THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES OF ÇANKAYA UNIVERSITY

DEPARTMENT OF INTERIOR ARCHITECTURE

THE EFFECTS OF ARTIFICIAL LIGHTING ON VISUAL TASK EFFICIENCY IN ENCLOSED SPACES WITHOUT DAYLIGHT

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September 2018

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MELİKE ÖZÇAKAR ÜNSAL

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Submitted by Melike Özçakar Ünsal

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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.

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ABSTRACT

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Today, a majority of people spend most of their time working indoors. When these spaces are lit only by artificial lighting, certain problems arise as to user health and visual task efficiency. Therefore, the correct application of artificial lighting elements becomes essential, particularly for visual tasks involving fine work to be performed in indoor environments, which do not benefit from daylight. This thesis examines how artificial lighting affects the user performance at such working environments. Furthermore, a case study was conducted on a total of ten spaces of tailor and shoe repair shops located at the 1st and 2nd basement floors of five shopping centers in Ankara. These spaces were first analyzed by measuring the Illuminance, Color Temperature (CT) and Color Rendering Index (CRI) values of the used artificial lighting sources. After that, a questionnaire survey was conducted on the tailors and shoe repairers, to find out the problems experienced as to their visual task efficiencies. As a result of the case analyses, it was seen that being exposed to only artificial lighting having some incorrect applications may cause health problems such as; pain in the eyes, headaches or lack of focus, which affect the work performance negatively. As a result of this decrease in visual task efficiency, difficulty in stitching or choosing the right colors for sewing threads or shoe paints were observed. In this thesis, for such interior spaces, the possible outcomes of the issue of incorrect artificial lighting applications were examined and as to these applications, the design guidelines for an efficient professional working environment were developed.

Keywords: Enclosed Spaces, Artificial Lighting, Visual Task Efficiency

ÖZ

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Günümüzde, insanların çoğu zamanlarının büyük bir kısmını kapalı mekanlarda geçirmektedir. Bu mekanlar yalnızca yapay aydınlatma ile aydınlatıldığında ise, kullanıcı sağlığı ve görsel iş verimliliği konusunda bazı problemlerin ortaya çıktığı görülmektedir. Bu nedenle, gün ışığından yararlanamayan iç mekanlarda yapılacak ince görsel işleri kapsayan görevler için yapay aydınlatma sistemlerinin doğru uygulaması büyük önem kazanmaktadır. Bu tez, yapay aydınlatmanın bu çalışma ortamlarında kullanıcı performansını nasıl etkilediğini incelemektedir. Ayrıca, bu çalışma, Ankara'da bulunan beş alışveriş merkezinin 1. ve 2. bodrum katlarında yer alan toplam on adet terzi ve ayakkabı tamir atölyesi üzerinde detaylı vaka çalışmalarını içermektedir. Bu atölyeler, yapay aydınlatma kaynaklarının aydınlık, renk sıcaklığı (CT), ve renksel geriverim indeksi (CRI) değerleri ölçülerek analiz edilmiştir. Daha sonra, görsel açıdan iş verimliliği ile ilgili yaşanan problemleri tespit etmek için çalışanlar üzerinde bir anket çalışması yapılmıştır. Yapılan analizler sonucunda, yapay aydınlatmaya ilişkin yanlış uygulamalara maruz kalma ile; gözlerde ağrı, baş ağrısı ve odak eksikliği gibi iş performansını olumsuz yönde etkileyen sonuçlar görülmüştür. Görsel iş verimliliğindeki azalmanın bir sonucu olarak, dikiş işlerinde ve iplik ile ayakkabı boyaları için doğru renklerin seçilmesi konularında zorluklar yaşandığı gözlemlenmiştir. Bu tezde, bu tür iç mekanlar için yanlış yapay aydınlatma uygulamaları konusundaki olası sonuçlar incelenmiş ve bu uygulamalara ilişkin olarak verimli bir mesleki çalışma ortamı için tasarım ilkeleri geliştirilmiştir.

Anahtar Kelimeler: Kapalı Mekanlar, Yapay Aydınlatma, Görsel İş Verimliliği

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CHAPTER 1

INTRODUCTION

Physical properties such as light, color, heat, humidity, and solar radiation play essential roles in creating the physical environment that provides its user with comfort within structures. These physical factors make it necessary to create conditions that can meet the physiological needs of users of the space (Şerefhanoğlu, 1999). These conditions are the key elements to consider in all building types. For this reason, lighting should be regarded as a part of the design and it must be addressed in a multidisciplinary way.

Visual perception is one of the highly prioritized forms of perception that a person uses to communicate with his or her environment (Bayar, 1994). Illumination of a space directly affects the comfort, mental state, productivity, health, and safety of those living in that space (Boyce, 1999).

Lighting design is one of the fundamentals of interior design. While creating spaces, designers seek the most suitable for people in every way, in addition to their concepts. The artificial lighting design, the approach that designers take for healthy spaces and their solutions offered for problems that arise during the design process also serve as a guide from this aspect.

In today's world, in industrialized societies, time spent indoors is increasing day by day and the need for artificial light is increasing, accordingly. Artificial lighting used in interior architecture in recent years is characterized as a powerful means of expression in terms of perception of space. Light is important not only for aesthetic means but also for its functional uses. Appropriate lighting design is a workplace necessity because it sets our body clock. Poor or inappropriate lighting in work spaces affects work performance, directly. This can also lead to further problems like headaches, and eye illnesses. Besides the fundamental factor of functionality, proper lighting also brings aesthetic advantages to space users. There are lots of ways that a workplace can positively and negatively affect the productivity of employees because of its lighting techniques.

Artificial light is the name given to all kinds of lighting produced by using an electric power source. By the invention of electric light bulb, people started to stay awake any hour of the day. Nowadays, some people do not go to sleep and work for a long time. Because of working under artificial lighting, body functions begin to lose balance and it causes some health problems on people, as light does not only illuminate the environment and its objects, but also helps to balance the body.

Accurately designed and lit spaces, particularly with daylight have a positive effect on healthy working conditions, since light controls when hormones will be released, some brain activities, and when the body will enter the restoration process. Regarding these properties of light, people working indoors through long working hours, such as at the basement floors of shopping centers would begin to have certain problems.

The main problem for people working in enclosed spaces for long working hours under artificial lighting is the difficulties faced in terms of work efficiency. Exposure to artificial lighting for a long time in an enclosed space causes a dramatic decrease in work efficiency. Accordingly, artificial lighting which is not designed for a working space will result in people having adverse effects on their health. Prolonged working hours and the consequent need for artificial light result in physical and psychological problems from the human health perspective while also revealing the necessity of evaluating lighting technologies used in places where people spend most of their time. At this point, considering the effects of lighting is important in terms of making proper lighting designs for better perceivable spaces. By adapting the knowledge obtained from research on various disciplines regarding spatial and lighting design, spaces that they can fully meet the visual needs of their users can be created.

1.1. Aim and Scope of the Study

There are certain conditions that must be established in spaces for providing visual comfort. These conditions include the ability to see details and colors of the work being done in the space, to prevent the formation of unnecessary shadows that mislead the user, to select suitable lighting means for the work and the user in order to ensure that the selected lighting fixtures do not cause any glare. In visual comfort, the goal is not only to create the necessary visual conditions, but also to maintain the same conditions for a long period of time without affecting the efficiency of the user.

The main goal of this research is to present the analysis of artificial lighting applications for visual task efficiency of people working in enclosed spaces without daylight and to explain methods to provide proper and healthy lighting designs for these spaces. In order to achieve this, tailors and shoe repairers working at basement floors of shopping centers were determined to be the subject of case studies. In this study, these working environments are analyzed as these spaces involve fine visual task and do not receive any daylight while only artificial lighting is used. This thesis provides information on how to prevent problems regarding visual task efficiency and the conditions for suitable and healthy artificially environments, as to the work efficiency in these types of spaces. In the case study analysis part, the thesis presents the examination of certain issues related to working indoors under artificial light for a long period of time. Both aims described above are visualized clearer in Figure 1.1.

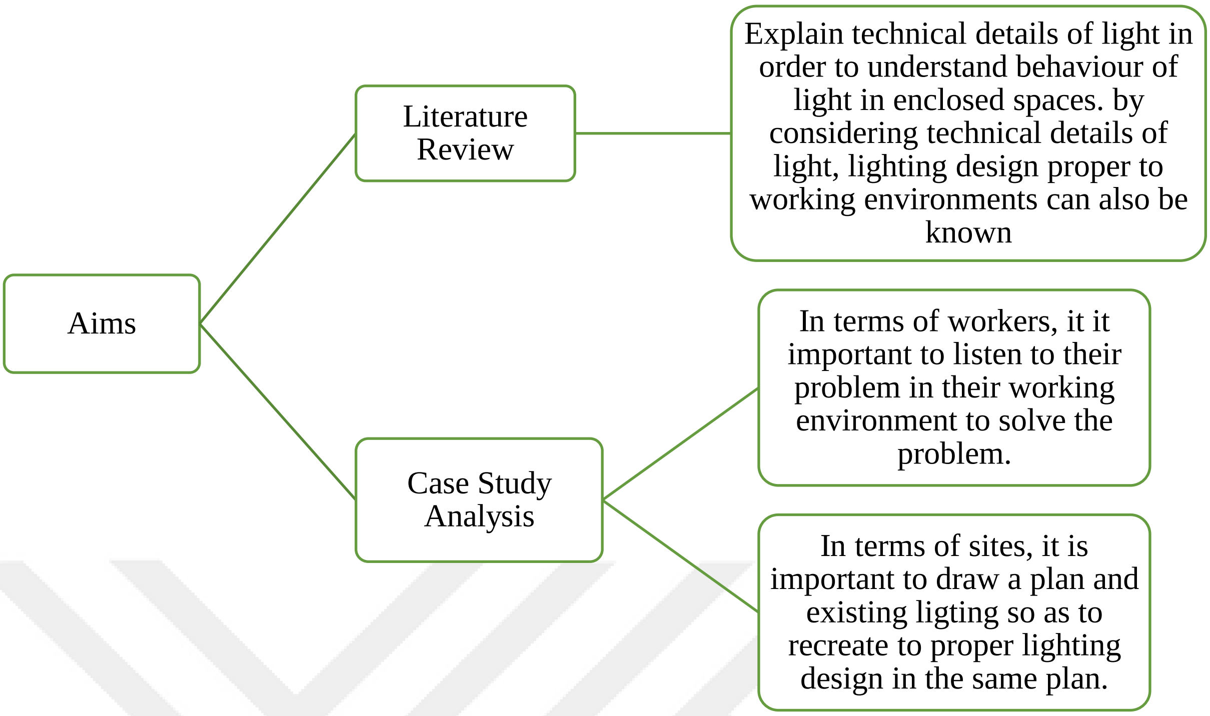


Figure 1.1: Visual Representation of The Aim of The Thesis

Artificial lighting in a working area has very prominent impact on people because generally people spend all their day-time within one place. If a proper working environment is not provided, people will have to deal with a decrease in their work efficiencies over time. The scope of this study is about the artificial lighting in terms of technical details of workplaces of tailors and shoe repairers, and proper lighting design for these areas. The research questions of the study are as follows:

- What are the principles to use artificial lighting?
- What are the physiological and psychological effects of artificial lighting on people working on fine visual tasks in enclosed spaces not benefitting from daylight?
- What are the parameters of proper artificial lighting design fine visual tasks in enclosed spaces not benefitting from daylight?

The goals of the study are;

- Explaining the importance of interior lighting,
- Comparison of the data collected from the literature, with the data collected from case studies,
- Expressing the importance of the establishment of better conditions and determination of application principles from the aspect of the examined case sites.

1.2. Methodology

The assessment methodology of this thesis focuses on whether people working in spaces illuminated by only artificial lighting are provided appropriate standards in terms of visual comfort and work efficiency. This work can be seen as a way of detecting the visual effects of light for determining high quality spaces as to their illumination. In this framework, this work will be identified with an analysis of artificial lighting quality in 10 different locations without reaching a unique numerical data, as well as an evaluation of numerical and non-numerical variables together.

As to the research methodology, firstly, all related issues pertaining to the technical details of artificial and natural lighting were identified in detail. In other words, an in-depth literature review on relevant terms and definitions that provide the basis of the known aspects of lighting as natural and especially artificial lighting in enclosed spaces was conducted. After finding out the related parameters concerning the research subject, questions were developed for the case studies to determine certain problems regarding the examined issue.

In this framework; a total of ten case studies of tailors and shoe repairers, which do not get any daylight, located at the basement floors of five different shopping centers in Ankara were selected. The first section of the case study analysis (Section A) involved taken measurements and making observations in the spaces. The illuminance (lux), color temperature (CT), and color rendering index (CRI) values were measured by the CL-70F CRI Illuminance Meter tool of Konica Minolta and were recorded for each case spaces. This device was supplied by the Building Physics and Environmental Control Laboratory of the Faculty of Architecture at

Çankaya University. The spaces were observed for their lighting applications and several design aspects. Plan and section drawings were produced and photographs were taken. The second part of case study analyses (Section B) involved face-to-face interviews and conducting a questionnaire on the users of these spaces. The interviews with the workers provided detailed information about the use and the work efficiency of these case spaces. Together with these case analyses, derived solutions to the determined problems were presented. At the conclusion section, certain design guidelines were produced for such working environments.

1.3. Structure of the Thesis

In the first chapter of the thesis, the aim, scope and the method of studying are explained and the aim expected from the thesis and the data to be obtained are presented. In the second chapter, the importance of lighting, together with its main purposes will be explained. The effects and contributions of lighting on space users will be examined. Also, the necessity of effective and successful indoor lighting design will be explained with its technical details. In the third chapter, tailors and shoe repairers located in five shopping malls in Ankara will be examined and compared according to the criteria collected from the literatures. Findings and Discussion part will provide observations based on the measurements and the conducted questionnaire results.

Finally, based on these case analyses and findings from literature, the conclusion part will present design guidelines for spaces involving fine visual tasks, which do not benefit from daylight.

CHAPTER 2

ARTIFICIAL LIGHTING

There is no doubt that artificial light enables not only making interior spaces brighter, but also helps people to experience a better space. Lighting design is an art and a technical phenomenon affecting physical and mental health conditions of humans. Artificial light activates sense of sight and affects the atmosphere of a space positively or negatively. In other words, lighting design of an interior should be satisfactory for both functional and psychological perception. Artificial lighting may enable desirable and dramatic effects, at the same time, it has effects on people's physical and psychological health.

According to Ganslandt and Hoffmann (1992) there are two types of good and bad lighting choices which can be defined as:

> "Good lighting is an energy saver and provides efficiency. Perception of lighting is limited to the intended object. Good lighting provides night time visibility. Lastly, it needs to control the brightness in space. Bad lighting is waste of energy. It causes light pollution. Bad lighting also creates visual distortion and glare. It dims the view of stars. Lastly, bad lighting has bad effects on recycling."

2.1. Electro-Magnetic Spectrum

The visible light is the part of the electromagnetic spectrum that is visible to the human eye which corresponds to a wavelength range of 380 – 770 nanometers (nm) and a color range of violet through red. The human eye is not capable of 'seeing' radiation with wavelengths outside the visible spectrum. The spectral distribution of daylight enables perfect color perception (Ataç, 2013). The visible spectrum could be thought as a rainbow. Sunlight is refracted as all the color of rainbow when it shines through a prism as seen in Figure 2.1. In reality, all the colors of nature come from light. It can be said that maybe because of this reason, when the natural light meets the space, it affects our psychological health and emotional well-being (Egan, Olgyay, 2001).

