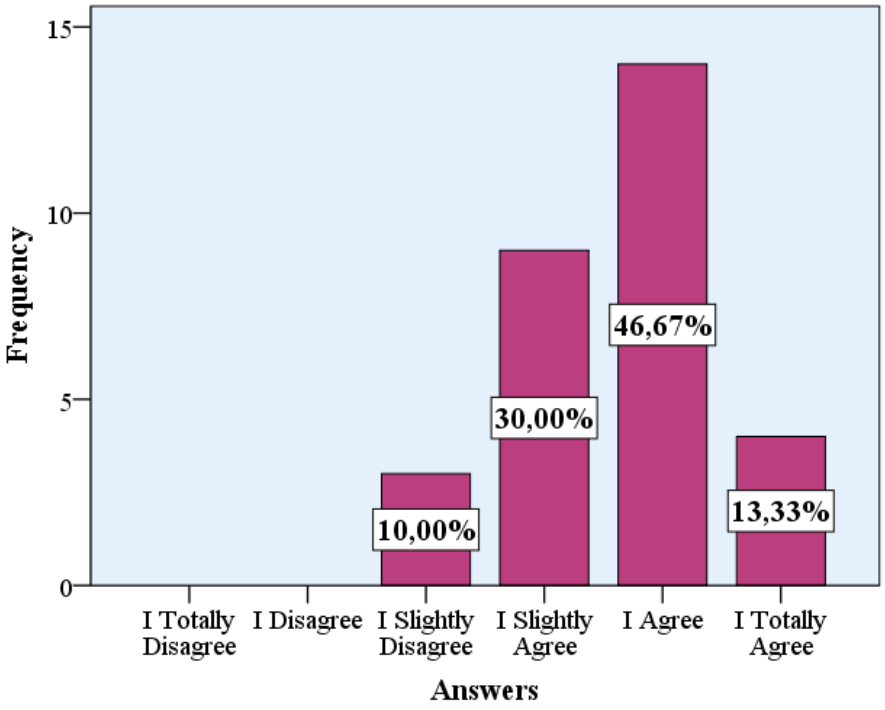

Figure 4.16: Zone B lighting increase space spaciousness

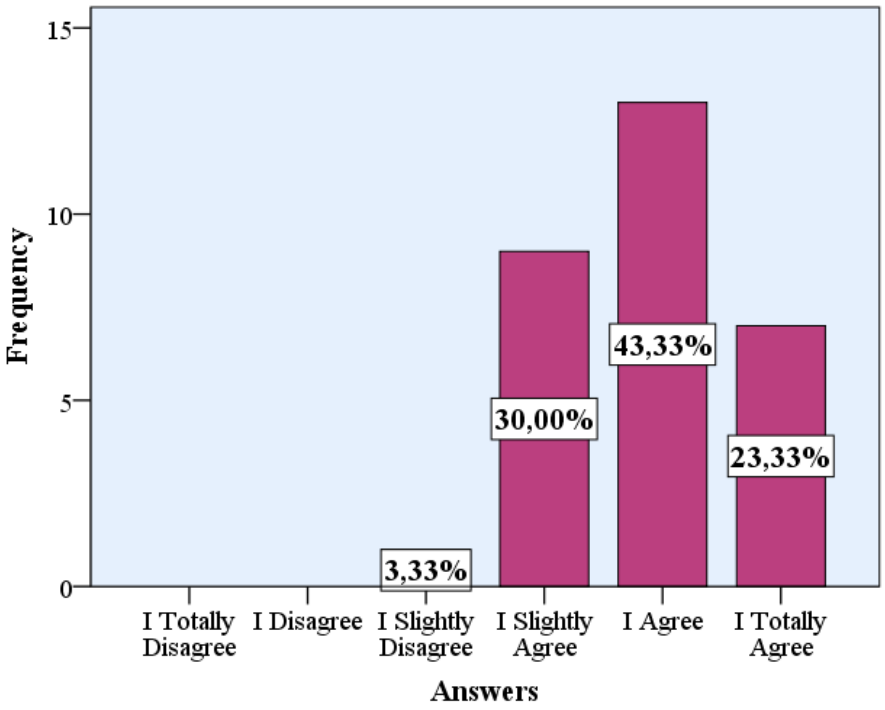

Figure 4.17: Zone B lighting relaxation effect and stress reduction

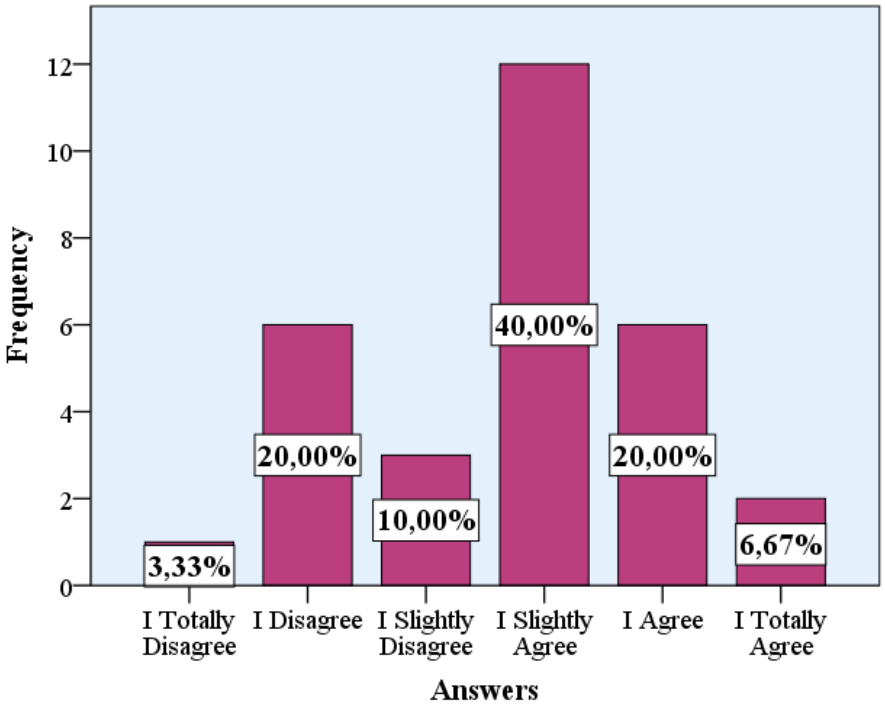

Figure 4.18: Zone B lighting increase privacy

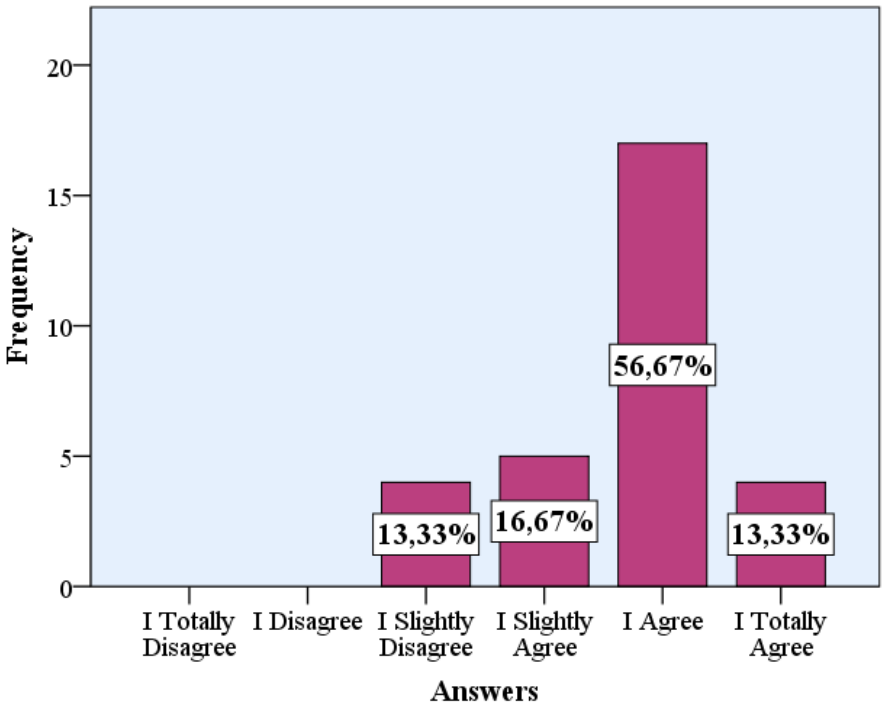

Figure 4.19: Zone B lighting provided uniformly and evenly

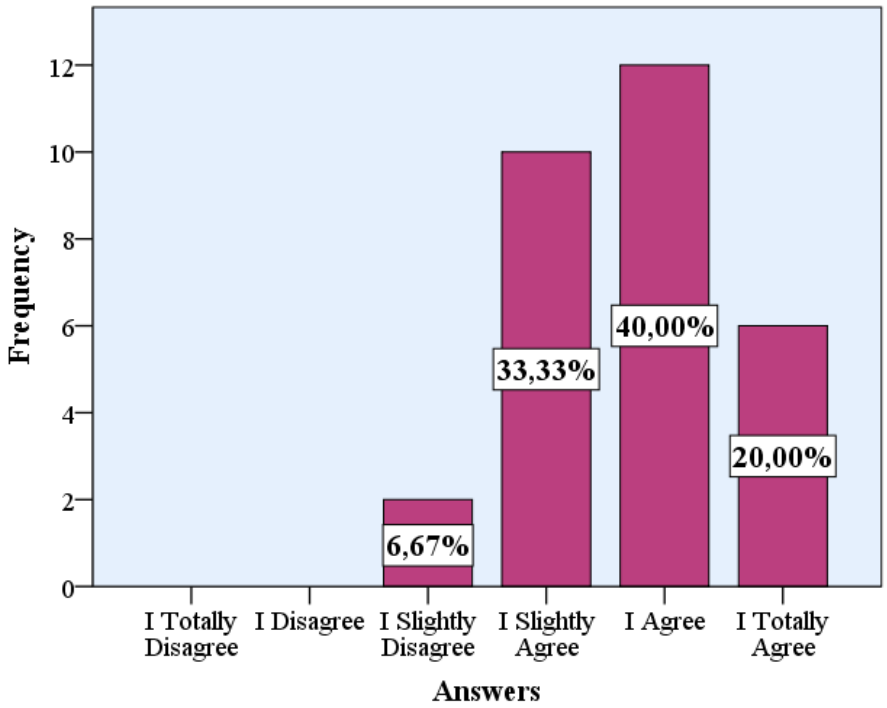

Figure 4.20: Zone B lighting increase pleasantness

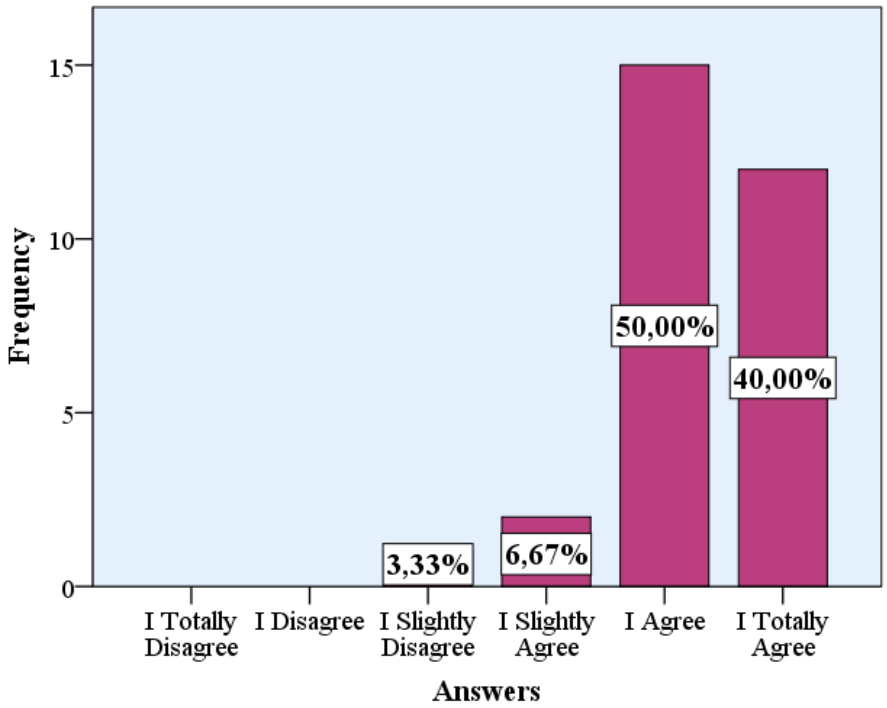

Figure 4.21: Zone B lighting suffecient for performed tasks

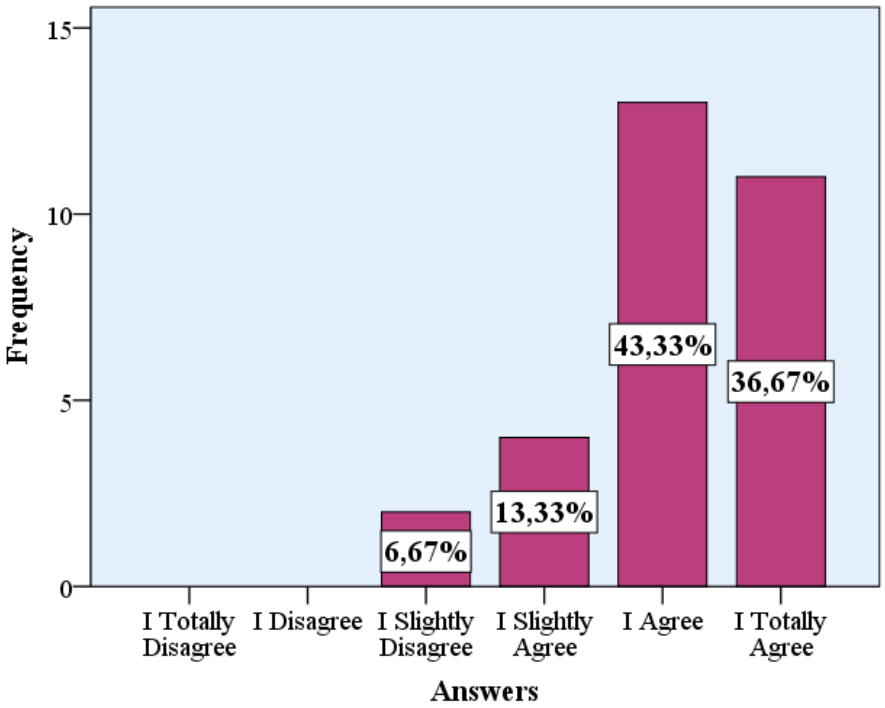

Figure 4.22: Zone B lighting has a positive effect

Similar to zone B, zone C have had high agreement rate on all of the lighting perception indicators except for privacy and where a significant percentage expressed their disagreement. As shown in Figures 4.23 to 4.30, and previously in the charts for zone B, these two zones have had the highest rates for visual clarity and impact on space spaciousness, which is an effect of the natural ligthing provided in these areas through the skylight.