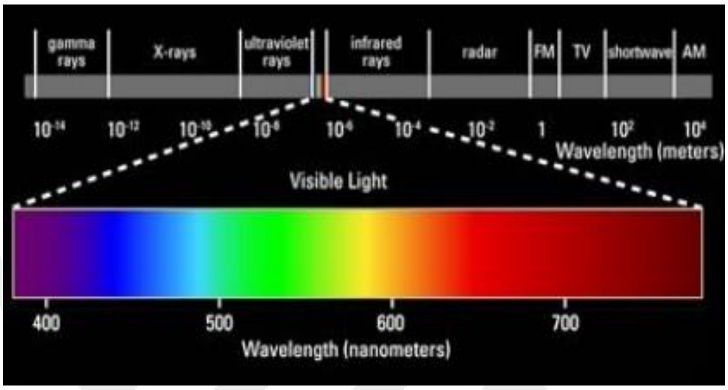


Figure 2.1: Light Spectrum (“Light Works”, 2016).

Visible light is a small portion of the electromagnetic spectrum. The energy in the nonvisible portions of the spectrum still affect us and must be considered along with the visible portion. In addition to the visible spectrum, the ultraviolet (UV) and infrared (IR) regions of electromagnetic spectrum are of particular importance to the designer (Egan and Olgyay, 2001).

Figure 2.2: Different Colors of Daylight on Different Times of The Day (Ungrungseesapon, 2012)

2.2. Physics of Light

This topic addresses 2 main points. The technical details of light such as wavelength, frequency, and intensity are one of them, and secondly, luminous intensity and luminous efficacy of light.

2.2.1. Wavelength, Frequency, and Intensity

A wavelength is a measure of distance between two points in a wave. Lighting wavelength works with all light bulbs like fluorescent tubes, halogen lamps, or lighting emitting diode (LED) lighting. Different electro-magnetic waves in light that can be seen by the human eye form different colors. Shortly, wavelengths in light create colors. Color type depends on wavelength. In 1960s, photo biologist Dr. John Ott coined the term ‘full spectrum lighting’ to describe light source emitting a full spectrum of natural light, which included both ultraviolet and visible light, and promoting the same health benefits of sunlight in humans, animals and plants (Zeytinoğlu, 2015).

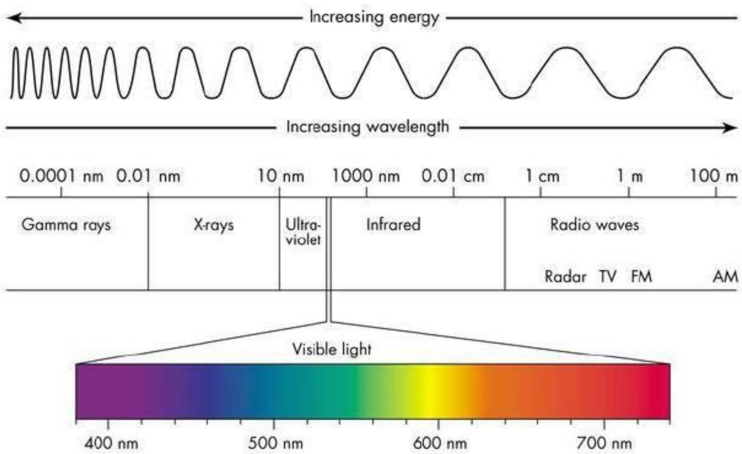


Figure 2.3: Wavelength (Whitwam, 2017)

Light waves also come in many frequencies. The frequency is the number of waves that pass a point in space during any time in one second. It is measured in unit as hertz. The frequency of visible light referred to as color, and ranges from 430 trillion hertz, seen as red, to 750 trillion hertz, seen as violet. The full range of frequencies extends beyond the visible portion, from less than 3 billion hertz, as in gamma rays (Harris and Freudenrich, 2000).

In order to perform any visual activity, there are some physical criteria such as level and intensity of light within an interior space. Optimum visual conditions should be provided to accomplish a specific task via functional lighting. Intensity indicates brightness and is measured as the rate at which light energy is delivered to a unit of surface, or energy per unit time per unit area. To exemplify, traditional lighting is concentrated on choosing the most difficult visual task which will be done in an interior space and apply uniform lighting over the space. Lam (1977) suggests a more detailed analysis considering the location, type and the time interval of the activity for a perception-oriented lighting setting.

Surface reflectance qualities and intensity of light falling on a surface change the visual perception of an interior. Gordon (2003) says perception is independent of the quantity of light entering the eye; it is based on the quantity of contrast: the difference between light and dark. The same light source with the same light distribution creates different impacts in the room with pink and blue tiles than yellow and blue tiles. Yellowish space is perceived as wider with high intensity of light. Under the same intensity of light, pinkish space looks smaller and lighting level is perceived as if its dimmer.

2.2.2. Luminous Intensity and Luminous Efficacy

As Dönmez (2014) states:

> “To provide quantity of light is only one elementary step in creating comfortable and good-quality luminous and visual environments. It can be agreed that bad quality lighting does not allow people to see what they need to see or may not provide visual comfort. On the other hand, lighting should be proper for visual task. So, it should not cause visual discomfort. Also, it depends on the specific application and case, both insufficient lighting and too much light can lead to bad-quality lighting”

(p. 68).

There are a number of lighting-related factors that may can cause visual discomfort and there is no straight-forward path to follow in creating visually comfortable luminous environment (Veitch, 1998).

Luminous intensity is the quantity of visible light that is emitted in unit time per unit solid angle. The unit for the quantity of light flowing from a source in any one second is called the lumen. The lumen is evaluated with reference to visual sensation. The sensitivity of the human eye is greatest for light having of 550 nanometers (Egan and Olgyay, 2001).

The aim of lighting designer is controlling the luminous space in order to affect the perceived space. In a luminous space, a person's emotional state in a visual environment depends on if the biologically necessary information is clearly distinguished or not. In addition to sufficient visibility, luminous environment should fit to our expectations which means, not everything should definitely be visible, but luminous interior should make sense as a clearly structured space (Ganslandt & Hoffmann, 1992).

In these modern times, there are various types of light and lighting. Each of them has different luminous intensities. However, in types of light, energy saving is an important factor. For instance, Compact fluorescent light functions differently than other bulbs as seen in Figure 2.5. Especially in terms of energy saving, it needs a little more energy when first turned on, but once the electricity starts moving, compact fluorescent lamps use about %70 less energy than incandescent lamps. Shortly, this compact fluorescent lamp uses approximately 20 W of electric power and produces 300 lumens.

Figure 2.4: The Compact Fluorescent Lamp (Photograph taken by the author)

"LED" stands for light emitting diode. LED light bulbs, such as compact fluorescent lamps, have energy saving capabilities. LED lighting products illuminate approximately %90 more efficiently than incandescent light bulbs. LED lamp uses 4W of electric power and it produces 108 lumens (Erol, 2008).

Figure 2.5: LED Lamp (Photograph taken by the author)

2.3. Perception of Light and Color

Light perception is the process of perception and interpretation of a person by the light environment. To achieve this, the light must first reach an organ-based device capable of receiving visual inputs, such as eyes possessed by many organisms. Light, some processing forms, such as the brain or a computerized system, turn sensory input into meaningful perception when the light or light hits the organ or device receiving it. In other situations, such as in the case of human perception, the light provides detailed information about the exterior, such as colors, spatial data, and well-defined shapes. The first part of the light perception occurs when light from some sources interacts with a sensory organ such as the human eye. The human eye can focus on certain peripheral features and thus can make selective light perception.

As the word 'perception' means recognition and interpretation of sensory information. Actually, in that matter, the topic is directly related with visual perception. Visual perception is the ability to perceive what some individual sees. In short, perception of light is directly related to visual perception.

Color is the sensation and perception which is created by the light and it is created with the help of reflection from objects or comes from a light source with the means of eye and brain. People have five senses, however, seeing is the most effective and permanent sense among the perception-creating five senses.

Colors have two main priorities in our lives. One of them is spectral separation. It is effective when it is necessary to separate objects that are similar in shape to each other but have color differences. For example, it works to differentiate fruits or vegetables from each other. Another task of colors is to give information about what the spectra is. For example, it is understood according to the color of rural area, whether it is steppe or pasture. In short, color vision tells us about the condition of an object. For instance, in figure 2.1. and 2.2., it seems clearly that the importance of colors (Memiş, 2007).

Figure 2.6: A Chromatic Image of a Picture Taken from Grocery Store (Memiş, 2007, pp.4)

Figure 2.7: An Achromatic Image of a Picture Taken from Grocery Store (Memiş, 2007, pp.4)

Researches about color show that color is not only in the field of psychology but in chemistry, physics and art as well. Color has vibrations like sound. While sound vibrations are detected with the help of the ear from our sense organs, color vibrations are perceived with the aid of the eye. In addition to these, light is needed in order to perceive the color on matter.

Colors have physical properties and these properties are based on light. Color doesn't appear without light and the biggest and most important light source is the sun. However, in some cases, people may not receive any sunlight/daylight. In this situation, design should be executed for the perception of work (Erim, 1999).

2.3.1. The Human Eye

We have the sense organ that allows us to see the eye with the help of ambient light. The human eye is the most complex organ in our bodies. As Egan and Olgyay (2001) states:

> "Figure 2.9. shows various parts of human eye. The cornea and lens focus light on the multi-layered retina which transmits impulses through the optic nerve to the brain. The size of the pupil is controlled by the iris-the larger the pupil, the greater the amount of light admitted into the

eye. Under conditions of high brightness (e.g., bright skies outdoors) the reserve occurs-the iris reduces the size of the pupil so less light is admitted. The ability of the eye to control the amount of light it admits and to change the sensitivity of the retina is called adaptation" (p.36).

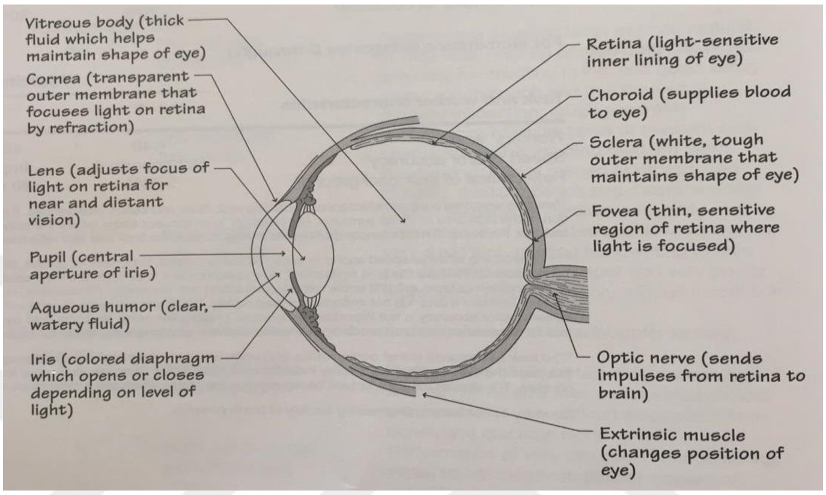


Figure 2.8: The Human Eye (Egan and Olgyay, 2001)

"In an inadequate lighting, particularly in dark-colored work, fatigue symptoms, visual disturbances, and headaches occur. Especially, in jobs working older people the level of illumination must be at an optimal level. A 60-year-old worker needs about 2-5 times stronger illuminated space than a 20-year-old worker" (Su, A., B., 2001, p.162).

Table 1 shows that some of the problems that people experience with the progression of age. When this table is examined, comments can be made that people 40 years old and over have difficulty with near vision. With aging, people have more difficulty in terms of vision like cataracts, presbyopia and increasing risk of dry eye. And then, in 60 years old and above, eye problems increase that eye changes cause visual disturbances such as spots and floaters and ability to see in low lighting decreases. In final, at the last stage, people generally have advanced level cataracts and lack of color vision.

Table 1. Vision and Aging ("Vision Changes", 2017)

Age	Eye Problems
40s	You can't escape presbyopia (difficulty with near vision focus)
	Be aware of increased risk of dry eye & computer vision syndrome.
50s	Risk increases for cataracts. Glaucoma & macular degeneration.
	Presbyopia become more advanced.
	Risk of dry eye increases for woman after menopause.
60s	Risk increase for common age – related eye disease (see 50s above).
	Ability to see in low lighting decreases.
	Age – related eye changes cause visual disturbances such as spots & floaters.
70s & 80s	Most people in this age group already have or will develop cataracts.
	Color vision declines, and visual fields begin to narrow.

2.3.2. Illuminance and Luminance

In short, illuminance is a term that describes the measurement of the amount of light coming into and spreading over a given surface area. Also, illuminance correlates with how human eye perceives the brightness of an illuminated area. Another short meaning of illuminance is the quantity of light. "The quantity of light, or *illumination level,* is only one of several important characteristics of lighting systems" (Egan and Olgyay, 2001, p.31). As Boubekri (2004) states:

> "British Design Development DD 73 Standard determines illumination levels regarding the purpose of use of the building interiors. According to the standard, in drawing offices in the educational, office or factory buildings; illumination of 500 to 750 lux should be maintained. The standard recommends maintaining illuminance of 300 to 500 lux in

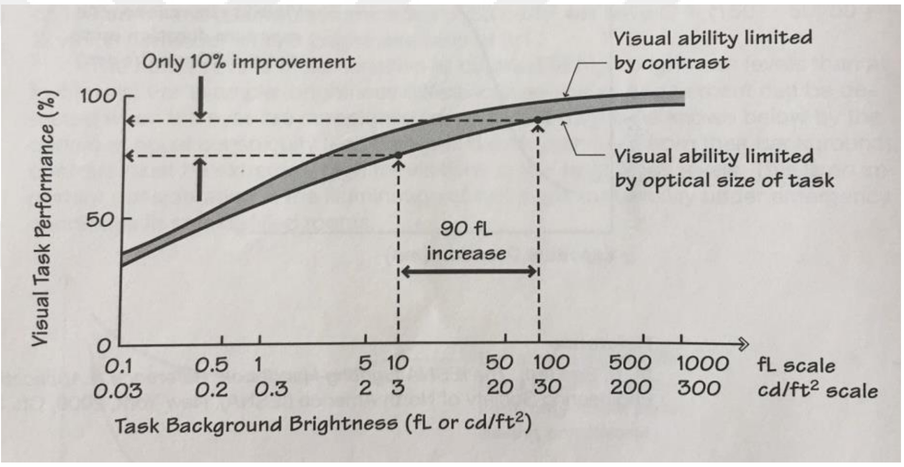
formal teaching and seminar rooms, 300 to 500 lux in deep plan teaching spaces, 300 lux in the music and music practice rooms" (Boubekri, 2004).

Table 2. Recommended Daylight Illuminance (lux) in the DIN 5034 – 4 Standard (Boubekri, 2004)

Stage	Daylight Illuminance (Lux)	Visual Task
1	15	Temporary Task
2	30	
3	60	Easy Task
4	125	
5	250	Normal Task
6	500	
7	750	Difficult Task
8	1000	
9	1500	Very Difficult Task
10	2000	
11	3000	Very Special Task
12	5000 and more	

Luminance means that the measurement of the amount of light emitting, passing through or reflected from a particular surface from a solid angle. It is also directly related the human eye as how much luminous power can be perceived by the human eye. This definition means that luminance indicates the brightness of light emitted or reflected off of a surface. As Egan, Olgyay (2001) states: Luminance values are a limited determinant of our ability to see, as shown in Figure 2.8. At 10

FL (or 3 cd/ft) on the object to be viewed, our speed of reading is already nearly 80 percent of our maximum ability; increasing the task luminance to 100 FL (or 30 cd/ft) only provides about a 10 percent additional increase. After the first 10 to 20 FL (or 3 to 6 cd/ft), our ability to see is largely determined by factors such as the size and other characteristics object being viewed, the lighting geometry, and the abilities of the observer. Notice that the horizontal scale on the graph below is logarithmic; this is indicative of how we perceive brightness (i.e., we notice a doubling of brightness, but may not be able to perceive a 25 percent increase). It is also evident from this graph that people can see adequately over a very wide range of luminance levels, further diminishing the significance of luminance quantity alone as a lighting design criterion (p.20).



2.9: Luminance and Visibility (Egan, Olgyay, 2001)

2.3.3. Color Temperature

The choice of color temperature of light is related to human psychology, aesthetics and naturalness. The choice is made according to the brightness level, the volume properties of the interior surfaces and the furnishings and the climatic conditions (CIE, 2001). It is generally preferred to use colder-colored light in cold climatic regions rather than in warm climatic regions. In the case of cold climatic regions, the opposite applies.

Color temperature describes the appearance of light provided by a light bulb.

It is measured in degrees of Kelvin (K) and it is between 1,000 and 10,000. Electric light source expresses its warmth or "coolth". To exemplify, as seen in Figure 2.9., when Kelvin goes down, color temperature is warmer like a candle flame. However, when Kelvin goes up, color temperature is in more bluish tones like skylight in North-western skies. In Figure 2.9., color temperatures are given for electric light sources and daylight (Flynn, Mills, 1962).

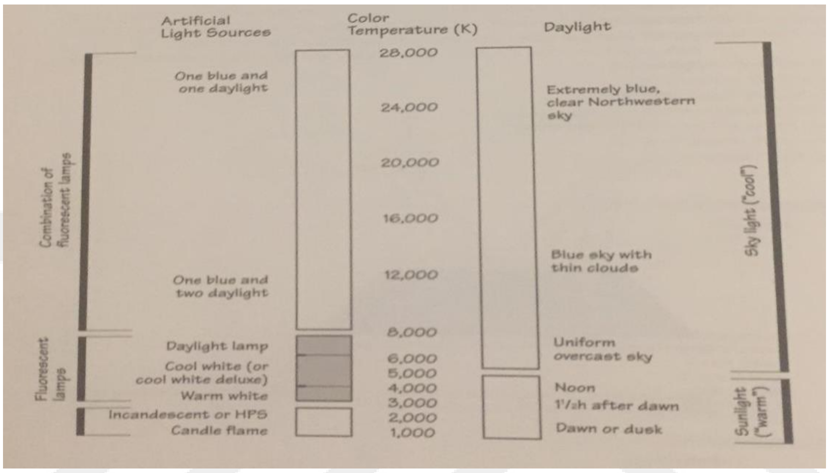


Figure 2.10: Color Temperature Scale (Flynn, Mills, 1962)

"In a study conducted at different color temperatures, it was concluded that the effect of cold light sources on people was negative, while the effect of warm light sources was positive in low light levels" (Özkum, 2011, p.97). It is stated in Table 4 that kelvin value between 2000-3000 has warmer tones and it is more suitable for living rooms, bedrooms, or ambient lighting. Kelvin value between 3000-4500 has cool white color tones and it is for task lighting, work environment. However, kelvin value 4500 and above is for works requiring attention such as display areas, security, or tasks.

Table 3. Color Temperature According to Usage Areas

	2000-3000K	3100-4500K	4600-6500K
Color Temperature (KELVIN)	2000K - 3000K	3100K - 4500K	4600K - 6500K
Light Appearance	Warm White	Cool White	Daylight
Ambience	Cozy, calm, inviting, intimate	Bright, vibrant	Crisp, invigorating
Best for	Living room, kitchens, bedrooms, bathrooms, restaurant/commercial ambient lighting, decorative outdoor lighting	Basements, garages, work environments, task lighting, bathrooms	Display areas, security lighting, garages, task lighting

2.3.4. Correlated Color Temperature

Correlated color temperature (CCT) is the appearance of color of light source which can be measured in degrees of Kelvin (Egan & Olgyay, 2002). It was seen in the researches that have been conducted before on CCT mostly focused on mood, perception, psychological effects, working performance, and individual liking (Boyce & Cuttle, 1990; Davis & Ginthner, 1990; Hoof et al., 2009; Knez & Kers, 2000; Manav & Küçükdoğu, 2006; Manav & Yener, 1990; Odabaşıoğlu, 2009), and the building types explored in terms of color temperature are offices, working areas, residential buildings, nursing homes and clinics.

When a Kelvin is a warm light is around 2700 Kelvin, moving the neutral white t around 4000 Kelvin, and to cool white at 5000 Kelvin or more. According to American National Standards (1987), one of the fundamental aspects of lighting is the quality of lighting and correlated color temperature is one of the most important components of quality of light on human perception, which provides comfortable and effective visual environments (Veitch & Newsham, 1998; Katsuura, 2000; Samani, 2011).

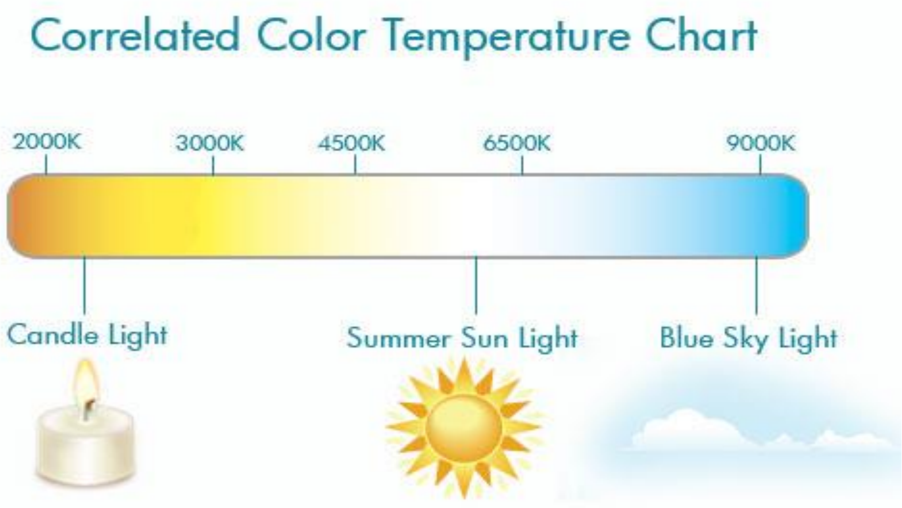


Figure 2.11: Correlated Color Temperature Chart (Organic Electronics, 2017)

2.3.5. Color Rendering Index

Color rendering index refers to how colors appear under artificial light sources as seen in Figure 2.11. Daylight which is ideally presented in this respect is taken as reference in determining the color rendering criteria of artificial light sources. The color rendering index (CRI) is defined by Egan & Olgyay (2002) as the measure of how well the light source renders color. It can be called as the effect of the light source on the color appearance of objects (Rea, 2000).

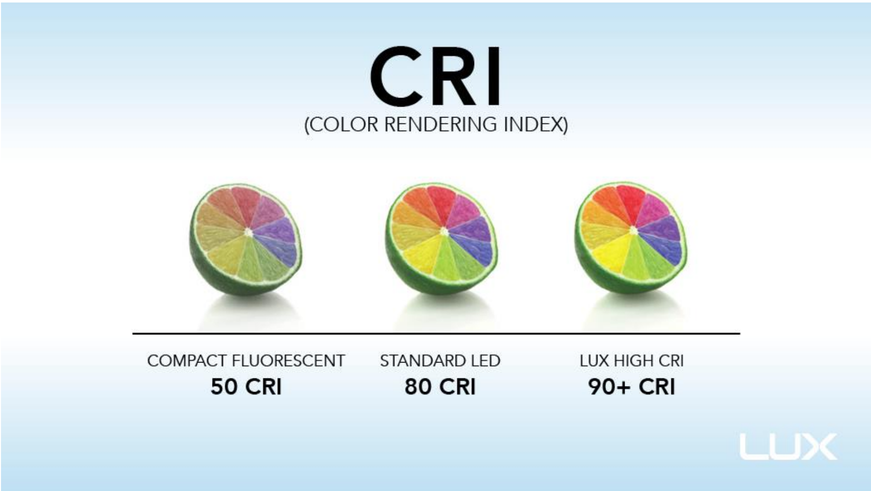


Figure 2.12: The Example View of Color Rendering Index (CRI means, 2017)

Light source must ensure that colors are perceived as accurately as possible. Daylight is considered 100%, and other artificial light sources may contain different values. Measurement and evaluation are made one by one on 14 colors and the average is taken (“Color rendering index”, n.d.).

As color rendering index gets higher, the lighting source shows colors becoming more natural. CRI is measured on a scale from 0-100 where 100 is the best. For example, a lighting with CRI of 10 appears more natural (Philips, 2015). The CRI is an indication of how similar the color of an object is rendered by a light source relative to a specific Kelvin temperature on the black body line (Kumoğlu, 2013).

Typically, light source with a color rendering index of 80 to 90 are regarded as good and those with a CRI of 90+ are excellent points. The general rule is that the higher the CRI, the better color rendering capacity. In the Figure 2.14., it is a good depiction of differentiating CRIs, with each image having the same warm color temperature (2700K).

Figure 2.13: Color Rendering Index in Same Color Temperature (Westinghouse Lighting)

2.4. Control of Light

Control of light which is used in interior spaces consist of 5 main parts. These are direct lighting, indirect lighting, diffuse lighting, task lighting and accent lighting.

2.4.1. Direct, Indirect, Diffuse, Task, and Accent lighting

Direct Light

A direct source of light casts downwards from a fixture to provide lighting with uniform levels of illumination. Open, louvered, and lensed fixtures can be identified as ‘direct lighting’. In this type of lighting, %0-10 of lighting is reflected upwards, whereas %90-100 of lighting downwards. It consumes less energy. Because of the physical structure and shape of the armature, direct delivery of the produced beam prevents light loss and provides high efficiency. However, as a consequence of direct arrival of light, shadows on the place become stiffer. Reflection or glare problems may occur due to the fact that the light source is obvious. The characteristics of the armature used must be so as to reduce the inconveniences that arise (Zeytinoğlu, 2015).

We can get rid of the negative effects of this lighting by using a combination of different fixtures. These luminaires are of two types: ceiling luminaires and wall luminaires (Tuncel, 2009).

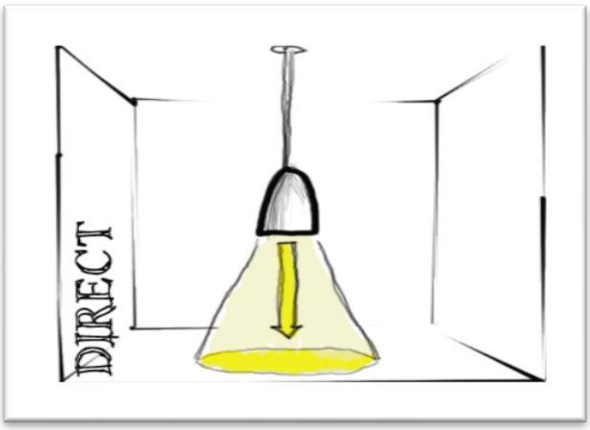


Figure 2.14: Direct Lighting Diagram (“Lighting”, 2012)

Figure 2.15: Direct lighting is used in Café Wien at Reasürans Passage Teşvikiye (Tuncel, 2009, pp.xx)

Indirect Light

An indirect source of light casts upwards from a fixture and bounces down to provide lighting with minimal glare and more uniform levels of illumination. In this type of lighting, %90-100 of lighting is reflected upwards, whereas %0-10 of lighting downwards. Naturally, the amount of lighting is low because it comes after light hits a surface. Energy consumption is high. There are never hard shadows forming in the place. This type of lighting helps provide a homogeneous lighting experience in the place. This type of lighting is used in places that do not require much attention to detail (Zeytinoğlu, 2015).

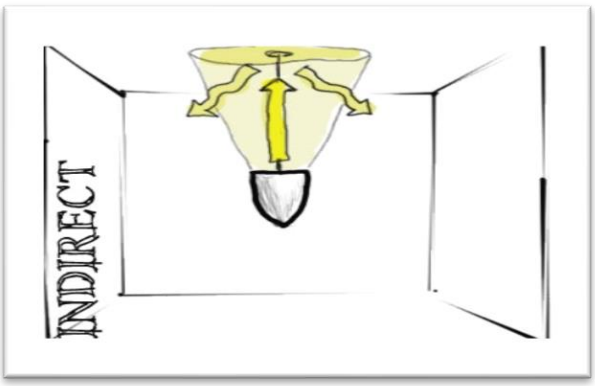


Figure 2.16: Indirect Lighting Diagram (“Lighting”, 2012)

Figure 2.17: Indirect Lighting Fixture (“Lighting”, 2012)

Diffuse Light

If light from the armature is evenly distributed in all directions, this is called diffused lighting. It is used as a reflector of the entire space in this lighting form. For this reason, materials used in the room become more important in places where diffused lighting is used. Energy consumption and energy efficiency are proportional to each other. However, there are differences in lighting efficiency according to the materials used in the room. Diffused lighting generally is preferred in libraries, working spaces like offices or schools. As the fitting is completely enclosed or concealed, as with some globes or ceiling panels, there is not any glare (Zeytinoğlu, 2015).

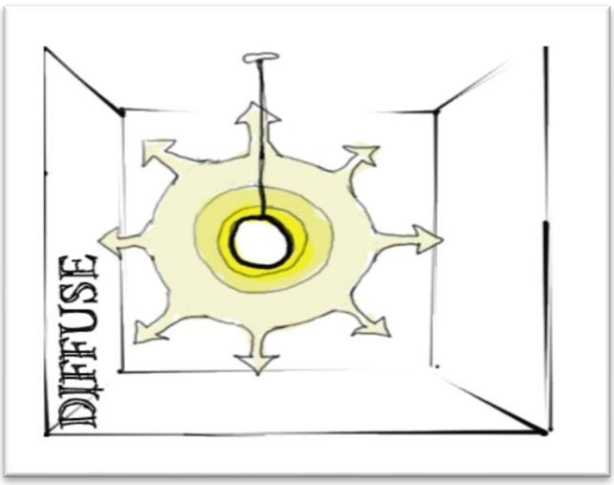


Figure 2.18: Diffuse Lighting Diagram (“Lighting”, 2012).

Figure 2.19: Diffused Lighting Fixtures ("Lighting", 2012)

Task Light

Task lighting is the one of the lighting distribution strategies. This type of technic is used for lighting a particular area and it makes the completion of a task easier as opposed to other technics. Task lighting becomes especially important in software or hi-tech industries, or any other industry where tasks cause eye strain or employees work in front of a computer for long hours. Focused lighting is a crucial part of an ergonomic workstation as it relieves eye strain (Ergodirect, 2014).

Figure 2.20: Task Lighting Fixture ("Busyboo", 2014)

Accent Lighting

Accent lighting has more artistic goal compared with other type of lighting strategies. It uses generally in professional or commercial places where businesses or artists look to highlight products and artwork by using light to accentuate image and style. Accent lighting is for those that want to create extra drama and character to their most cherished areas or objects. Applying accent lighting will draw further attention towards what you want to stand out. These lights are made to tweak the presentation and stature of already existing items or areas within the home or garden ("Electrical products", 2015).

Figure 2.21: Accent Lighting Fixtures ("Indoor lighting", n.d.)

2.4.2. Reflectors

The emitted light flux from the lamp must be directed to certain directions so that the desired light intensity, light flow, and light distribution can be obtained. Direction of the lamp's light flux is predominantly provided by the reflection of the light rays from a surface.

In the reflection of light from the lamp into the desired directions, the geometrical forms of the reflector and the properties of the material play a decisive role. In terms of geometric shapes of reflectors used in lighting devices, this can separately be grouped into three as below.