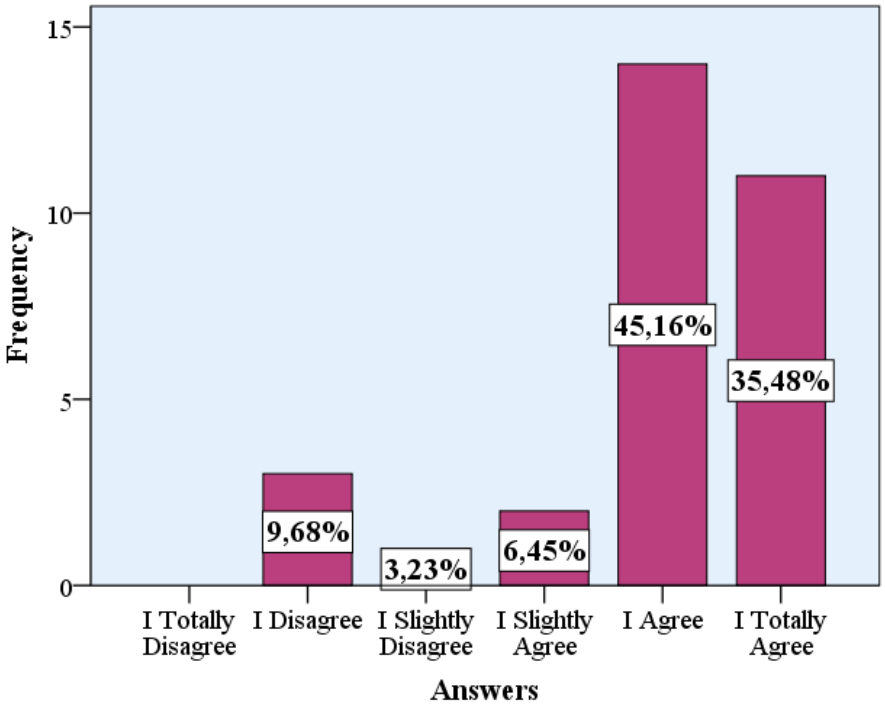

Figure 4.23: Zone C lighting suitable for visual clarity

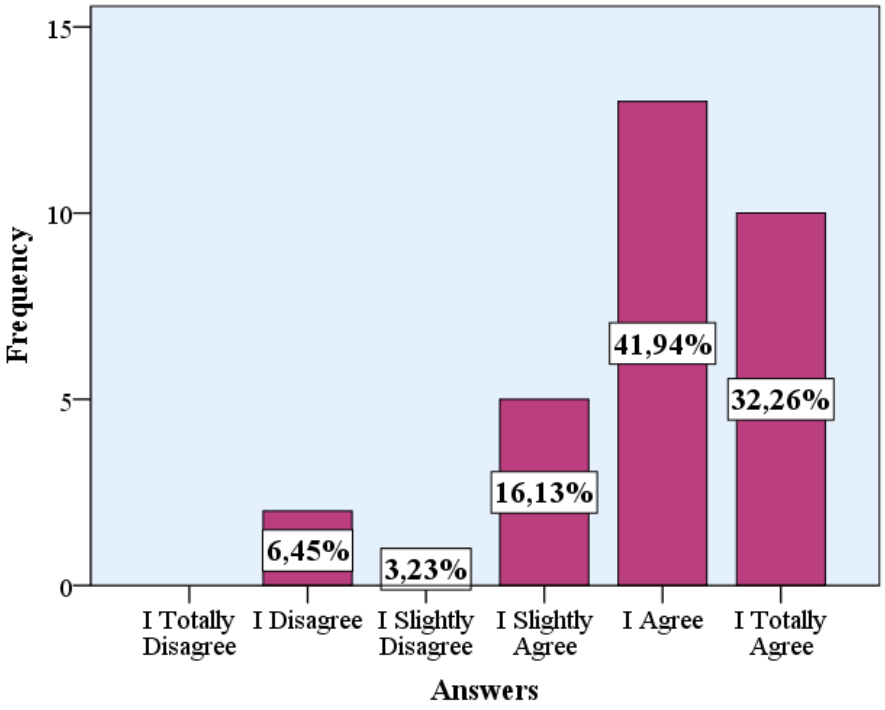

Figure 4.24: Zone C lighting increase space spaciousness

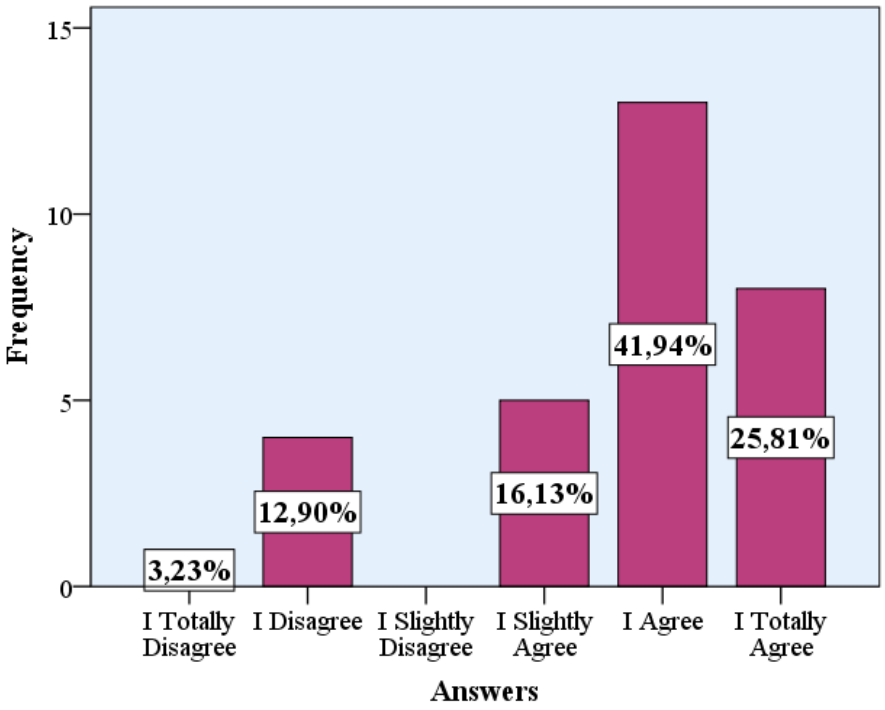

Figure 4.25: Zone C lighting relaxation effect and stress reduction

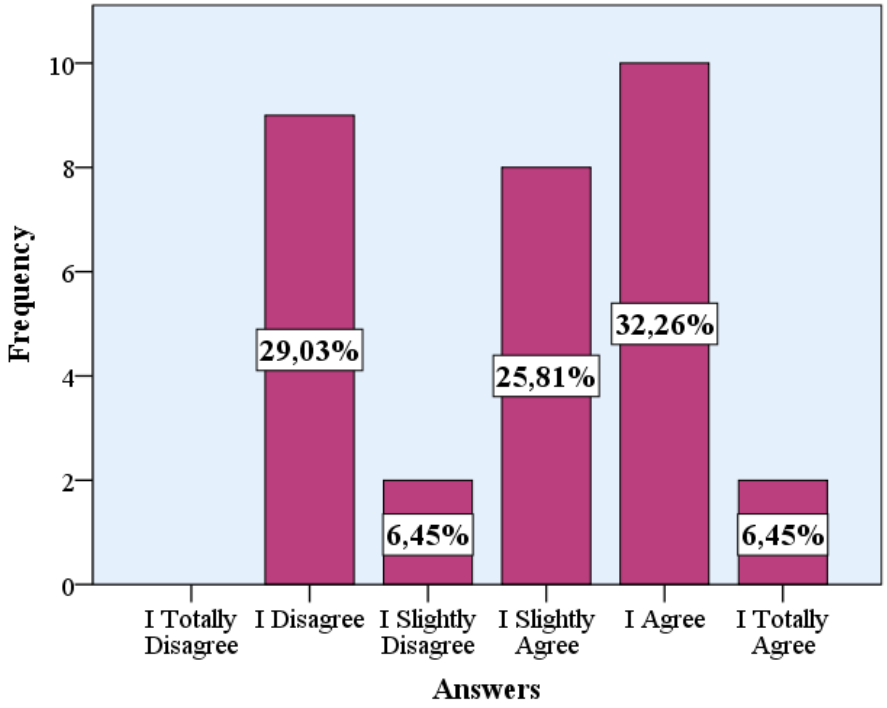

Figure 4.26: Zone C lighting increase privacy

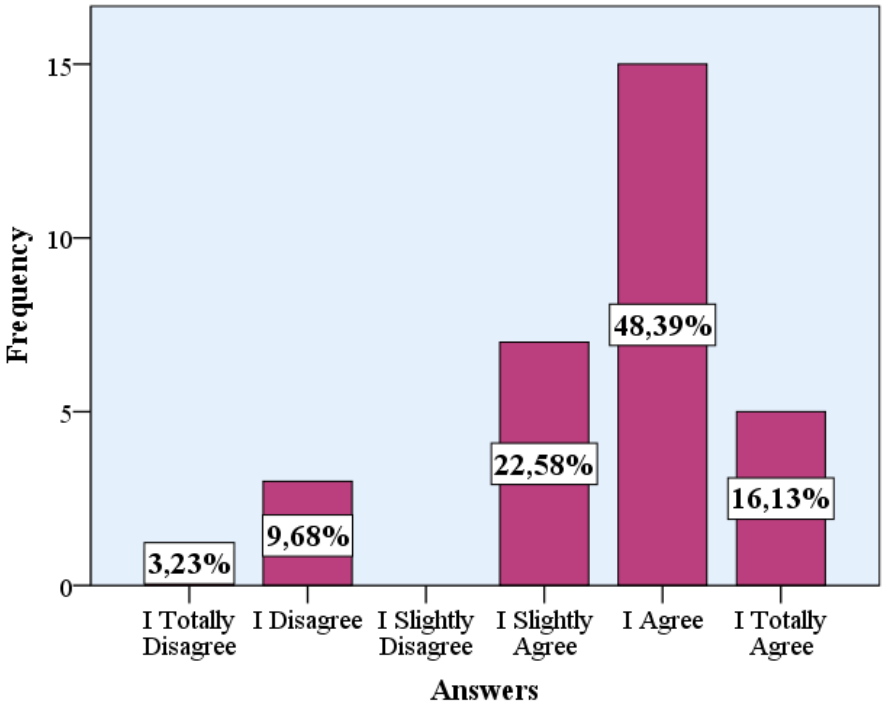

Figure 4.27: Zone C lighting provided uniformly and evenly

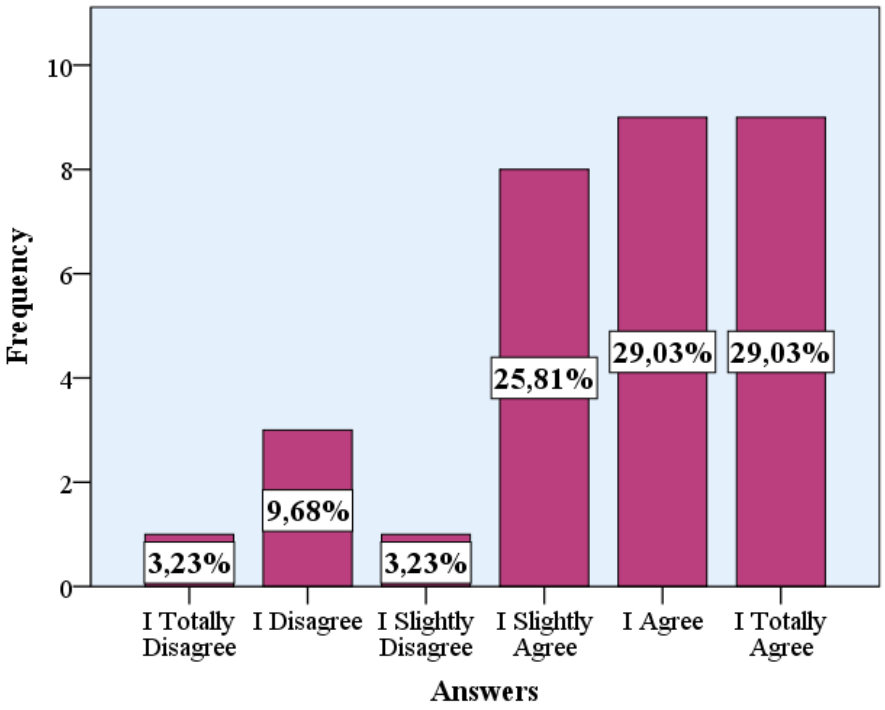

Figure 4.28: Zone C lighting increase pleasantness

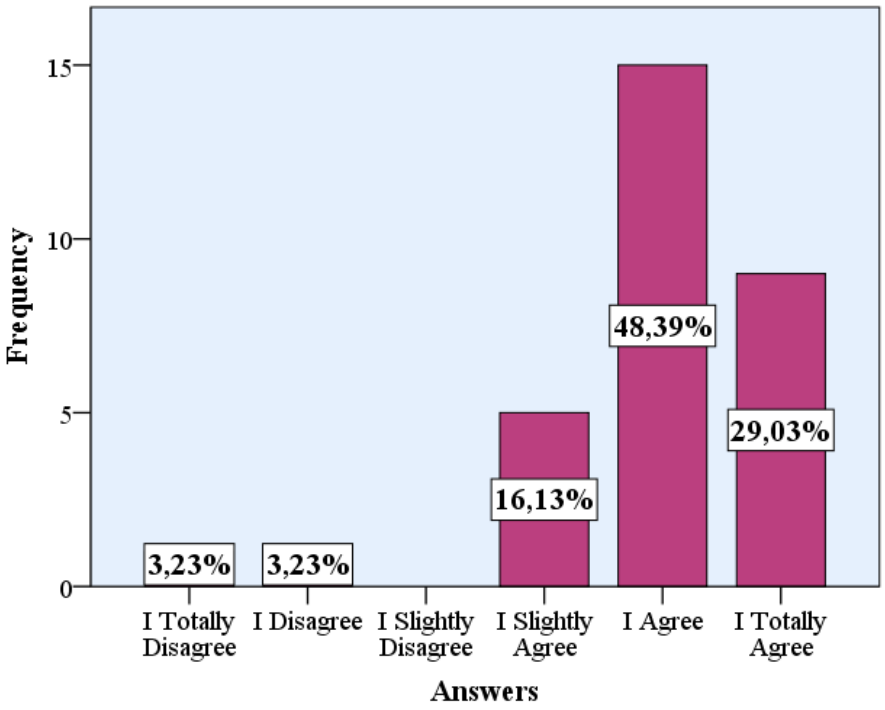