- Plane surfaces

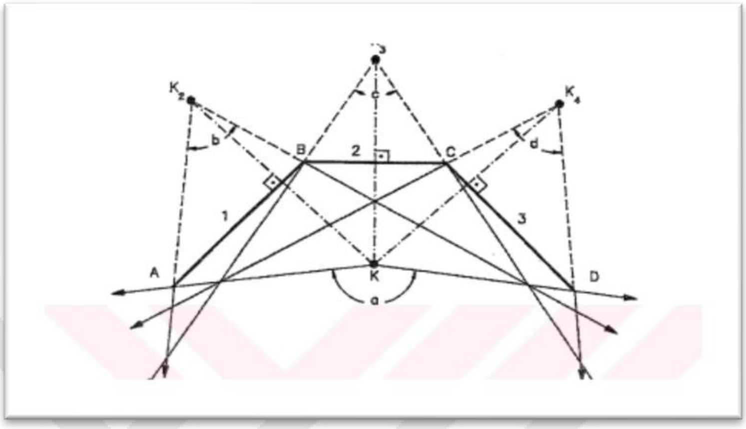


Figure 2.22: Plane Reflector Consisting of Three Parts (Aydın, 2005)

- Single convex surfaces (various cylinders)

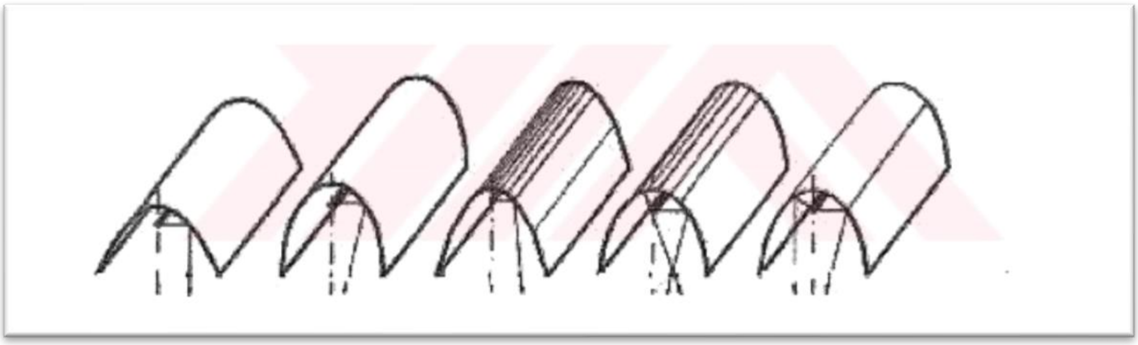


Figure 2.23: Single Convex Reflector Example Using Linear Light Source (Aydın, 2005)

- Concave surfaces

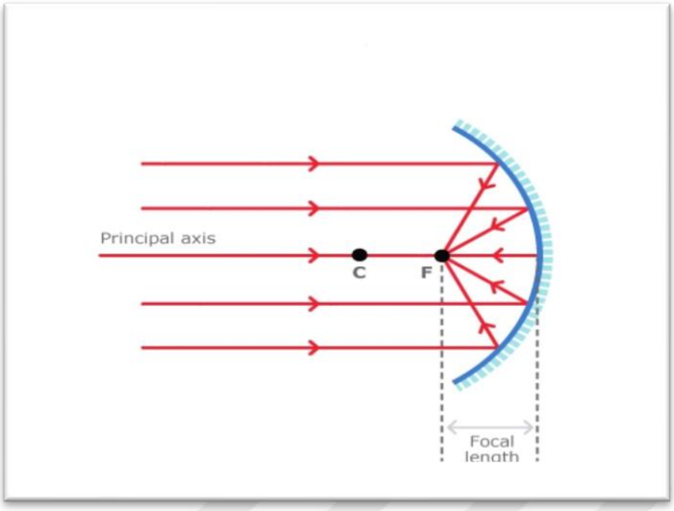


Figure 2.24: Reflection of Light on Concave Surface

Planar, single-convex and concave reflectors can be used for both point and line light sources. (Aydın, 2005)

2.4.3. Indoor Lighting Techniques

The most important purpose of the lighting technique is to ensure that visual perception takes places under the best conditions. It is known that a proper lighting technique will improve the performance in schools, increase performance in production and workplaces, and reduce occupational accidents. Lighting is to apply light most suitably for visual perception on certain objects and surfaces. The lighting technique is a science that utilizes scientific data and information spreading over a very wide area, which includes highly complex calculations of aesthetic and architectural concepts, kinds of measurement techniques, light reflection and transmission properties of surfaces and materials, various properties of light bulbs and lighting fixture, art branch and specialist (Tuncel, 2009).

For example, In the work of Özkum, features of the area to be illuminated, to be used in aesthetic as it affects the choice of the armature, such a luminance, light color, and color temperature should also be considered in terms of comfort. It is uncomfortable and tiring to see the source of light, directly, at the eye, and it also reduces the use of light. That is, light coming directly to the eye causes the illuminated object or areas to appear darker than it is, and is harmful for eye health. Glare is a common lighting problem. The bright light source located on the ceiling or wall which is not positioned correctly causes glare, as seen in Figure 2.24. This situation affects and restricts the workers' ability to see his/her task. Very bright and poorly positioned lighting source cause direct glare. When the light is reflected by the surface it is called indirect glare.

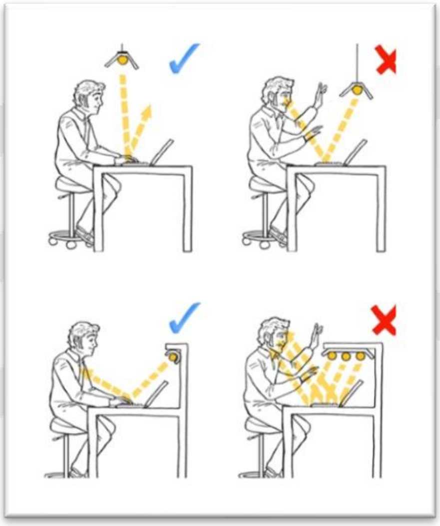


Figure 2.25: Locations of Lighting Sources (Lighting Ergonomics, 2016)

Some methods can be applied to prevent glare. These are;

- A few small lighting sources can be used instead of one high power lighting source.
- Ambient lighting luminaires should be used. Indirect lighting prevents glare.
- Location of the light sources can be changed to prevent glare, either directly or as a result of reflection.
- Preferring to use matte or semi-gloss paint on walls and work surfaces

may prevent glare.

- General lighting values of the environment should be kept at the recommended levels.

"The key to eliminating reflected glare is eliminating glare sources and high contrast in the offending zone. The offending zone is the area behind user that the user would see if the screen were a mirror" (Ankrum, 2015).

2.4.4. Light Distribution Strategies

This section provides numerous advanced lighting guidelines for the lighting design criteria identified in the IESNA Lighting Handbook, 9th Edition. These criteria are organized in three general categories:

Light Distribution, including:

- Task and ambient lighting
- Day lighting integration

In tailors and cobblers, generally, ambient lighting is used. However, people working in a task need a task lighting. Therefore, the differences between task lighting and ambient lighting should be considered.

Task lighting is brighter light provided just where designers need it, such as for tailors or cobblers. It helps workers perform certain tasks like seeing the yarn (Dönmez, 2016).

Ambient lighting is also named as general lighting. It is the generally favorable light level that allows people to see whole spaces. Contrary to direct lighting fixture, ambient lighting is like natural daylight (Dönmez, 2016).

2.5. Artificial Light Source

Artificial lighting is defined as 'artificial lighting by using artificial light sources’ (Hasol, 2005). Artificial lighting is illuminating a room when natural light is inadequate. The concept of artificial light that emerged with the discovery of fire has evolved with the ability to control the fire over time and carry it with various elements. Firstly, artificial light used in the form of a torch, then transformed into lamps to provide climatic conditions. User needs and requirements are thus eliminated (Zeytinoğlu, 2015).

The subject of artificial lighting from the past has revealed significant developments and continues to develop with new technologies. The use of oil, candle, torch, and oil lamp, etc., has made a prominent breakthrough with incandescent lamps (Zeytinoğlu, 2015). Incandescent bulbs followed gas-discharge lamps and LEDs.

2.5.1. Incandescent Lamps

“An incandescent light bulb or light source is any device that uses electricity to heat a filament – or wire – until it is hot enough to glow white. If that was done in the open air, in the presence of oxygen, the metal filament would burn up before it got that hot” (Lewis, 2017, n.p.).

Lighting has changed a lot in the historical process. The change in science and technology will continue the issue of lighting, undoubtedly. One of the most important breakthroughs in lighting is the production and use of incandescent lamps by the invention of electricity. Incandescent lamps were mostly used by hanging from the middle of the rooms. However, the fact that these types of lamps only give little light just makes visible. With the development of age and technology, more and cheaper light sources have been produced as well as incandescent lamps with low light (Kosif, 2015).

Figure 2.26: Incandescent Light Bulb (“Lighting”, 2012).

2.5.2. Gas Discharge Lamps

It works by generating light from discharges by applying voltage to the electrodes at both ends of a glass tube filled with gas into discharge lamps. Most of the discharge lamps require high voltage to work. Today, most used discharge lamp is the fluorescent lamps (Karaoğlu, 2013)

Energy efficiency plays a huge role in lighting design. In some countries, the restaurant must be restricted in the number of watts per square foot. It brings along further planning and specification to relate the design concept needs. Limiting the use of incandescent lighting effects, the energy efficiency. The incandescent lighting uses more power than fluorescent lamps. The incandescent lamps radiate more heat than fluorescent lamps. It could mean an increase in HVAC needs. Still, fluorescent lamps are not interesting light sources since the compress the atmosphere of area. These factors influence the lighting designers for design concepts (Brandi, 2006). Also, fluorescent light tubes are cold, but many emit higher than acceptable levels of ultraviolet radiation (Heritage Collection Council 1998). Also, gas discharge lamps are separated into 3 headers. These are low pressure discharge, high pressure discharge, and high intensity discharge.

Low Pressure Discharge

These types of lamps have working with pressure lower pressure than atmospheric pressure. It contains fluorescent lamps and low-pressure sodium lamps.

It produces approximately 200 lumens per watt, however, it has very poor color rendering. Because it produces monochromatic yellow light, it is just used in street lighting or similar applications.

Figure 2.27: Low Pressure Discharge Lamp (“Discharge Lamps”, 2018).

High Pressure Discharge

High pressure lamps operate at lower pressures compared to atmospheric pressure. It contains metal halide lamps, high-pressure sodium lamps, and high-pressure mercury-vapor lamps.

High Intensity Discharge

Also, this type of lamp is best known as high intensity discharge lamps. The meaning of high intensity discharge lamp is the use of a special type of electrode in the lamp. Also, it is powerful in energy efficiency and tends to have the longest service life of any lighting type.

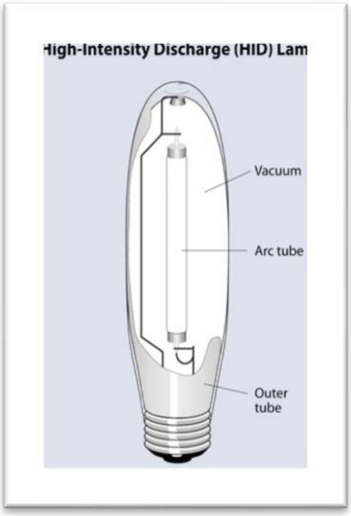


Figure 2.28: High Intensity Discharge Lamp (“Discharge Lamps”, 2018).

2.5.3. Light Emitting Diodes (LED)

Nowadays, the light-emitting diode, which is LED, is the new type of lighting. This low voltage type light is used to focus light in a specific direction. It can give more light and leave less cost behind than incandescent lamps (Piotrowski, Rogers and IIDA, 2007).

LEDs are fast emerging technology. LEDs for room illumination are today only in the first phases of commercialization, but already now they provide replacements for both clear and non-clear light bulbs. They are likely to become alternatives to the full range of lamps in the near future (“Incandescent Bulbs”, 2009)

Figure 2.29: Decorative Light-Emitting Diode (LED) Lamps with Clear Bulb (“Lighting”, 2012)

2.6. Benefits of Daylight

In today's architecture, designs are made to use daylight more. In places, the size of a room is determined by the light and sky. Different architectural plans have been implemented in different climatic regions of the world, according to the effect of daylight. In the cold and dark regions, daylight was used more and more by using large windows. Natural lighting can be defined as a lighting system designed to meet the visual comfort requirements of daylight, the main source of sunshine (MEGEP, 2013).

Daylight is an important part of visual comfort. Most spaces do not use the daylight effectively or do not control daylight that enters their spaces, resulting in glare and reduced comfort. Windows are also important for another physiological reason in interior spaces. When people looked out a window, it must ensure visual relief. In short, day lighting design has significance for visual comfort (Dönmez, 2016). The most important feature that separates daylight from artificial light is its variable and non-monotone structure. The intensity of daylight and the colors produces offer an unlimited variety. With this feature, daylight is suitable for human nature (Koçu, 2008).

The most important advantage of natural lighting in terms of function is that it allows us to see and perceive volumes, objects, colors, and textures in the closest and natural state (Özkum, 2011). Yener (2008), in addition to providing the physiological and psychological comfort of the users, the main goals of the illumination of the volumes with daylight to reduce energy consumption are as follows:

- Efficient use of daylight
- Ensuring the appropriate level of brightness
- Controlling direct sunlight so as to avoid glare
- Establishing a visual relationship with the external environment
- Feeling the qualitative and quantitative differences of the external luminance level during the day

- Reducing the use of artificial lighting and heating-cooling systems

Daylight illumination of the buildings is provided with the help of windows and roof skylights. Some buildings get light from the side walls due to their structure and some of them have taken light from the roofs. The application of size and location of the windows which are the most important elements of structural elements that provide the relationship between the architectural spaces and the sunlight, directly affects the natural lighting design (Avcı, 2010). Different windows types and the light distribution examples can be seen in Figure 2.31. and Figure 2.32.

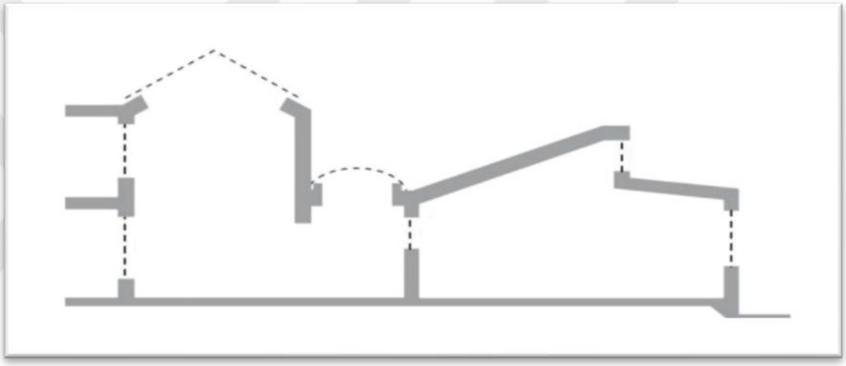


Figure 2.30: Different Window Types (Loe et al., 1999)

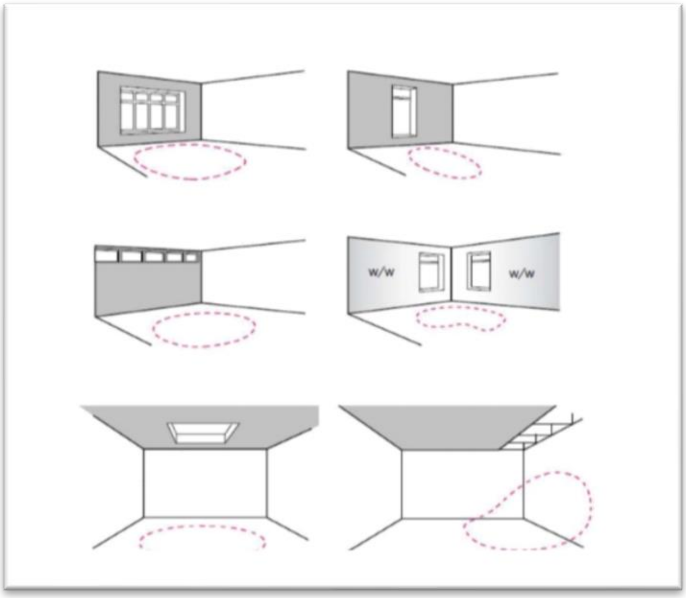


Figure 2.31: Light Distribution by different window types (Loe et al., 1999)

Usually for basement floors, natural light is possible with windows or skylights opening from the roof and the samples can be seen in Figure 2.33., Figure 2.34., and Figure 2.35. Openings in the roof of the building are called roof windows (Aksoylu, 2008). The roof openings and sloping windows are intended to provide sufficient and controlled daylight by not providing external visibility. Each of these types of openings has a different effect on the building form and interior arrangement as well as the daylight distribution they provide (Yener, 2008).