Figure 4.29: Zone C lighting suffecient for performed tasks

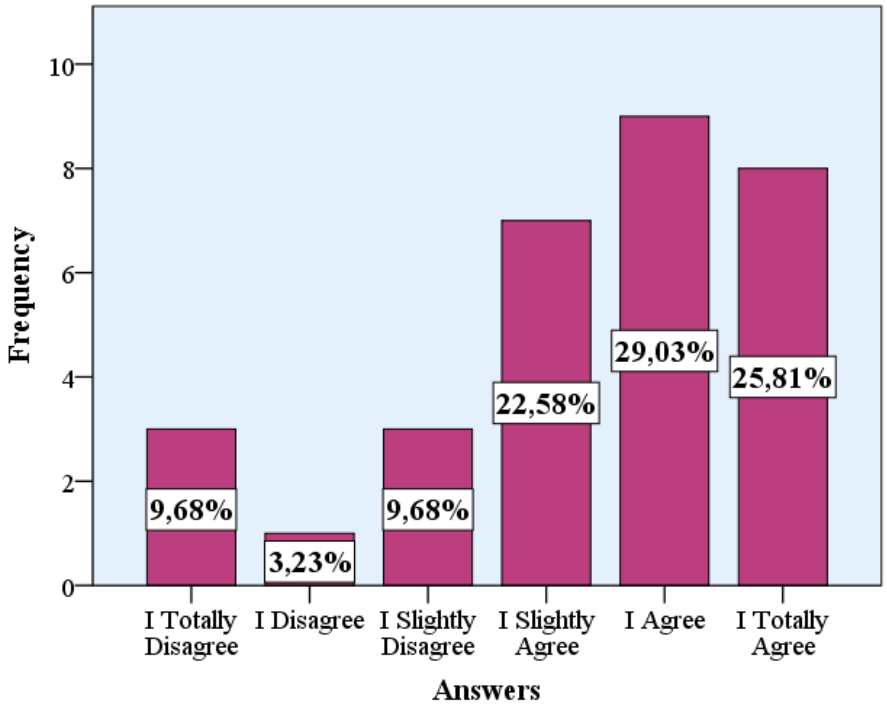

Figure 4.30: Zone C lighting has a positive effect

For zone D located in the second floor of the library and above zone A, the results for visual clarity, space spaciousness and suffeciency for performing tasks were close to the middle region. However, the majority of the participants agreed that the lighting in the zone increases privacy and reduces stress. Furthermore, the results show that the participants believe that the lighting in zone D is not uniformly distributed, while the majority considerd it pleasant and positive. Results shown in Figure 4.31 to 4.38.

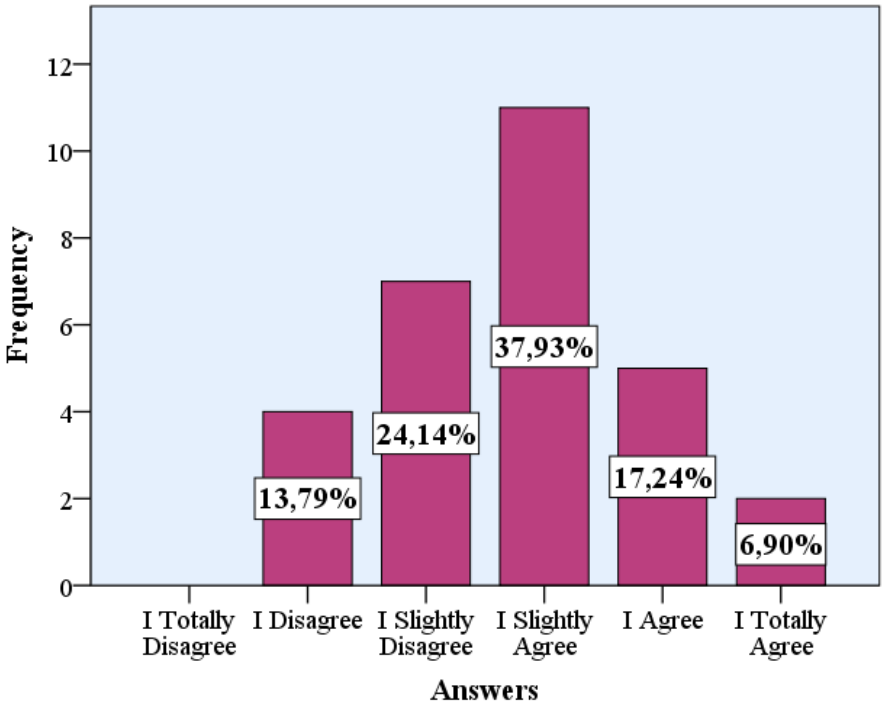

Figure 4.31: Zone D lighting suitable for visual clarity

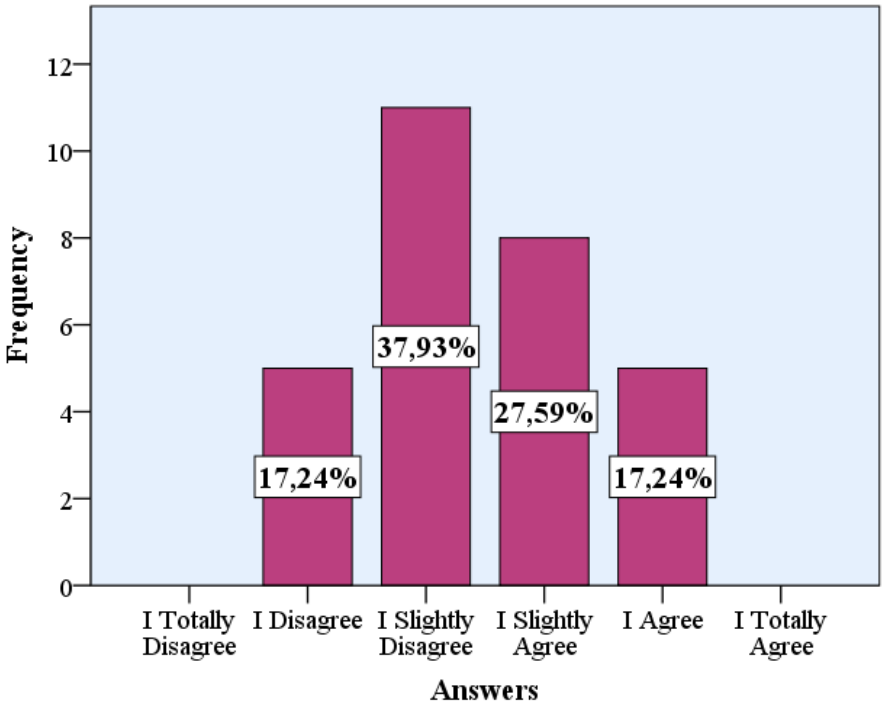

Figure 4.32: Zone D lighting increase space spaciousness

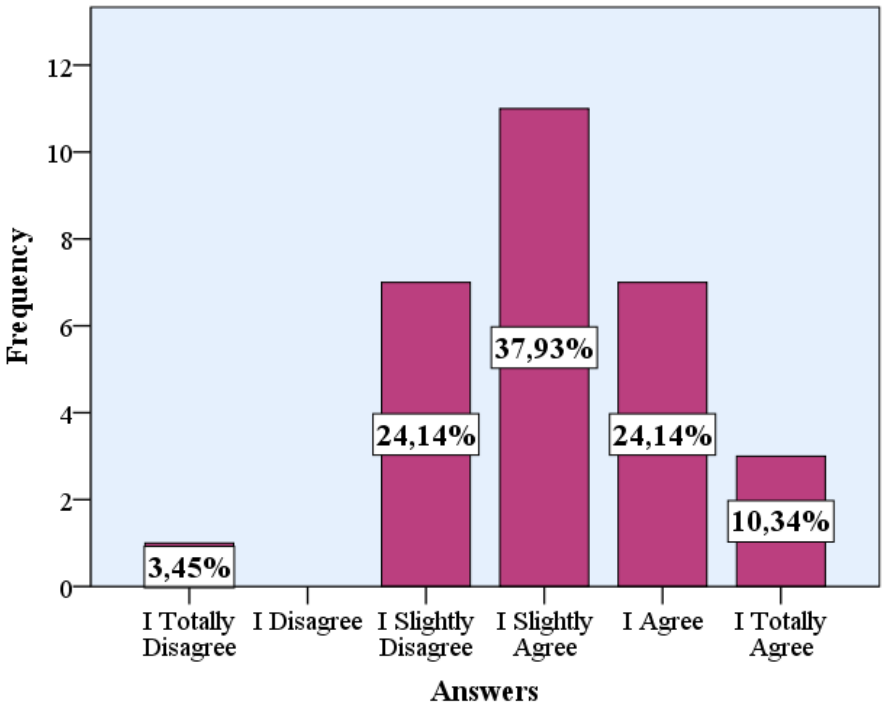

Figure 4.33: Zone D lighting relaxation effect and stress reduction

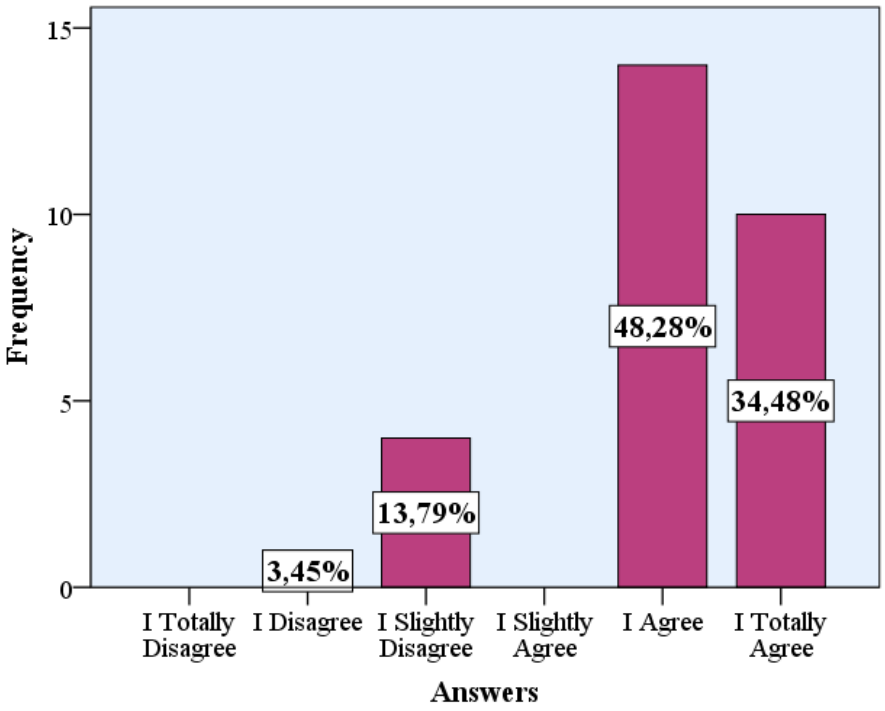

Figure 4.34: Zone D lighting increase privacy

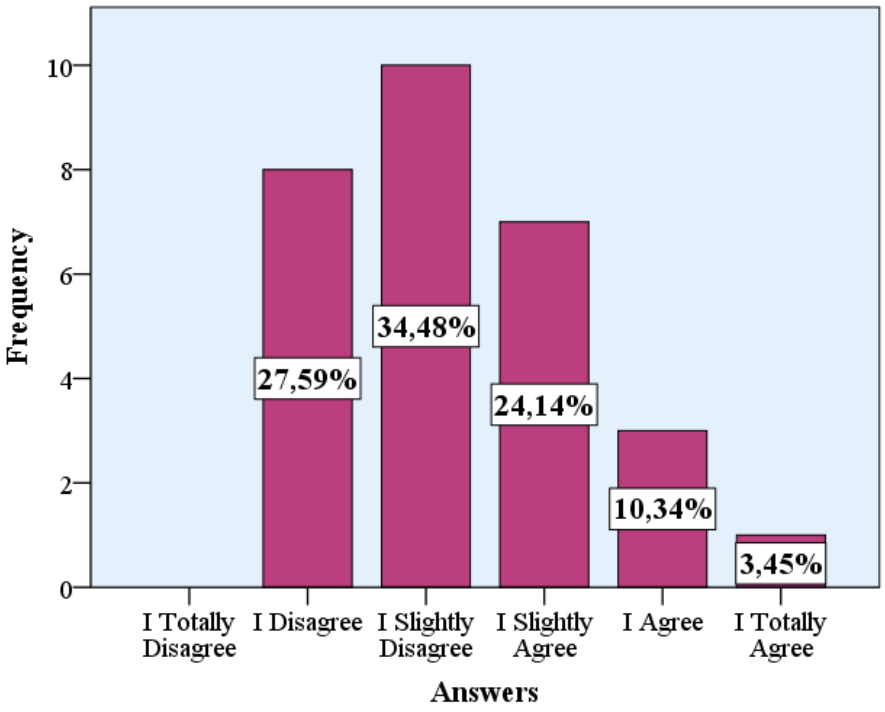

Figure 4.35: Zone D lighting provided uniformly and evenly

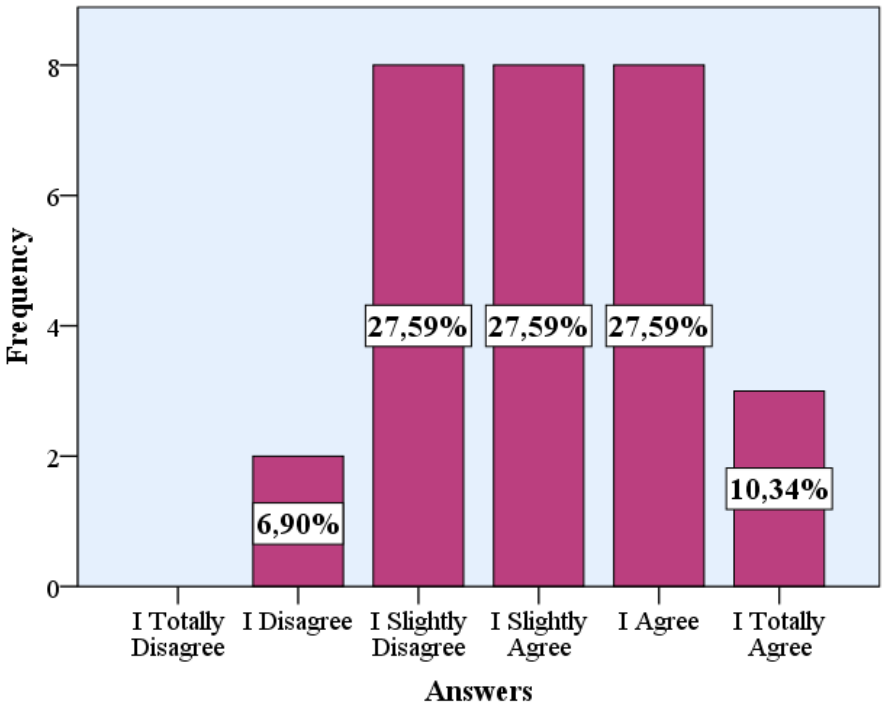

Figure 4.36: Zone D lighting increase pleasantness