Figure 2.32: Daylight from Roof Window (Aksoylu, 2008)

Figure 2.33: Daylight from Roof Window (Özmen, 2010).

Figure 2.34: Daylight from Roof Window (Aksoylu, 2008).

2.6.1. Sick Building Syndrome

The environment is anything outside the human organism. The environment can be separated natural or artificial environment, or physics, biological or social environment. Physical and chemical factor are called abiotic factors, and other organisms are called biotic factors. There are important factors that can directly or indirectly affect health in the environment. These factors can act in different ways on human health (Güler and Akın, 2006).

In recent years studies have shown that various symptoms have emerged depending on the buildings. Diseases associated with buildings are referred to as 'sick building syndrome'. The sick building is a negative condition defined as a harm of health in building (Özyaral, Keskin, Hayran, 2006). Sick building syndrome is a term that has emerged in recent years as a result of studies. It has started to be reported with increasing frequency since 1970s (Kubo, Mızoue, Ide, Tokuı, 2006). The symptoms that arise when a person lives and works in a particular building but moves away from this environment are called symptoms of the patient building syndrome.

For instance, sunlight contains intense blue wavelengths. These wavelengths call human body into action. Shortly, the body goes into day mode and prepares itself for action. In the same way, with the reduction of blue wavelengths, the metabolism begins to slow down and enters night mode. This is the natural balance of the human body. The main problem starts at this point because artificial lighting, computer screens, especially TV and mobile phone screens emit blue wavelength intensely.

The blue wavelength forces the body to be constantly awake as under sunlight. This may also be caused by impaired hormonal balance and lack of relaxation (Tutkunlar, 2014).

Studies on sick building syndrome are increasing in the world. As a result of these studies, it is determined that the symptoms in the person can be related to the buildings they live in. Although there are studies on indoor air pollution and its effects on the Turkey, does not have much research to determine the effects of health and sick building syndrome. It is very important for health to know the health effects of the buildings we have spent most of our time with and to take our precautions accordingly and to raise awareness. It will be an initiation point to find out if there are people with symptoms of sick building syndrome and the reasons for which we live and work in the buildings.

CHAPTER 3

ANALYSIS OF THE EFFECTS OF ARTIFICIAL LIGHTING IN ENCLOSED SPACES WITHOUT DAYLIGHTING

As mentioned above, lighting design in working environments is one of the most important environmental components affecting the visual comfort and working performance of people. The correct application of light is crucial for handling the visual task properly, as it enables the interaction between worker and the task being done. Studies on lighting related to its functional aspects such as; visual clarity, visual perception and visual comfort were carried out in the 1950s (Boyce, 1981). Whereas, research that evaluates lighting elements in the context of human and environmental relations has begun to take its place in literature after 1970s (Flynn, 1977). Today, it is necessary to conduct research on the architectural lighting features particular to some specific functions of spaces, as the requirements of each function are unique and some lacking factors may still be found.

3.1. Aim of The Study

The main goal of this research is to present the analysis of artificial lighting applications for visual task efficiency of people working in enclosed spaces without daylight and to explain methods to provide proper and healthy lighting designs for these spaces. Also, the main issue of this thesis, which is examining the effects of artificial lighting on visual task efficiency in interior spaces that do not get any daylight, was analyzed through varying techniques, namely; on-site observations, taking measurements and conducting a questionnaire. Face-to-face interview was chosen as the data collection technique for the questionnaire survey. As case studies, a total of ten work spaces were chosen, which are tailor shops and shoe repair shops that do not benefit from daylight, located at the basement floors of five different shopping malls.

Table 4. Details of Case Spaces

Case Number	Name	Location
Shoe Repairer 1 (SR1)	Salmander	Oran mah. 182/16 Panora AVM, Turan Güneş Blv., 06450 Çankaya/ANKARA
Shoe Repairer 2 (SR2)	Salmander Lostra	Birlik mah. 428. Cad. 365 AVM, No:41 06610 Çankaya/ANKARA
Shoe Repairer 3 (SR3)	Pabuç Tamir Merkezi	Eskişehir Yolu No:6 Söğütözü mah. Armada AVM, Çankaya/ANKARA
Shoe Repairer 4 (SR4)	Erfi Kundura	Koru mah. Ankaralılar cad. Gordion AVM 2/A, 06810 Çankaya/ANKARA
Shoe Repairer 5 (SR5)	Yeni İskarpini	Atatürk blv. Tiryaki İş Merkezi No:64 Kızılay, Çankaya/ANKARA
Tailor 1 (T1)	Erdal Ergün	Oran mah. Kudüs Cad. One Tower AVM, No:6/A Çankaya/ANKARA
Tailor 2 (T2)	Bizim Terzi	Birlik mah. 428. Cad. 365 AVM, No:41 06610 Çankaya/ANKARA
Tailor 3 (T3)	Ada Terzi	Eskişehir Yolu No:6 Söğütözü mah. Armada AVM, Çankaya/ANKARA
Tailor 4 (T4)	Ada Terzi	Koru mah. Ankaralılar cad. Gordion AVM 2/A, 06810 Çankaya/ANKARA
Tailor 5 (T5)	Terzi Sude	Atatürk blv. Tiryaki İş Merkezi No:82 Kızılay, Çankaya/ANKARA

The analysis of case spaces consisted of mainly two parts. The first part was based on the observations made, sketches drawn, as well as, photographs and measurements taken by the author. Here, the plan and section view sketches were made to examine the approach in artificial lighting applications and their relationship between the task surfaces. The light distribution strategies and the type of light sources used for general and task lighting in spaces were observed and recorded. The spaces were examined if there were any light sources within the offending zone as well.

To gather the technical data regarding the specifications of the artificial lighting sources used, measurements were taken by the CL-70F CRI Illuminance Meter of Konica Minolta. This device was supplied by the Building Physics and Environmental Control Laboratory of the Faculty of Architecture at Çankaya University. With this tool, the Illuminance Level (lx), Color Temperature (K) and Color Rendering Index (CRI) values of the light sources used were measured and recorded separately for general lighting and task lighting. These measurements were evaluated by taking previous studies in literature and developed standards into account. The Spectral Power Distribution (SPD) graphs of the sources were also produced and examined as to the CRI values and the composition of colors in the light sources.

The second part of the analysis which included a questionnaire survey was conducted by one-on-one dialogues with the users of the spaces who were actively involved in sewing or shoe repairing works. Initially, the participants were asked questions related to their personal information; such as gender, age, duration of daily work or time span of professional experience. After that, their personal experiences and opinions regarding the issues of lighting applications and color perception in their work spaces were asked. Finally, all of the collected data were examined to make an overall evaluation and, to identify the correct and incorrect lighting applications in these case spaces. Moreover, based on the gathered data, the faced problems were found out and recommendations for artificial lighting design in work spaces involving fine visual tasks which do not benefit from daylight were developed.

3.2. Research Questions & Hypothesis

The research questions of the study are as follows:

- What are the artificial lighting sources?
- How should be the illumination level in a space?
- How should be the color temperature level in a space?
- How should be the color rendering index value in a space?

Firstly, it was clearly seen that in all of the case spaces, only general-direct lighting was used. In direct lighting, the light is delivered directly to the room surfaces, thus providing the highest illumination efficiency. There is no obstacle between the light source and the work surface. However, if the source is not properly located, the shadow of the user may fall onto the work surface, since the person is working between the work surface and the lighting source. In the questionnaire survey, no shadow problems were mentioned, however, in the observation part of the study, such problems were detected by the author. It is believed that the participants of the questionnaire hesitated to freely discuss the problems in their working environments as they thought it might affect their professional careers. To avoids such shadow problems on work surfaces, the best solution is supporting General-Direct Lighting with Task Lighting.

In terms of illumination level, the ability to see varies according to the brightness level. Visual performance is at the highest level while eye health is maintained in a visual and convenient environment. The use of the place to be illuminated and the need for illumination are determinative in the design of artificial lighting. As seen in Table 4., the desired level of illumination level is specified according to the categories of work to be done. As the sensitivity of work done increases, the illumination level also increases. The highest brightness level of lighting required for very fine visual task is considered as 1.000 lux. Therefore, as to their illumination levels, in our case spaces values close to 1.000 lux was expected. The values are given in Table 3. When Table 5 is examined, in terms of task lighting illumination level, it is seen that the closest values to the technical data found in literature is in cases SR 1 and T 4 as 1020 and 1050 lux. People working there see all objects in the closest color tone to the truth. It should be also noted that task lighting should be three times higher than general lighting. When appropriate lighting design are provided for workers, work accidents and poor work performance are avoided. Therefore, obtained technical information is important. In the light of these information, Table 5 clearly shows the level of conformity in spaces. For example, the task lighting illumination level of SR 2, SR 3, SR 4, T 1, T 3, and T 5 are lower than the general lighting level. This result is exactly the opposite of what it should be and mistakes made on the job, low work efficiency, and even job accidents are inevitable. Moreover, these results show that %50 of the surveyed spaces have false lighting design. As an overall evaluation, these low illumination levels may lead to poor work quality and even some work accidents.

Depending on the color temperature of the light, it is possible to change the psychological environment, and it is possible to change the way of perceiving all objects in a space. The color temperature of the light can be changed according to the ambience to be given in the space. As seen in Table 3, values below 3000 K are used mostly in resting places like studying environments, offices, or kitchens. Finally, the Kelvin values over 4500 K are used in focus and attention-gathering areas such as security or display lighting. As noted in Table 3, in surveyed spaces, the approximate color temperature required is 4000 Kelvin and above. These values should be reached especially, in task lighting. As seen in the Table 5, generally, majority of spaces have color temperatures with values is in T 3. It has 9177 K in the task lighting and 9458 K in the general lighting. These values point to very cool color lighting within the space. It may help to concentrate on work but may lead to an unpleasant ambiance.

Finally, a light source with a maximum CRI value of 100 is known as the source that provides best color perceptions. In Table 6, the color rendering index values can be seen. Higher the CRI value better the color discrimination. In our case, CRI value is especially important as it plays a significant role in the selection of right shoe dyes, shoe laces, or thread colors. Daylight has perfect color rendering. As seen in Figure 2.13., when CRI value is 50, the color of objects is seen different than their original colors, in the words different from they are perceived under daylight. When Table 5 is observed, it is seen that the color rendering performances are not so ideal among the surveyed spaces. This situation affects the work performance, negatively. In such spaces where color discrimination is very important, CRI values above 90 should be preferred.

3.3. Description of The Site

A good understanding and introduction of the surveyed places is important to interpret the technical data obtained. Therefore, the details of surveyed spaces can be seen in Table 5 as plan drawings, section drawings, and photos.

Table 5. The Architectural Details of Surveyed Spaces

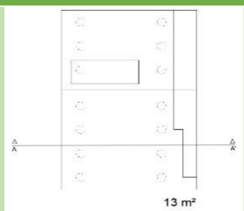
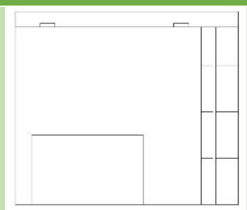
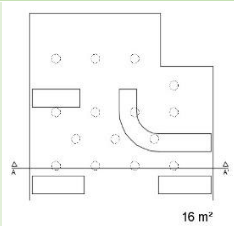
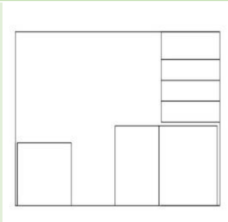
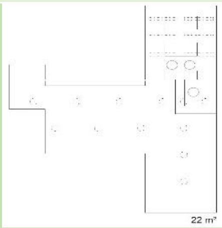
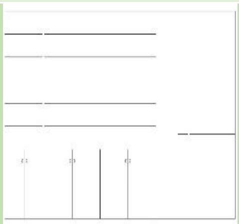
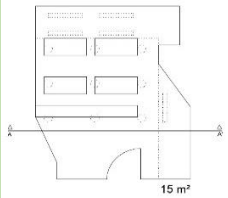
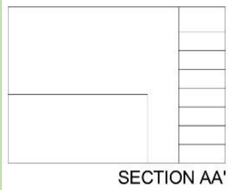
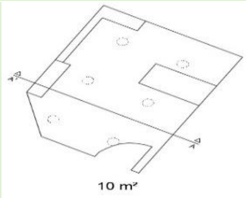
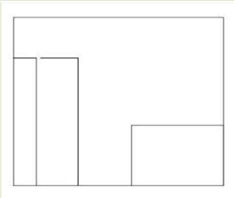
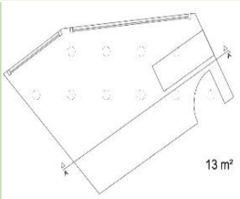
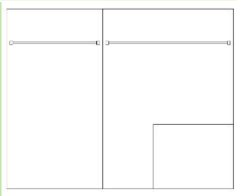
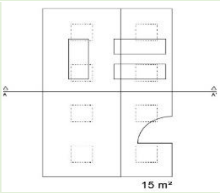
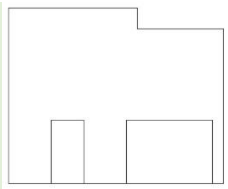
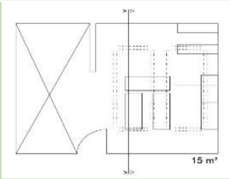
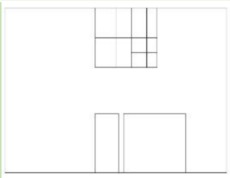
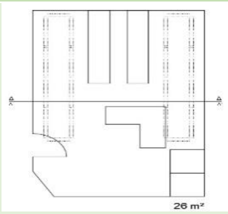
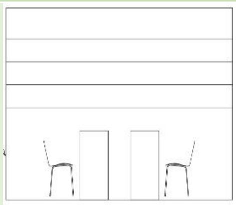
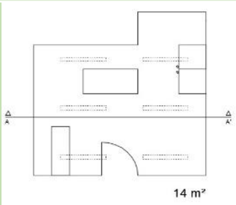
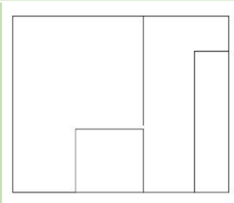
SPACE	PLAN	SECTION	PHOTOS
SR 1			
SR 2			
SR 3			

Table 5. Cont.

SPACE	PLAN	SECTION	PHOTOS
SR 4			
SR 5			
T 1			
T 2			
T 3			
T 4			
T 5			

3.4. Participants

In this survey, according to the results of the questionnaire, the answers of the employees do not vary much. It is believed that, the reason is people respond with the instinct to protect the work they do. Respondents by gender can be seen with improper distribution in Figure 3.7. According to the survey conducted on 10 different places, all of the employees are composed of males. Usually, tailors and shoe repairers are males in Turkey.

As it is can be seen from Figure 3.7., the age range of 30-39 years is %40, the 40-49 age range is %30, and the 50-59 age range is %20, in the distribution order. Lastly age range is 18-29. However, there are no participants at the range of 60+.

As seen from Figure 3.7., workers are mostly composed of young employees. It means that they are in most effective period in terms of physical health. Because as people become older, their visual performance diminishes, like their physical performance. Especially as it can be seen in Table 6., problems of not being able to see close areas occur often with aging.

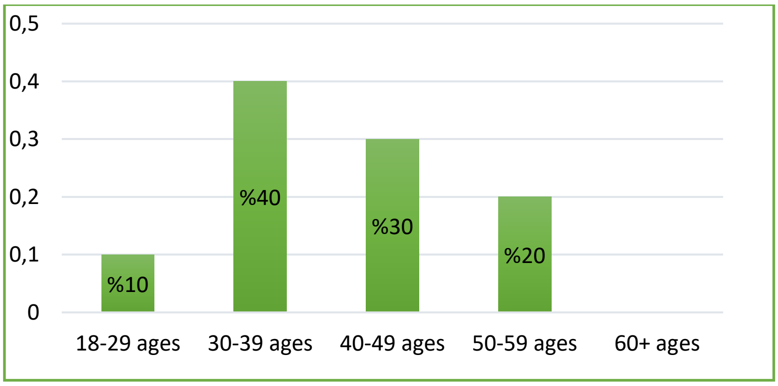


Figure 3.1: Age Range of Participants

60% of the people participating in the research served in the business for 16 years or longer. The rate of participants who served between 7 and 10 years was

30%. The rate of those who have worked for 11 to 15 years is 10%. There are no participants who have worked under 7 years of professional experience. It means that employees are very experienced in their work and know their needs well. They know what they need to be able to get the best results from the ergonomics in the space.

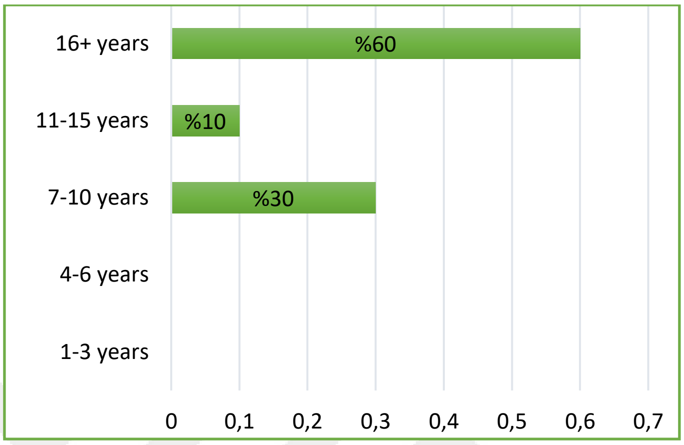


Figure 3.2: Distributions of Participants According to the Years they Served

Considering Turkey's labor laws, the rate of participants who work for 8-10 hours was found as 80%. Apart from this, only 20% of the participants serve more than 10 hours. The economic system and the production relations that are exposed to the hours of working conditions are not only harmful to the employees but also do not benefit the workplaces at the same time. The rate in the figure 3.9. shows that employees are working long hours in the same work. Workers have worked more than 10 hours, but they always gave the same answer because they were legally prohibited to work more than 10 hours. In this situation, lighting design is gaining importance. In an inadequate and improper lighting design, doing task work can lead to eye problem and headaches in workers in time.

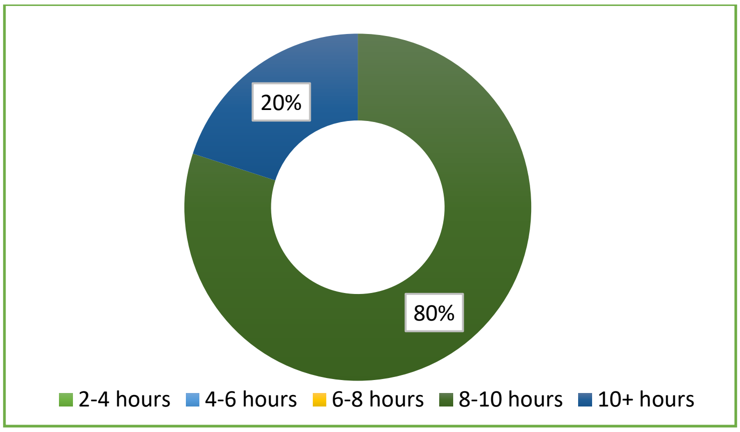


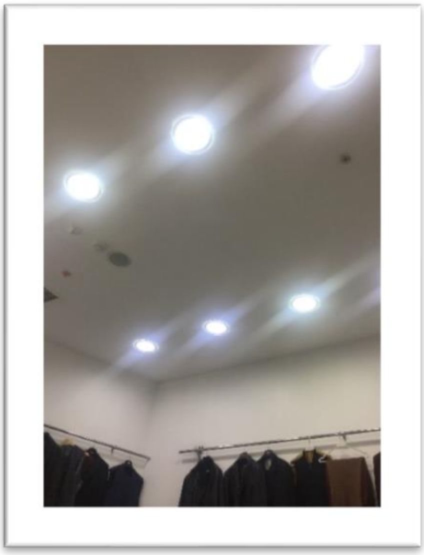
Figure 3.3: Distribution of Participants According to Their Daily Working Time

3.5. Results and Discussion

3.5.1. Observation and Measurement

Many factors such as the amount of light, color of lighting, or color of surfaces should be considered for successful lighting in interior spaces. A light-colored polished surface can reflect almost entirely, while dark matte colors reflect only a fraction of the light falling on a task surface. The lighting should be bright enough to provide easy visibility but at the same time not have a high brightness contrast to create glare and discomfort for the user. Glare would not only make it harder for the user to see and reduce the work efficiency, but also cause the number of accidents or incorrect applications to increase. For example, if the lighting fixtures is in the task surface , a tailor may not be able to choose the right thread colors- or he may have frequent headaches. In other words, lighting and interior design have a very important role, for fine visual tasks. In this context, the incorrect applications and their consequences regarding this issue can be found out, if these case spaces are examined thoroughly.

In case T 1 as well, General-Direct Lighting was used, which has low energy consumption and higher energy efficiency. The lighting fixtures were applied as recessive fixtures within suspended ceiling, however, this application technique still provides the ease of maintenance.



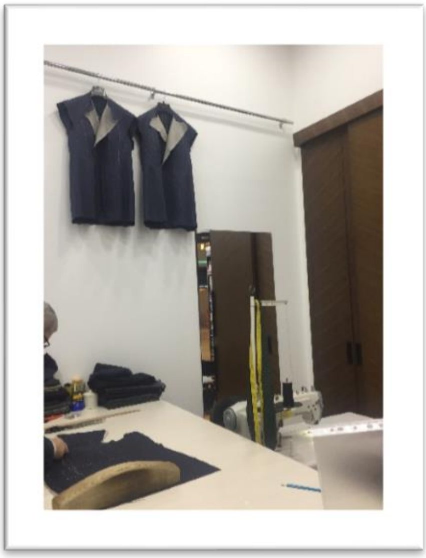


Figure 3.4: The Lighting Design of T1 (Photograph taken by the author)

As seen in the Figure 3.2., the walls in the space are placed at an angle. Walls and ceiling are all painted in white color. Therefore, the light is highly reflected in the space. This case has the best working conditions among the case tailor shops.

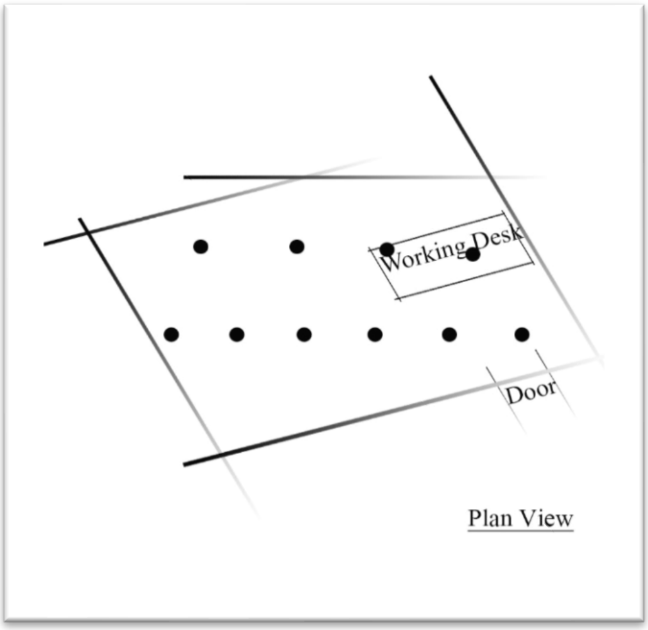


Figure 3.5: The Plan View of Lighting Design of T1 (Plan drawing by author)

In Figure 3.3. and 3.4., it is seen that as to the types of light sources, compact fluorescent lamp is preferred in both shoe repairer shops, SR 2 and SR4. However, there are also serious disadvantages of fluorescent lighting for the space users. Fluorescent and compact fluorescent lamps which have become increasingly popular in recent years due to their particularly efficient electricity saving have serious hazards to human health. The main source of this danger is the mercury vapor present in this type of lighting and the electromagnetic radiation they emit. Eye disturbances, headaches and lack of concentration caused by light vibrations that are not visible to the human eye and repeated 100 times in a second are the most important problem on the human being of fluorescent and compact fluorescent lighting. Prolonged exposure to low levels of mercury may indicate different symptoms to the workers such as fatigue, insomnia, increased nervousness, memory weakness can be specified ("Fluorescent Lighting", 2016). Since these case spaces also prefer these types of light sources the workers are under the risks of such health hazards. Therefore, LED lighting which is the most energy efficient and long-lasting type should be used.

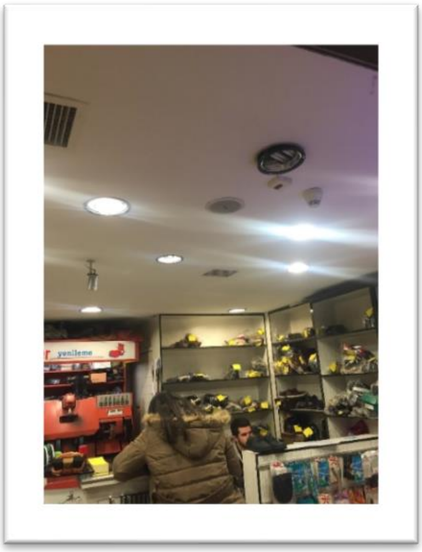


Figure 3.6: The General Lighting of SR 2 (Photograph taken by the author)

Figure 3.7: The General Lighting of SR 4 (Photograph taken by the author)

Technical data of surveyed places are shown in Table 6. There are 10 different general lighting value, 10 different task lighting value in terms of illumination level, color temperature and color rendering index, and 10 different SPD graphics in the survey.

Table 6. Technical Data of Case Spaces

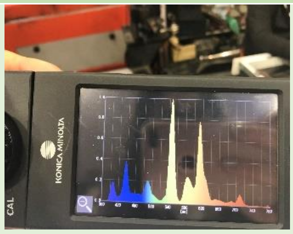
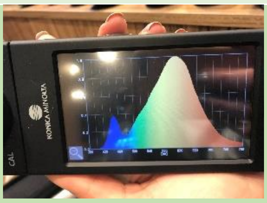
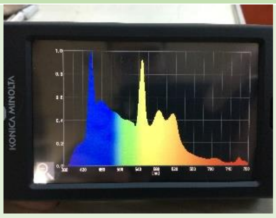
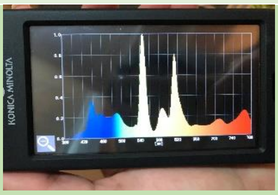
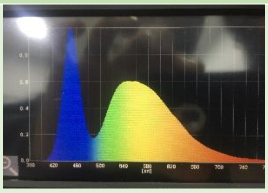
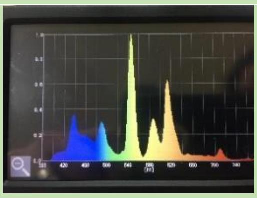
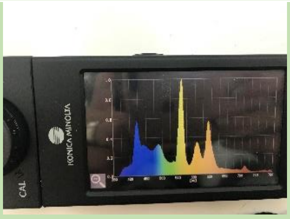
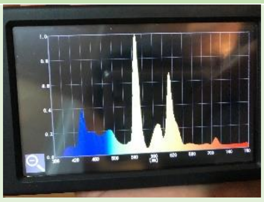
Case	Illumination level		CT/CCT		CRI		SPD Graphic
	General	Task	General	Task	General	Task	
SR 1	**546 lux**	**1020 lux**	**6705 K**	**4401 K**	**80.9**	**81.4**	
SR 2	**695 lux**	**239 lux**	**3914 K**	**3740 K**	**77.4**	**78.8**	
SR 3	**919 lux**	**599 lux**	**2842 K**	**3961 K**	**82.6**	**86.9**	
SR 4	**276 lux**	**232 lux**	**7728 K**	**7244 K**	**83.5**	**84.6**	
SR 5	**714 lux**	**859 lux**	**3008 K**	**3133 K**	**82.9**	**76.7**	
T 1	**502 lux**	**334 lux**	**6575 K**	**6089 K**	**75.6**	**76.6**	

Table 6. Cont.

Case	Illumination Level		CT/CCT		CRI		SPD Graphic
	General	Task	General	Task	General	Task	
T 2	272 lux	284 lux	4927 K	4626 K	80.8	79.3	
T 3	763 lux	760 lux	9458 K	9177 K	80.1	79.6	
T 4	864 lux	1050 lux	6424 K	6120 K	82.1	81.4	
T 5	937 lux	734 lux	4963 K	4485 K	81.4	88	
Average	648.8	611.1	5650	5297	80.7	81.3	

As can be seen in Table 6, lux color temperature, and color rendering index values are quite different. However, almost all participants gave similar answers. SR 1 and SR 4 as shoe repairer, have quite different lux, CT/CCT, and CRI values. While SR 1 has 1020 lux, 4401 K, and 81.4 CRI value in task lighting, SR 4 has 232 lux, 7244 K, and 84.6 CRI value in task lighting. Nevertheless, both of them are satisfied with the color of light, the power of light, in short, the lighting conditions.

Task illumination level should have 3 times higher value than general illumination level. When looking at average values, it seems clearly that task illumination level has lower value. This situation creates problems in job such as wrong application, fatigue in time or even job accidents. Also, in average, both in general lighting and task lighting, there is a good value in terms of color temperature as seen in SPD graphic because color temperature should be over 4500 K in order to gather attention. In terms of color rendering index, there is approximately 81. This value is not good because 90 points and above is good. This situation causes wrong application such as wrong paint selection, wrong shoelaces selection because if color rendering index value is low, the color will be misunderstood.

3.5.2. Questionnaire Survey

When the workers were asked about the general lighting level of the work space, 50% of them gave the answer that they have found it adequate. 30% of participants said that they found the lighting level of the working environment slightly inadequate. Finally, 20% of the participants consider the level of illumination of the working environment to be barely adequate.