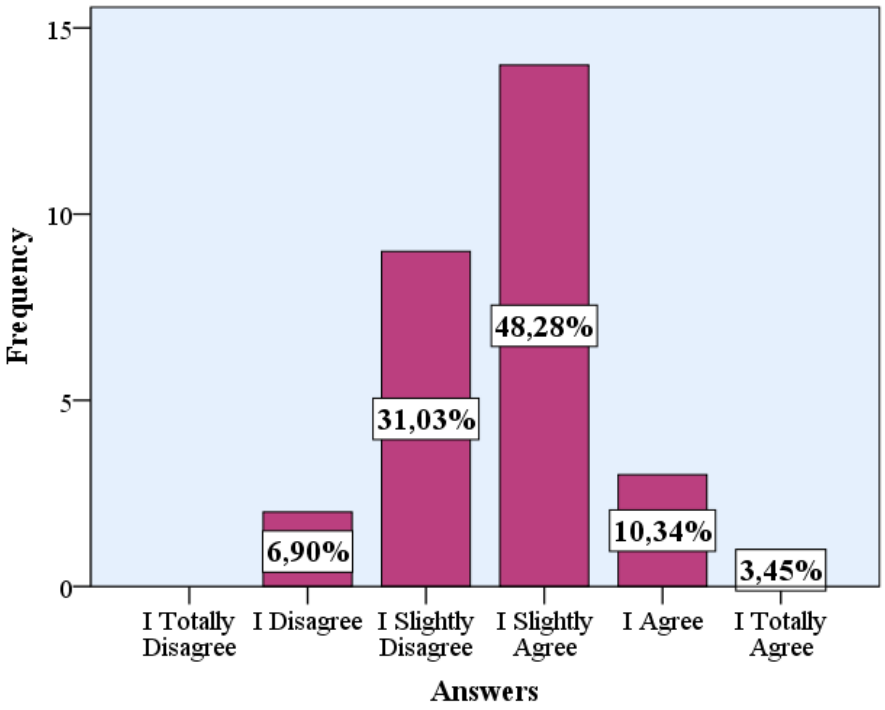

Figure 4.37: Zone D lighting suffecient for performed tasks

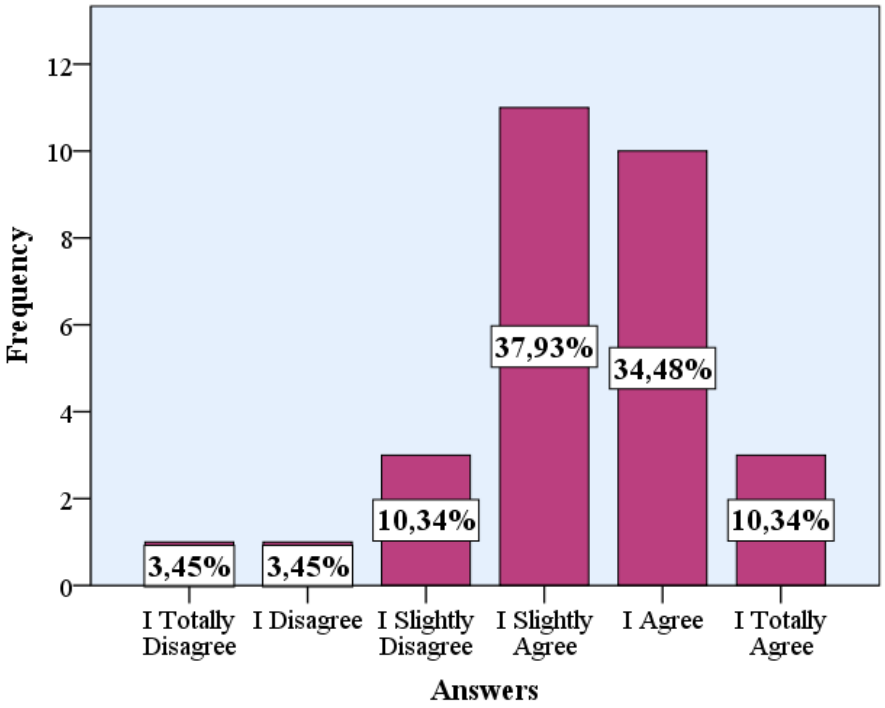

Figure 4.38: Zone D lighting has a positive effect

In the last part of the questionnaire, the participants evaluated the overall lighting of the library, as shown in Figures 4.39 to 4.46. The results show that the highest perception indicators are suitability for visual clarity, relaxation effect and reducing stress, and sufficiency for the performed tasks. Nevertheless, privacy and uniformity were given the lowest score among the indicators.

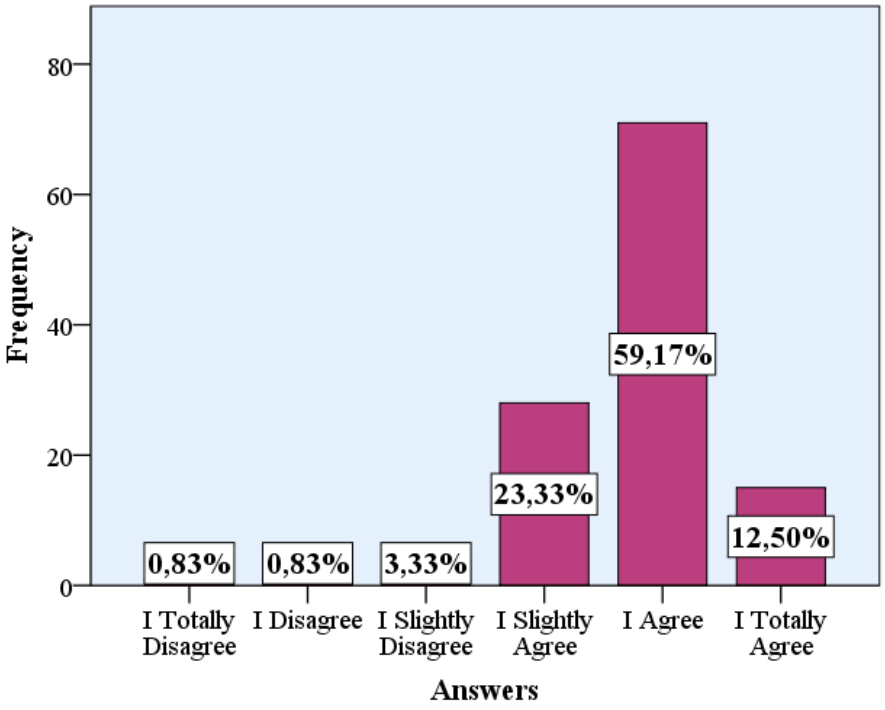

Figure 4.39: Overall lighting in library suitable for visual clarity

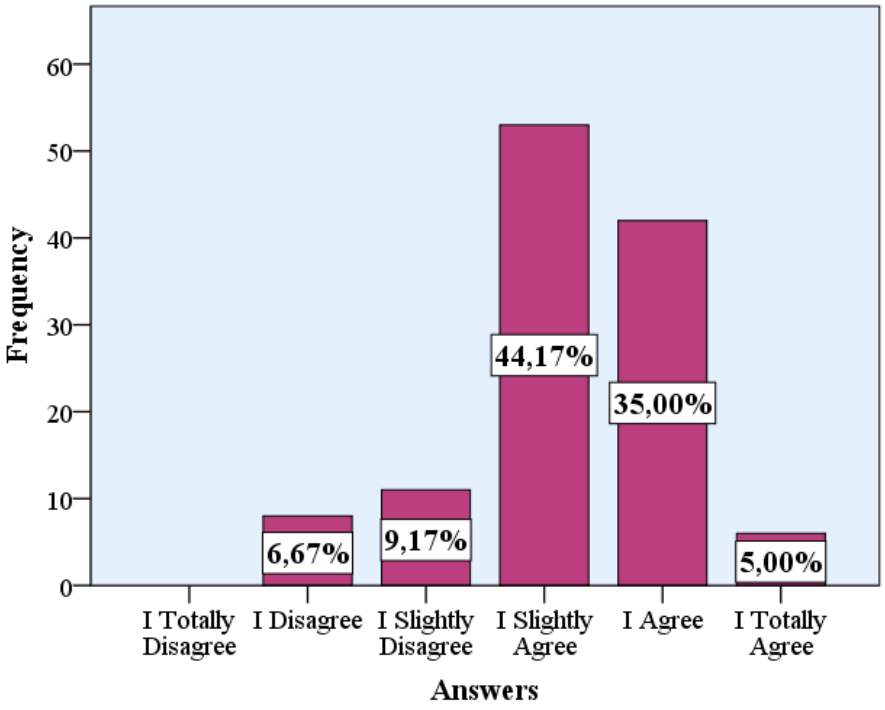

Figure 4.40: Overall lighting increase space spaciousness

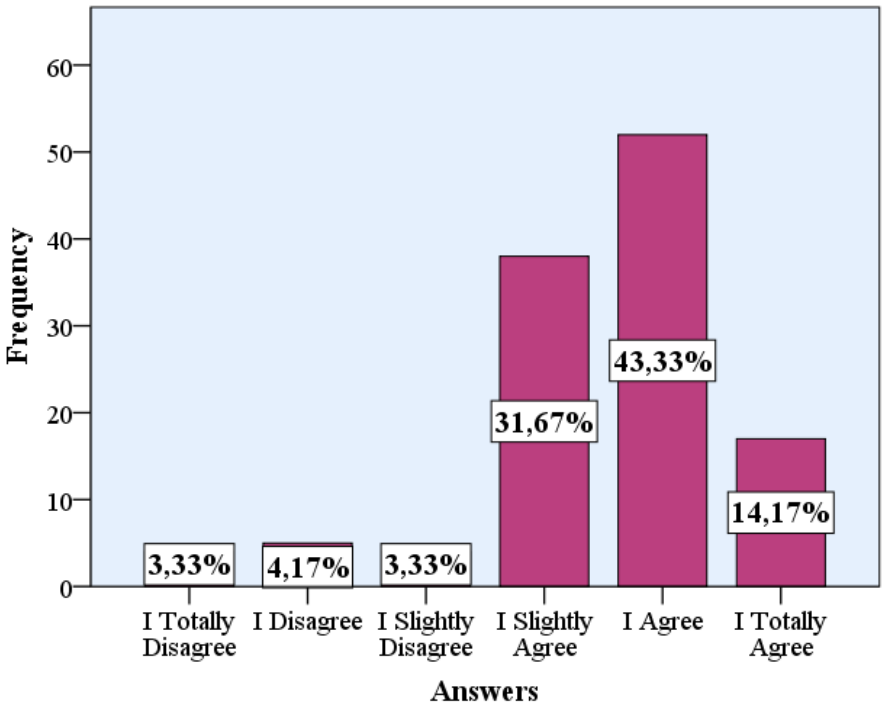

Figure 4.41: Overall lighting relaxation effect and stress reduction

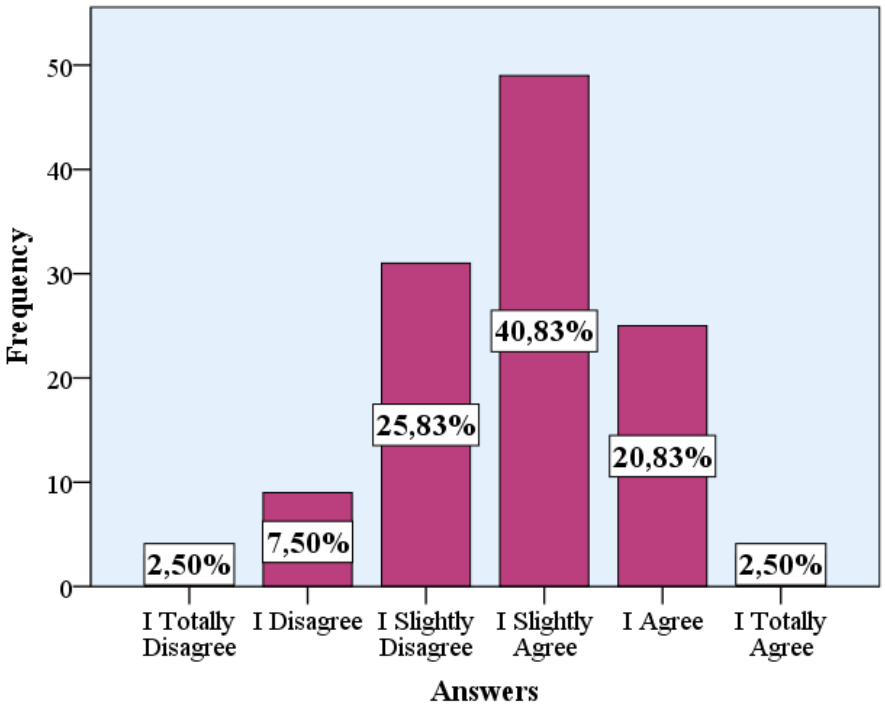

Figure 4.42: Overall lighting increase privacy

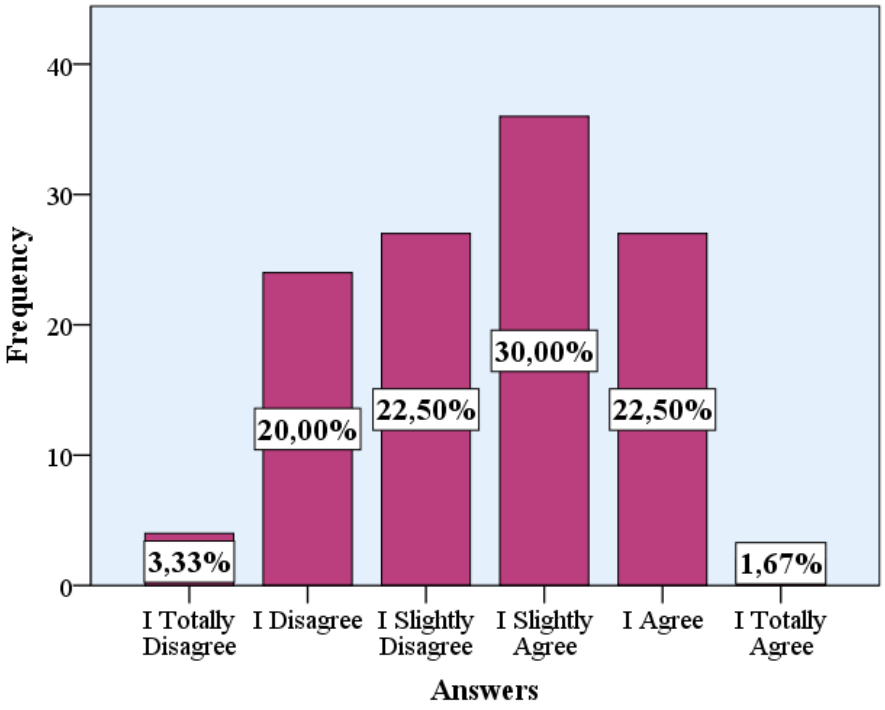

Figure 4.43: Overall lighting provided uniformly and evenly

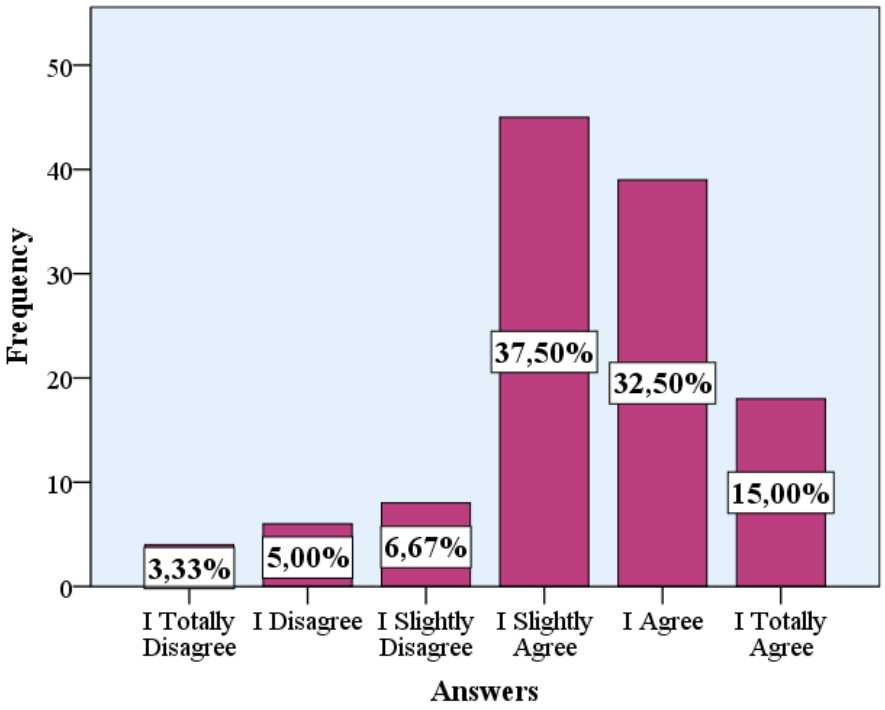

Figure 4.44: Overall lighting increase pleasantness

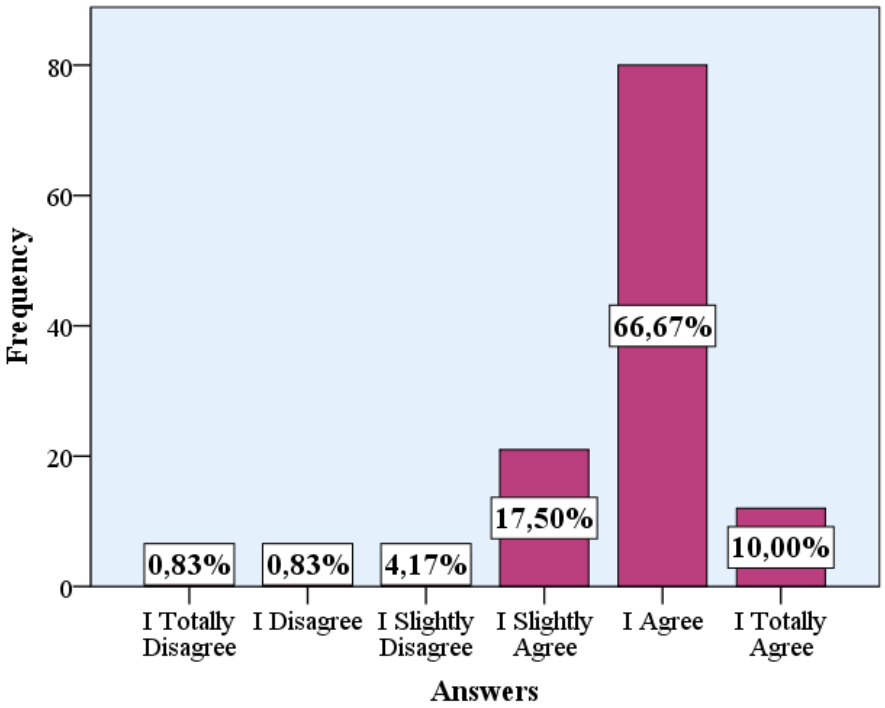

Figure 4.45: Overall lighting suffecient for performed tasks

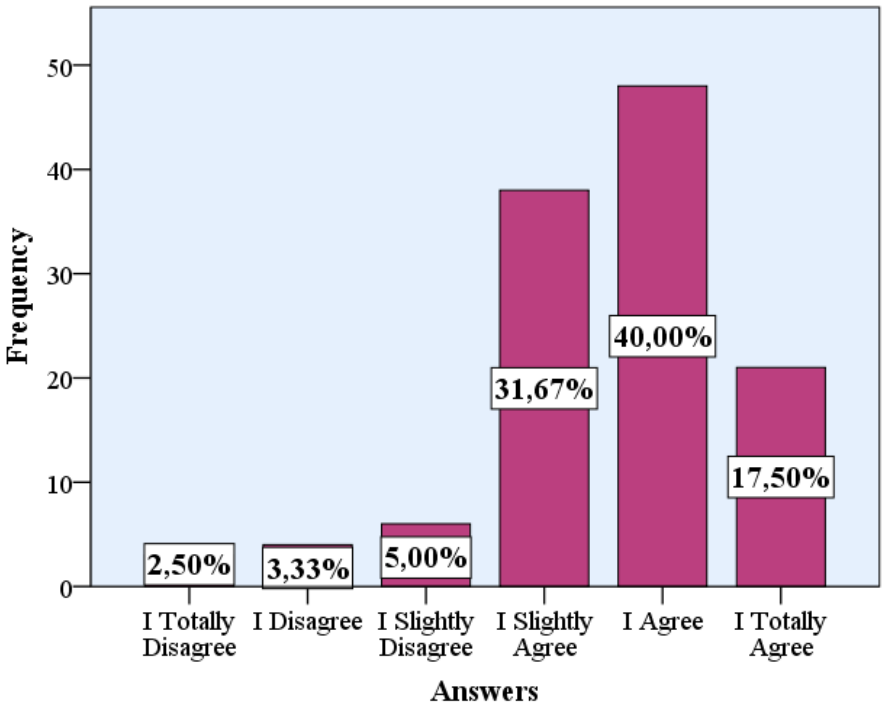

Figure 4.46: Overall lighting has a positive effect

4.2 Analysis and Discussion

Several analytical tests were performed in order to extract the significant correlations and variances between the different parameters. The most significant correlations were found between the objective and the subjective measurements using Spearman's coefficient, and between the different lighting perception indicators using the same technique. Significant variances were found between the evaluations of the participants for the different zones.

However, in testing the correlations and variances based on demographic data and library usage data using one-way ANOVA and Independent Sample t-test, no correlations or significant differences were found between the variables, except for the variance between the preferred periods to visit the library, and specifically between the noon and afternoon period.

4.2.1 Correlation between Objective Measurement and Subjective Perception

Using Spearman's rho, the relationship between the objective illuminance measurements and the subjective evaluation by the participants are correlated. The testing results, as illustrated in Table 4.3, show weak to medium correlations between the two variable sets. The behavior of the correlation factors in the clear and cloudy weathers are similar, as an evidence of consistent data. The highest correlation is between the sufficiency for performed tasks and the lux average readings in both weather conditions (0.544), which is a medium correlation in indicating the proportional relationship between them.

Other medium correlations were found with suitability for visual comfort (0.422 and 0.413), effect on space spaciousness (0.470 and 0.475), and uniformity (0.356 and 0.342). Correlations with relaxation effect and stress reduction (0.274 and 0.272), pleasantness (0.199 and 0.200), and positive effect (0.266 and 0.262) are considered weak. The last correlation is for the increase of privacy, where the negative sign of the correlation (-0.277 and -0.263) show that privacy decrease with the increase of the lux level and indicate a weak correlation between the two variables.

Table 4.3: Correlation between illuminance averages and lighting perception in the case space using Spearman's rho coefficient

Lighting Perception Indicator	Average Illuminance in Clear Weather	Average Illuminance in Cloudy Weather
Suitability for visual clarity	0.422**	0.413**
Effect on space spaciousness	0.470**	0.475**
Relaxation effect and stress reduction	0.274**	0.272**
Increase of privacy	-0.277**	-0.263**
Uniformity	0.356**	0.342**
Pleasantness	0.199*	0.200*
Suffeciency for performed tasks	0.544**	0.544**
Positive effect	0.266**	0.262**

**. Correlation is significant at the 0.01 level (2-tailed)
*. Correlation is significant at the 0.05 level (2-tailed)

4.2.2 Correlation between Lighting Perception Indicators