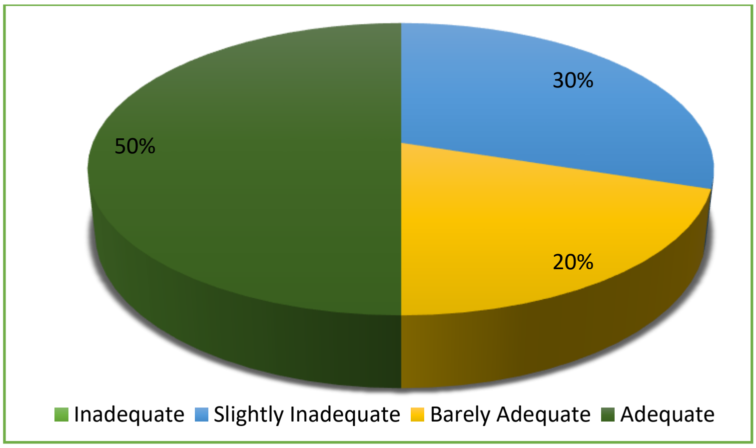


Figure 3.8: Evaluation of General Illumination Level of The Work Space

General lighting in the spaces are used to create a general level of the perception of the space. It is the lighting that makes us feel comfortable and able to conduct certain easier tasks in the space. It is necessary to choose what type of lighting will lighted and which type of lighting element will be used according to the amount of light needed in the space while forming the lighting plan in architectural layout. Especially in areas without daylight, the lighting option and the amount of light need to be adjusted well. According to the Table. 4, general illumination level should be between 50-750 illuminance level at least in terms of general lighting. When the Table. 7 is viewed, SR 4 and T 2 have lower value from 500 illumination level. Actually, they have quite low values. It is almost a too low value to make it difficult to perceive the space. According to the acquired lighting, it is necessary to make improvements in the lighting in these spaces. In addition to these, despite the types of illumination are similar to each other, the measured values by the Konica Minolta CRI Illuminance Meter 70 F are different. The obvious reason has been observed that the intensity of illumination used is very different from each other. In fact, it shows that people do not design their working environment according to a certain standard. As a result, as the professional support is not received, the measured technical data is quite extensive.

For both selected occupations task illumination is very important for doing fine work in the space. Looking at the Figure 3.11, it is seen that 50% of the workers found it to be adequate. 10% of them said that they found it the barely adequate for a task lighting level and 20% found it slightly adequate.

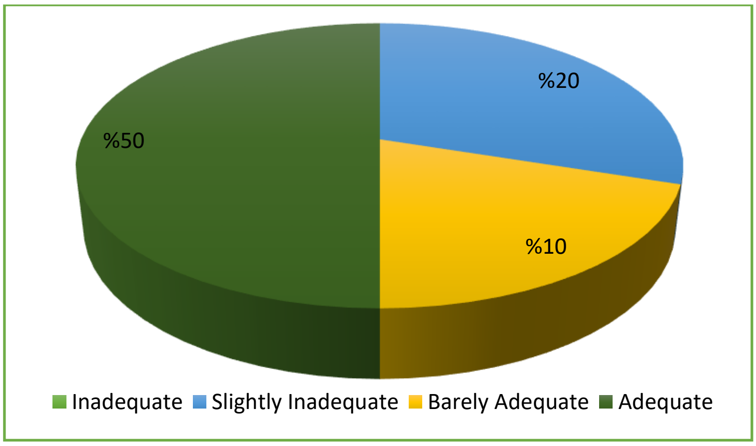


Figure 3.9: Evaluation of Illumination Level of Working Surface

Task lighting is as important as general lighting. These are types of lighting that serve a certain purpose in the space. “Task lighting is important because it is neither efficient, effective nor visually aesthetic to use the same amount of light across a whole room or working environment, therefore we need task lighting and specific task lights to deliver it” (Davis, 2017, n.p.). Task lighting should be three times higher than general lighting level. According to Table 4, as sensitivity of work increases, the level of illumination level increases. In the works as tailors and shoe repairers, jobs that require attention. Therefore, workers need more illuminated task areas. As seen on the Table 4, the space should be higher than 750 illumination level in these types of working. However, there are 5 surveyed places that do not provide this level. A large majority of employees said that they did not have any problems but half has a low task illumination level.

When the survey results presented in Table 5. are examined, general lighting is used throughout the working environment. Not using task lighting could create some problems on task working, however, according to the responses from the participants, it is understood that the current lighting used in the space is sufficient. During the observation part of the study, some task surfaces were detected to have shadows of the workers. It will be more accurate to use task lighting to eliminate the shadows falling on the task surfaces.

Each case space needed task lighting. However, there were no such demands by the users. As seen in Figure 3.10., despite the use of general lighting only, 60% of the workers said that there was no shadow falling on the task surfaces. 20% of workers were uncomfortable from their own shadows rarely, and 20% said that they were uncomfortable from their own shadows only sometimes.

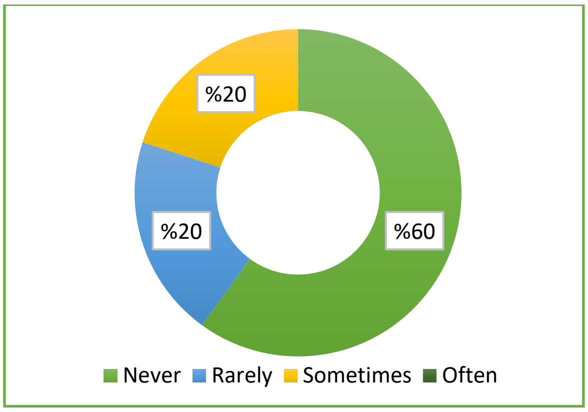


Figure 3.10: The Rate of Shadow Falling on The Work Surface During Operation

Shadows on the work surface indicate that the utility does not use task lighting, also this situation reduces work performance. In the work of Demirci and Armağan, as a result of researches and experiments carried out, it is more appropriate for the worker to come from behind the left side in artificial illumination. So, that the shadow of the head and hand fall to the right of the working surface. Thus, the working surface is not obstructed.

There are a number of lighting-related factors that may cause visual discomfort and there is no straight-forward path to follow in creating visually comfortable luminous environments (Boyce 2003, Veitch 1998). Daylight is not taken or in areas with less daylight, lighting is done through lighting systems. In interior lighting should be used devices that will complement architectural design integrity and aesthetics and not create light reflections that will not disturb the eye (Ünansal, 1990). Reflection is one of the most important factors about task handling because reflection may cause workers to have poor working performances and work accidents. 70% of the responses received regarding this question in the survey have been positive. 20% of the respondents said that they had problems sometimes with reflection, and only 10% answered as sometimes in Figure 3.11. Also, white color is generally preferred in working environments such as walls, ceilings, or floors and work table. White task surfaces are used as they are reflective and bright. Especially in tailors, work surfaces are chosen as white painted wood.

Workers spend majority of their time in their working environments.

Therefore, it is necessary to design ergonomically the interior architectural tools used in terms of the psychological and physiological comfort of the employee. Especially, for the proper lighting design according to work type, there are lots of information accepted in the literature. Although the answers given in the previous questions are highly positive, 20% of the participants said that they had some problems due to inappropriate lighting design like headaches or inability to focus. Half of the participants as 50%, said sometimes had problems. 10% of participants rarely have problems, only 20% have never had any health problems.

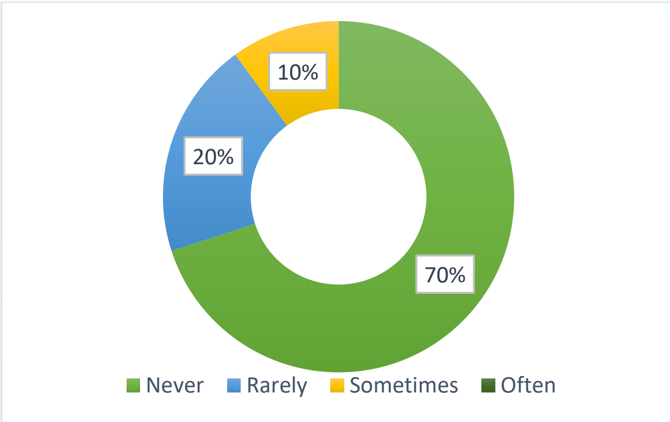


Figure 3.11: Light Reflection Rate on The Working Surface

There is a very close relationship between lighting and work efficiency. While appropriate lighting increases work efficiency, improper lighting causes physical discomforts such as eye strain and reduces work efficiency. Especially at workplaces where fine work is important for a long time, it is useful to give prominence to visual comfort and realize all the lighting principles that will provide this comfort. According to Figure 3.12., only %50 of workers' answers did not have any physical problem. Others have some problems because of incorrect lighting design. Workers have been more honest in asking about themselves, while they generally prefer to give positive answers to the work they do.

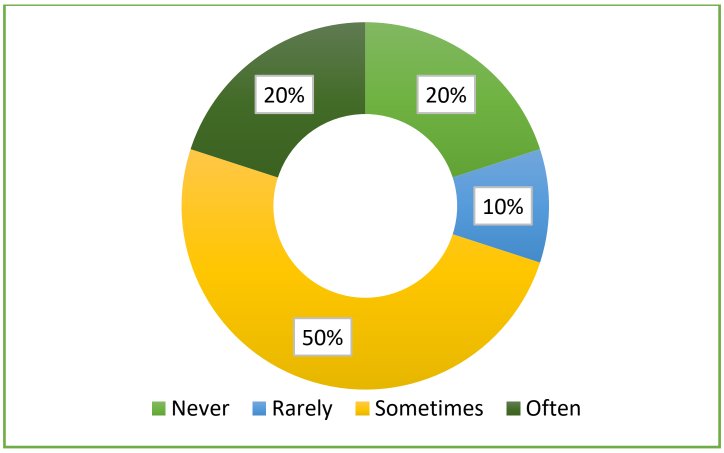


Figure 3.12: Physical Problems Caused by Incorrect Lighting (like headaches, inability to focus)

When color, textures or materials are used in contrast, it can compartmentalize in the interior space. Thus, there are lots of part of space, which have different atmosphere and mood of space. These alterations focus on the areas over psychological, functional, and aesthetical meanings (Mehyar, 2008). It plays an essential role in the type of lighting and color perception in the room. As a result of the survey, all of the business owners have opted for the white light-emitting fluorescent lamps. One of the main reasons for this that they think they see the product colors better under white light. One of the other most important reasons is that the fluorescent lamp is the second most energy-saving and long-lasting alternative as we have seen in previous chapters. According to these results, 70% of the participants stated that they never had any problems about color separation. 20%of participants said that they rarely had problems and 10% answered sometimes.

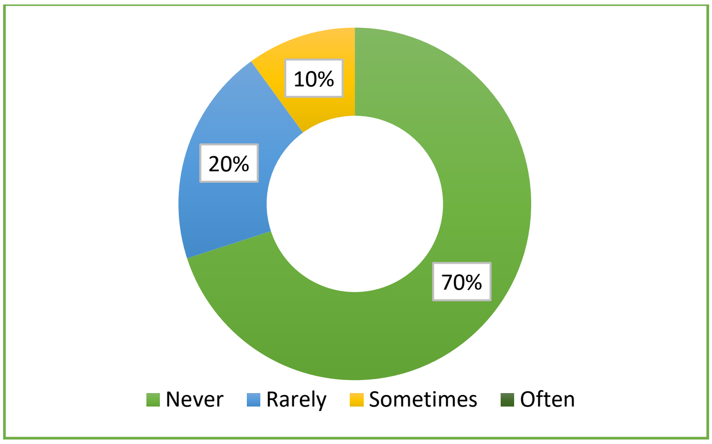


Figure 3.13: Difficulty in Color Separation (Difficulty in suitable Fabric and Shoe Paint Color Selection, etc...)

In terms of color perception, there are %70 positive results and %30 rarely. The big reason of it is that workers do not want to say truth because it affects their own work performance. Especially, when looking at SR 1, it seems clearly that this space has lower CRI value compared with other nine spaces. Most probably, people working in there have problem their works' result like choosing a different tone of shoe paint or shoe lace.

70% of the participants declared that they did not have any problems in terms of color perception when asked if they were experiencing problems with color perception in the participant space and that they have not received any negative feedback from related customers on this subject. Only 30% of the participants said that they rarely had problems and that they received negative feedback from customers in yarn color selection or shoe paint color selection.

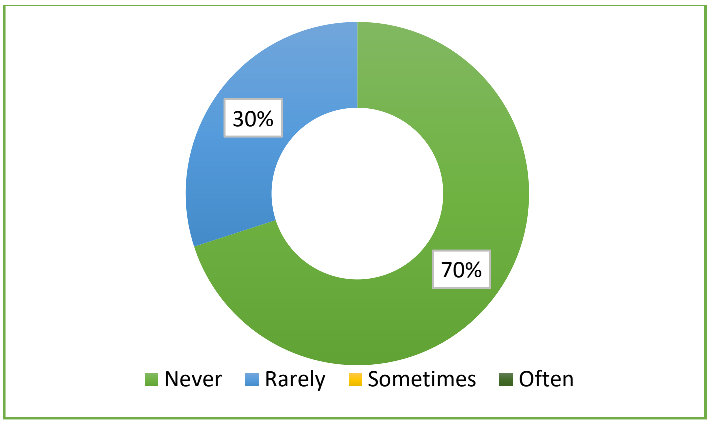


Figure 3.14: The Rate of Color Perception Problems Due to Improper Lighting

In addition to these, generally, most of workers said that they would like to work in the place where daylight is available. Participants who stated that the lighting levels in the working environment were sufficient during the survey, at the end mentioned that they would prefer daylight in the working environment. Also, 50% of the participants wanted the effect of lighting in the working environment to be relaxing/calming and %40 of the participants wanted the effect of lighting in the working environment to be attention gathering/focusing. Also, only 10% participants wanted working environment to be neutral/balanced.

Feedback from customers is an important part of this survey because they need to receive negative feedback from customers in order to be aware that employees are doing wrong. In this context, in the survey, 70% of respondents said they never received negative feedback from customers. Only 30% of the participants have rarely received negative feedback, as seen in Figure 3.15.

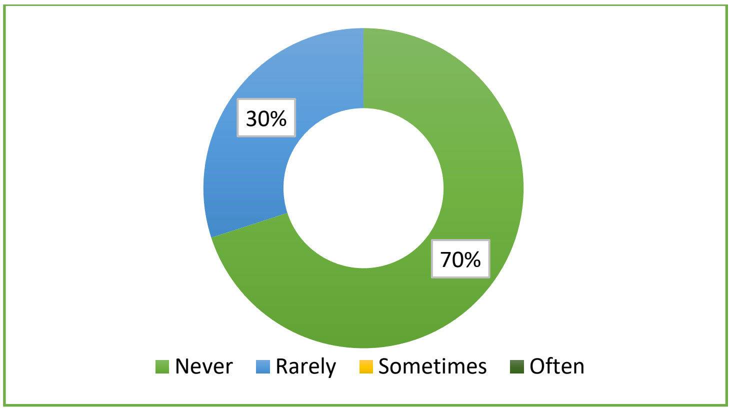


Figure 3.15: Negative Feedback from Customers on Color Separation

It is necessary to control all environmental conditions that affect the performance and productivity of the people to ensure a suitable working environment. Among these conditions, light and illumination are important for the employees to see quickly, correctly, comfortably, and safely. Many factors such as color, direction, dispersion, and quantity of light should be considered for good and proper lighting.

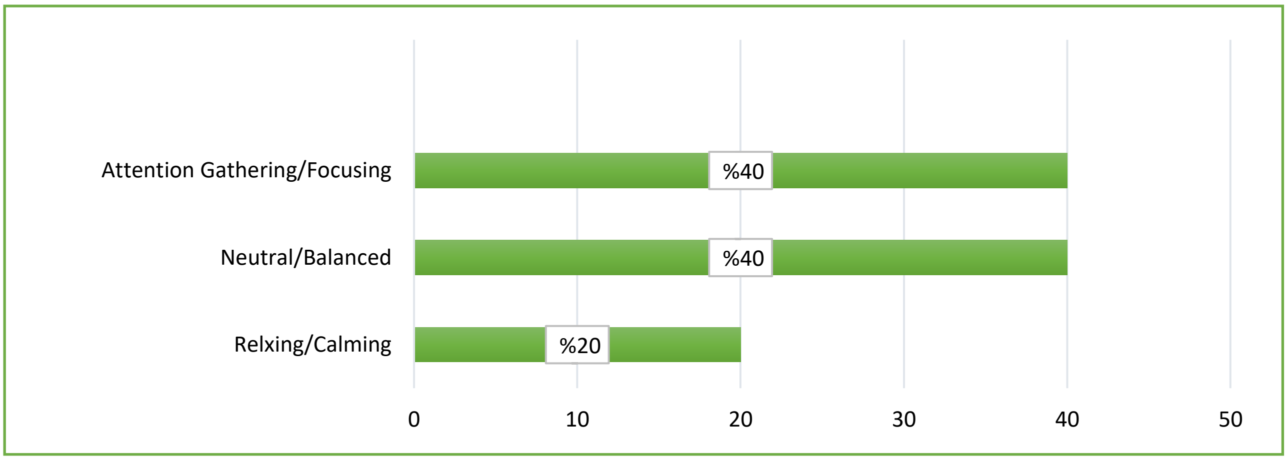


Figure 3.16: Effects of Working Environment Lighting on Workers

It can be seen that generally, lighting types according to the Kelvin values were chosen to aid attention. However, according to the survey results, 20% of the participants said that the working environment is relaxing and calming. For example, tailor working on T2 said that the working environment was relaxing/calming. However, as shown in figure 3.19., only white colored fluorescent lamps were used in the environment and brightness level is quite high. However, the participant thinks he works in a relaxing environment.

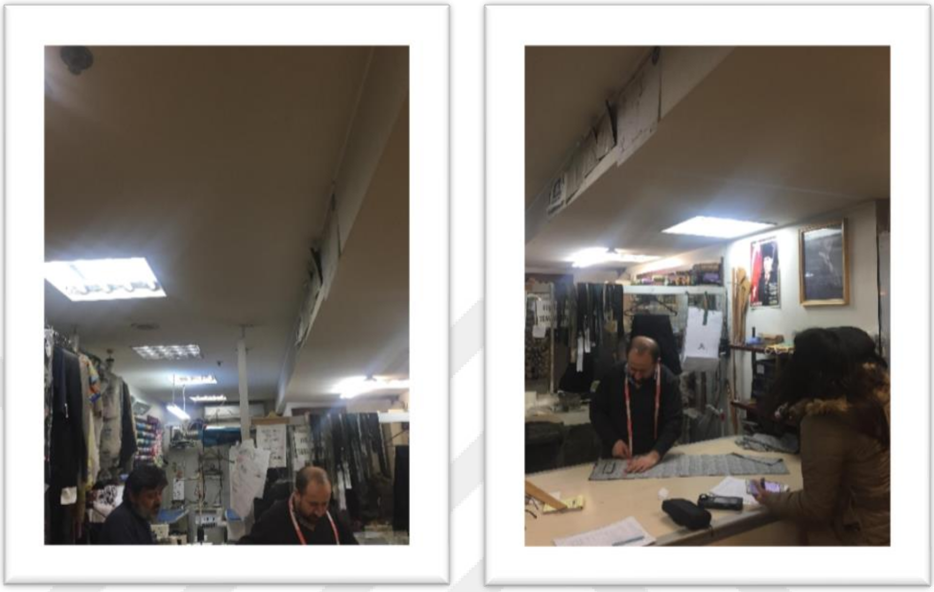


Figure 3.17: General View of T2 (Photograph taken by the author)

40% of participants said that their working environments are neutral and balanced. The other 40% think that their working environments are good for attention gathering focusing. Although the type of lighting and the technical data taken are very different, the feelings of the working environment for the employees are very different.

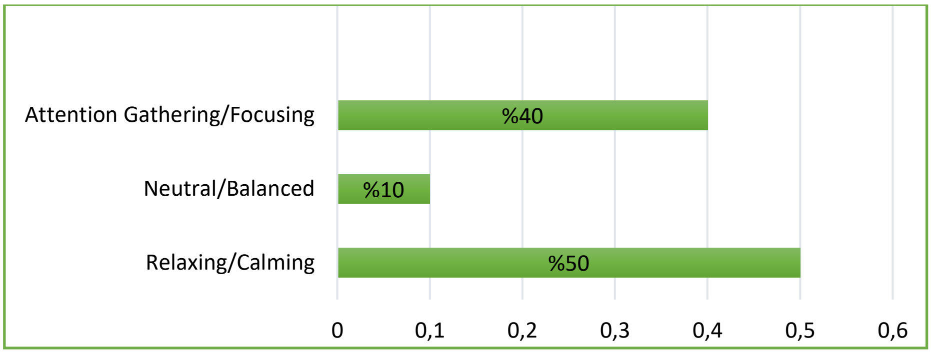


Figure 3.18: Expected Lighting Effect by Participants in The Working Environment

The intensity, color and positioning of light plays a major role in shaping the ambience desired to be created. Lighting enables the mental structure of the space users to be drawn to the desired spot. The intensity of light required in homes, offices and meeting rooms is different. In working environments, luminaires which provide homogenous lighting especially, in places where daylight cannot be used are preferred. Also, it is necessary to use additional task lighting for general lighting in work done on the work surface.

According to the survey results, all participants said that the white light makes it easy to see especially in task illumination. The second most important reason is the energy efficient and long-lasting illumination. As a result of using fluorescent or compact fluorescent lamp, the Kelvin value in the work space or task space was generally above 3.000 Kelvin. Only, in SR3, the general lighting value was 2842 Kelvin. Except that, all cases have CT values above 3500 Kelvins.

Figure 3.19: General View of SR3 (Photograph taken by the author)

Also, in that space, lux value is 919 for general lighting, and 599 for task lighting. This is because that task lighting is used only in one of the work desks as can be seen in the figure 3.2.2. except this, there was no task illumination at any other workplace. In addition to these, most of participants said that they wanted to work under natural lighting because not seeing daylight causes some psychological problems as much as physical ones. It seen that the lighting level is one of the most important parameters affecting visual comfort conditions (Manav, 2006).

Also, adequate illumination is very prominent in terms of visual acuity, maximum visual acuity, eye fatigue and eye strain. With the help of better lighting, more efficient operation and protection from accidents will also be provided. As a result of inadequate lighting, symptoms such as tiredness, redness dryness in the eyes and headache may occur (Güler, 2004).

CHAPTER 4

CONCLUSION

The development of technology has proved that lighting is an issue in itself, not only as a side information, with the work done in all areas related to human beings. The fact that people can live their life in space begins with the entrance of human and physiological and psychological needs into the space. The place gains meaning through interaction with people. One of these means of interaction is lighting. The light is one of the strongest elements that reveal the design, emphasize, and when necessary, constrain the desired features. The issue that have been ignored in researches in the field of lighting technology in the past are now confronted as health problems. Such as efficiency, performance, and space sensibility, have become indispensable due to the increase in problems caused by physical environment conditions, especially of indoor spaces. At this point, it is necessary to redefine the needs to think about and enlighten the human health framework in terms of producing, developing, implementing, and designing the light to ensure good vision conditions.

The design in the space come through the light and gain an identity according to the quality and quantity characteristics of the light. Lighting sources are an energy source that affects the biological system, balances the biological clock, acts on the hormone system and the psychological environment of the people, as well as being a physical component needed to perform visual activity. In an unappropriated lighting environment, eye vision is reduced, eye disorders occur, work accidents increase, and production slows down. Especially, inadequate lighting in spaces where sensitive work is done reduces the efficiency of the worker and causes the workers to be exposed to the stress.

This study was conducted with the aim of determining the effects of artificial lighting on people working in areas without daylight, in terms of work efficiency and provide solutions and guidelines for the mentioned issue. To sum up, it can be stated that, the lighting fixtures to be installed in spaces must be designed together with the space, especially when the visual performance level is desired to be high. It is necessary to know how to design with artificial light from its physiological, and psychological aspects for people who spend most of the time in indoor space such as tailors and shoe repairers. A place to be enhanced and the atmosphere to be created can be accentuated by light in the best way. It has been understood through research that providing better visibility conditions does not mean raising the brightness level in the environment and many applications that we have accepted as correct nowadays remain uncertain.

To sum up, the following guidelines are developed regarding improving the lighting conditions of working environments with fine visual tasks that do not get any daylight:

- As to light distribution strategies, General-Direct lighting supported by Task lighting should be used
- Task lighting should be three times higher than General-Direct lighting
- A space of fine visual work must have an illumination level of a minimum of 750 lux for task lighting
- Color temperature of light sources should be 4000 Kelvin and above for gathering attention
- Color rendering index (CRI) of light sources should be a minimum of 90. Higher the CRI value, higher the accurate color perception
- The lighting fixtures must be correctly positioned, i.e. -out of the offending zone to prevent glare
- Preferring light colors on walls and task surfaces may increase reflections and thus lighting efficiency
- The use of matte surface in working places minimizes glare
- The use of LED is important as to energy efficiency and long lamp life

When the above-mentioned guidelines are applied, and an appropriate lighting environment is ensured in working environments, benefits such as, increasing work efficiency and productivity, and reducing work accidents and sick leaves will be provided.

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Appendix A

Questionnaire on the Analysis of Artificial Lighting Applications as to Task Efficiency for People Working in Enclosed Spaces

This questionnaire invited people working in determined places in a research study conducted by a graduate student at the faculty of architecture at Çankaya University in Turkey, to obtain a master's degree in Interior Architecture.

Definition:

Nowadays, working hours are increasing day by day in closed areas. People are exposed to artificial lighting all day long. In this situation, lighting design has an important place in terms of work efficiency.

This study aims to obtain to the views of experienced professionals in the fields of tailors and shoe repairers.

This questionnaire should take about 10 minutes. All the information provided by the participants will be kept confidential and will be used only for academic purposes.

The agreement of participation:

I understand the above descriptive content and I agree on participating in this research study:

- Yes, I agree
- No, I don't agree

SECTION A

QUESTIONNAIRE ON THE ANALYSIS OF ARTIFICIAL LIGHTING APPLICATIONS AS TO TASK EFFICIENCY FOR PEOPLE WORKING IN ENCLOSED SPACES

Date: ___/___/_____

Case Study Details

- Case Study Number: ____
- Name of Shop: ____
- Address: ____
- Occupation: Tailor [ ] Shoe Repairer [ ]
- Type of Work Done: Stitching [ ] Shoe Repair [ ]

Other:
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1. **Lighting Applications**

- Light Distribution Strategies Used:

General Direct Lighting[ ] Task Lighting [ ]

General Localized Lighting [ ] Accent Lighting [ ]

Indirect Ambient Lighting [ ]

- Illuminance Level for General Lighting: ________________________________Lux
- Illuminance Level for Task Lighting: ___________________________________Lux
- Type of Light Source Used for General Lighting;

Incandescent [ ] Tungsten-Halogen [ ]

Fluorescent	[ ]	LED	[ ]
HID	[ ]		

- Type of Light Source Used for Task Lighting;

Incandescent	[ ]	HID	[ ]
Tungsten-Halogen	[ ]	LED	[ ]
Fluorescent	[ ]		

- Light Sources in Offending Zone: Yes [ ] No [ ]

If yes, Number of Location:

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SKETCH OF PLAN VIEW SKETCH OF SECTION

VIEW

- Color of Walls: ____
- Material of Walls: ____

- Color of Task Surface: ____
- Material of Task Surface: ____

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2. Color Perception

- Color Temperature/Correlated Color Temperature of General Lighting:

  Kelvin
- Color Temperature/Correlated Color Temperature of Task Lighting:

  Kelvin
- Color Rendering Index Value of General Lighting: __________________________
- Color Rendering Index Value of Task Lighting: ____________________________

SECTION B

QUESTIONNAIRE ON THE ANALYSIS OF ARTIFICIAL LIGHTING APPLICATIONS AS TO TASK EFFICIENCY FOR PEOPLE WORKING IN ENCLOSED SPACES

Date: ___/___/___

Case Study Details

- Case Study

  Number: ____
- Name of Shop: ____
- Address: ____
- Occupation: Tailor [ ] Shoe Repairer [ ]
- Type of Work Done: Stitching [ ] Shoe Repair [ ] Other:_____

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1. Personal Information

- Age:

  18-29 [ ] 30-39 [ ] 40-49 [ ] 50-59 [ ]

  60+ [ ]
- Gender:

  Male [ ] Female [ ]
- Years of Experience in Occupation:

  1-3 [ ] 4-6 [ ] 7-10 [ ] 11-15 [ ] 16+ [ ]

- Duration of Daily Work:

  2-4 [ ] 4-6 [ ] 6-8 [ ] 8-10 [ ] 10+ [ ]

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2. Lighting Applications

- How would you evaluate the level of lighting for your task surface?

  Inadequate [ ] Slightly Inadequate [ ] Barely Adequate [ ] Adequate [ ]

- How would you evaluate the level of lighting for the space in general?

  Inadequate [ ] Slightly Inadequate [ ] Barely Adequate [ ] Adequate [ ]

- Does your shadow fall onto the task surface while working?

  Never [ ] Rarely [ ] Sometimes [ ] Often [ ]

- Do you have difficulty in perceiving your task due to reflections of light on your task surface?

  Never [ ] Rarely [ ] Sometimes [ ] Often [ ]

- Do you experience any problems regarding bright light sources in your visual field?

  Never [ ] Rarely [ ] Sometimes [ ] Often [ ]

- Do you feel tired, have pain in the eyes/headaches or unable to focus while working?

  Never [ ] Rarely [ ] Sometimes [ ] Often [ ]

3. Color Perception

- Do you have difficulty in the discrimination of colors (i.e. for suitable fabric/thread selections, or for suitable shoe dye/leather selections)

Never [ ] Rarely [ ] Sometimes [ ] Often [ ]

- Have you experienced any problems regarding the discrimination of colors that affected your quality of work?

  Never [ ] Rarely [ ] Sometimes [ ] Often [ ]

- Have you received negative feedback from your customers considering this issue?

  Never [ ] Rarely [ ] Sometimes [ ] Often [ ]

  If yes, please explain:

  ____

- How would you evaluate the effect of lighting of your working environment on you?

  Relaxing/Calming [ ] Neutral/Balanced [ ] Attention Gathering/Focusing [ ]

- How would you prefer the effect of lighting of your working environment to be?

  Relaxing/Calming [ ] Neutral/Balanced [ ] Attention [ ] Gathering/Focusing [ ]

- What are your complaints/suggestions regarding the lighting of your working environment?

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CURRICULUM VITAE

PERSONAL INFORMATION

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EDUCATION

Degree	Institution	Year of Graduation
Bachelor	İhsan Doğramacı Bilkent Univ. Interior Architecture & Environmental Design	2014
High School	Selma Yiğitalp High School, İzmir	2006

WORK EXPERIENCE

Year	Place	Enrolment
2016- Present	Modalife Mobilya	Interior Architect
2015-2016	Lamphouse Aydınlatma	Interior Architect

FOREIGN LANGUAGES

Advanced English