It is beneficial to understand the relationship between the lighting perception indicator to understand the influence of each one on the other. Such an exercise is useful for designers and implementing lighting changes in the library space. Therefore, Spearman's correlation is tested between the indicator, where the highest correlation was found between space spaciousness, and relaxation and stress reduction (0.619), which is considered of a medium strength. Some of the highest medium correlations were also found between relaxation and stress reduction, and pleasantness (0.554), suitability for visual clearance and sufficiency for performed tasks (0.533), and visual clarity and relaxation and stress reduction (0.465). The relationship between these factors proves the relation between adequate lighting and the psychological and

physiological impacts on the space users that were discussed through (Boyce, Hunter, & Howlett, 2003). Table 4.4 provides the correlations between the lighting perception indicators.

Table 4.4: Correlation between lighting perception indicators using Spearman's rho coefficient

Lighting Perception Indicator	1	2	3	4	5	6	7	8
1.Suitability for visual clarity	1.000							
2.Effect on space spaciousness	0.427**	1.000						
3.Relaxation effect and stress reduction	0.465**	0.619**	1.000					
4.Increase of privacy	-0.060	0.202*	0.240**	1.000				
5.Uniformity	0.109	0.151	0.189*	0.364**	1.000			
6.Pleasantness	0.422**	0.403**	0.554	0.207*	0.491**	1.000		
7.Suffeciency for performed tasks	0.533**	0.370**	0.428**	0.033	0.076	0.389**	1.000	
8.Positive effect	0.497**	0.535**	0.589**	0.063	0.086	0.593**	0.502**	1.000

**. Correlation is significant at the 0.01 level (2-tailed)
*. Correlation is significant at the 0.05 level (2-tailed)

4.2.3 Variance in Lighting Subjective Perception based on Zoning

The difference between the four zones of the library are tested for variance in terms of lighting perception by the participants through one-way ANOVA testing at $p < 0.05$. The results, as shown in Table 4.5, show that there are variances with all of the lighting perception indicators.

Table 4.5: One-way ANOVA testing for variance in lighting perception based on zones

		Sum of Squares	df	Mean Square	F	Sig.
Suitability for visual clarity	Between Groups	33.362	3	11.121	11.703	0.000
	Within Groups	110.230	116	0.950		
	Total	143.592	119			
Effect on space spaciousness	Between Groups	37.651	3	12.550	12.357	0.000
	Within Groups	117.815	116	1.016		
	Total	155.467	119			
Relaxation effect and stress reduction	Between Groups	14.129	3	4.710	3.776	0.013
	Within Groups	144.671	116	1.247		
	Total	158.800	119			
Increase of privacy	Between Groups	36.862	3	12.287	7.230	0.000
	Within Groups	197.138	116	1.699		
	Total	234.000	119			
Uniformity	Between Groups	37.498	3	12.499	9.218	0.000
	Within Groups	157.302	116	1.356		
	Total	194.800	119			
Pleasantness	Between Groups	11.586	3	3.862	2.846	0.041
	Within Groups	157.406	116	1.357		
	Total	168.992	119			
Suffeciency for performed tasks	Between Groups	39.989	3	13.330	15.258	0.000
	Within Groups	101.336	116	0.874		
	Total	141.325	119			
Positive effect	Between Groups	20.768	3	6,923	5,065	0.002
	Within Groups	158.557	116	1,367		
	Total	179.325	119			

In order to understand the nature of the variance between the zones in terms of lighting perception indicators, Post-Hoc testing is performed for all the relations using Scheffe testing. A shown in Table 4.6, The majority of the significant variances are related to Zone D, due to its far deviation from the lighting specifications of the other zones, as well as the minimum and average lighting requirements for libraries. The Post-Hoc testing showed that there are no significance variances in terms of pleasantness and positivity assuming equal variances.

Table 4.6: Post Hoc/ Scheffe testing between different zones based on lighting perception indicators assuming equal variances – Most significant results

Lighting Perception Indicator	Zone (i)	Zone (j)	Sig.
Suitability for visual clarity	Zone D	Zone A	0.002
		Zone B	0.000
		Zone C	0.000
Effect on space spaciousness	Zone D	Zone B	0.000
		Zone C	0.000
Relaxation effect and stress reduction	Zone A	Zone B	0.044
Increase of privacy	Zone D	Zone A	0.001
		Zone B	0.006
		Zone C	0.010
Uniformity	Zone D	Zone B	0.000
		Zone C	0.001
Pleasantness	No significant differences		
Suffeciency for performed tasks	Zone D	Zone B	0.000
		Zone C	0.000
Positive effect	No significant differences		

4.2.4 Correlation between Library Visit Periods and Lighting Perception

The demographic and library use data have been tested for correlation with lighting perception indicators using Spearman's rho, and variances were tested using one-way ANOVA and independent sample t-test. However, there were no significant correlations yielded from this testing, except for the correlation with the library usual visit day periods, as illustrated in Table 4.7. Five of the eight indicators have a medium correlation with the library visit periods, as the highest correlations are for pleasantness (0.533), sufficiency for performed tasks (0.497), and Effect on space spaciousness (0.465). There correlations imply that student choose their visit timings to the library based on some of the lighting perception indicators, which affect their comfort and ability to study in a healthy environment.

Table 4.7: Correlation between lighting perception in the case space and library visit periods using Spearman's rho coefficient

Lighting Perception Indicator	Correlation Coefficient (rho) with library visit periods
Suitability for visual clarity	0.427**
Effect on space spaciousness	0.465**
Relaxation effect and stress reduction	-0.060
Increase of privacy	0.109
Uniformity	0.422**
Pleasantness	0.533**
Suffeciency for performed tasks	0.497**
Positive effect	-0.064

**. Correlation is significant at the 0.01 level (2-tailed)

5. CONCLUSIONS

As libraries are essential facilities in academic institutions, as well as frequent visited by many users, lighting is considered one of the most important factors to ensure that the library functions in the best possible manner. Moreover, lighting in general, and natural lighting specifically have been a matter of investigation by many scholars and scientists, in order to maximize its benefits and minimize any adverse effects. There are many sources of artificial lighting that are used in architectural and interior design; However, there is a direction to explore ways and techniques to utilize the natural lighting in order to decrease energy consumption and benefit from the psychological and physiological benefits of the sun light (Mead, 2008) (van der Rhee, de Vries, Coomans, van der Velde, & Coebergh, 2016) (Denissen, Butalid, Penke, & van Aken, 2008) (Yacan, 2014) (Mirrahimi, Ibrahim, & Surat, 2012). Other studies have measured the effect of natural lighting through experiments and questionnaires and found positive impacts of natural lighting on productivity, performance, emotional state, and development (Hameed & Amjad, 2009) (Boyce, Hunter, & Howlett, 2003) (Heschong, 2002).

Furthermore, natural lighting is found more efficient and superior to all types of artificial lighting in terms of achieving the suitable and comfortable lighting illuminance (Pechacek, Andersen, & Lockley, 2008). While it might look challenging to achieve the goal of utilizing natural lighting in interior spaces, there were many assemblies reviewed within this research that could achieve the maximum benefit from natural lighting through reflection and filtering, and avoid the negative effects such as glare and overheat (Abdelatia, Marenne, & Semidor, 2010) (Phillips, 2004).

In this research, a subjective and objective measurements of the impact of natural lighting on library users are designed through several sources from the literature. (Durak, Olgunturk, Yener, Guvenc, & Gurcinar, 2007) showed different types of

lighting, illuminances and lighting parameters that could be used in studying the lighting in interior space. Moreover, (Eo & Choi, 2014) provided further lighting perception indicators that were used in this study. The same strategy of studying the lighting in the library space through different time period through the day is also adopted from (Thangaraj & Balaji, 2014), and the minimum and average illuminance requirements for the different library functionalities are reviewed in (Dean, 2005).

By dividing the library of Çankaya university (Ankara, Turkey) into four main zones based on their initial lighting level and orientation towards natural lighting, 120 participants using the different zones evaluated the lighting in the library based on their zones and the library in general. Furthermore, illuminance measurements were taken using a lux meter. Several measurements were taken in the same zone in different time periods and different weather conditions. The readings showed that a weather condition such as cloudy could reduce the lighting in the library by an average of 23.1%, while many readings have fallen below the minimum requirements because of this factor. Moreover, areas with natural lighting provided through a skylight have succeeded in providing adequate lighting throughout the day time.

The participants have shown through their indirect answers that they prefer using the library during the period, where illuminance is its peak, as well as indicating their preference for the zones where natural lighting is provided. Through the eight lighting perception indicators chosen for the study to be evaluated in a zone and an overall basis, several correlations and variances were found. The first main correlation was found between the objective measurements and the lighting perception provided by the participants, with medium to weak Spearman's correlations ranging between -0.277 and 0.544. Furthermore, the lighting perception indicators were also correlated to each other using the same method and most of the relationships were rated weak to medium. The strongest correlation was found between the space spaciousness, and relaxation and stress reduction (0.619).

The different zones in the library showed significant variances on the perception results of the questionnaire; however, the most significant variance verified by Scheffe Post-

Hoc testing was between Zone D at the second floor and the rest of the zones. It was also evident from objective illuminance measurement that Zone D lack the minimum limits of illuminance most of the day, while other areas supplied with natural lighting exceeded them and provided lighting within the recommended average. In a trial to correlate the demographic and library usage data to the lighting perception of the participant, the only significant correlation was found with the time period that users prefer to visit the facility. The results of Spearman's correlation show that lighting sufficiency for the performed tasks, visual clarity and effect on spaciousness were among the top reasons the users choose the time period to visit the library.

5.1 Recommendations and Future Work

The main recommendations for this study are regarding the current lighting strategy in the library of Çankaya university. At zone A, there were minor issues regarding the uniformity of the lighting. Thus, this issue will be evaluated through a measurement plan using the techniques recommended in (Eo & Choi, 2014) and complying it within the minimums and averages of illuminance provided by (Dean, 2005). Moreover, the lighting in zone D is completely below the limits set in the literature. Therefore, the same procedure recommended as for zone A, in addition to supplying the area within additional artificial lighting. Natural lighting is highly recommended to be used in both zone by using reflectors and filters' assemblies that are reviewed within the literature.

In future research, the impact of natural lighting could be extended to night hours to fully measure the contribution of natural lighting to the overall lighting strategies in the library. Furthermore, the study is conducted in July, which is known for its high sun radiation in Turkey. Hence, a similar research during the other months could form a complete picture about the effect of natural lighting and its contribution on the psychological and physiological state of the facility users.

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APPENDIX A

(QUESTIONNAIRE FORM)

Questionnaire about lighting in Libraries

Dear Sir/ Madam,

We are performing a study to evaluate lighting in libraries. Kindly take 5 minutes of your time to evaluate the lighting in the Library at Cankaya University.

Thank you for your time and effort

Demographics and Library Use					
1.Gender	Male			Female	
2. Age	…….				
3. Time when taking this survey	9:00 to 10:00	10:00 to 12:00	12:00 to 14:00	14:00 – 16:00	After 16:00
4. Area when this survey is taken – Kindly use attached map	Zone A	Zone B	Zone C	Zone D	
5.How many times do you visit the library per week	Less than 3 times	Almost everyday	More than once per day		
6.What time do you often use the library?	Early morning	Late morning	Noon	Afternoon	Evening
7.Please rank the following areas of the library according to your preference. (1 being the most preferred area) – Kindly use attached map	Zone A	Zone B	Zone C	Zone D	

Lighting Evaluation						
According to the area you are using right now do you agree with the following:	**I Totally Agree**	**I Agree**	**I slightly agree**	**I slightly disagree**	**I disagree**	**I totally disagree**
Rating Scale	**6**	**5**	**4**	**3**	**2**	**1**

8.The lighting provided in the area is suitable for visual clarity						
9.The lighting provided in the area makes the place more spacious						
10. The lighting provided in the area increases the relaxation and reduces stress						
According to the area you are using right now do you agree with the following:	**I Totally Agree**	**I Agree**	**I slightly agree**	**I slightly disagree**	**I disagree**	**I totally disagree**
Rating Scale	**6**	**5**	**4**	**3**	**2**	**1**
11. The lighting provided in the area increases the privacy						
12. The lighting provided in the area is uniform and even						
13. The lighting provided in the area gives a pleasant feeling						
14. The lighting provided in the area is sufficient for the tasks performed						
15. The lighting provided in the area gives a positive feeling						
Considering the lighting in library in General, please rate the following:	**I Totally Agree**	**I Agree**	**I slightly agree**	**I slightly disagree**	**I disagree**	**I totally disagree**
Rating Scale	**6**	**5**	**4**	**3**	**2**	**1**

16. The lighting provided in the area is suitable for visual clarity						
17. The lighting provided in the area makes the place more spacious						
18. The lighting provided in the area increases the relaxation and reduces stress						
19. The lighting provided in the area increases the privacy						
20. The lighting provided in the area is uniform and even						
21. The lighting provided in the area gives a pleasant feeling						
Considering the lighting in library in General, please rate the following:	**I Totally Agree**	**I Agree**	**I slightly agree**	**I slightly disagree**	**I disagree**	**I totally disagree**
Rating Scale	**6**	**5**	**4**	**3**	**2**	**1**
22. The lighting provided in the area is sufficient for the tasks performed						
23. The lighting provided in the area gives a positive feeling						