A COMPARATIVE STUDY ON SPATIAL PERCEPTION IN REAL AND VIRTUAL OFFICE ENVIRONMENTS UNDER DIFFERENT LIGHTING CONDITIONS

A Master's Thesis

by

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Ankara

January, 2019

To my parents…

A COMPARATIVE STUDY ON SPATIAL PERCEPTION IN REAL AND VIRTUAL OFFICE ENVIRONMENTS UNDER DIFFERENT LIGHTING CONDITIONS

The Graduate School of Economics and Social Sciences
of
İhsan Doğramacı Bilkent University

by

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ANKARA

January 20

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts in Interior Architecture and Environmental Design.

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Supervisor

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ABSTRACT

A COMPARATIVE STUDY ON SPATIAL PERCEPTION IN
REAL AND VIRTUAL OFFICE ENVIRONMENTS UNDER DIFFERENT
LIGHTING CONDITIONS

Kuş, Büşra

MFA, Department of Interior Architecture and Environmental Design

Supervisor: Assist. Prof. Dr. Semiha Yılmazer

January, 2019

The aim of study iş to conduct a comparison between real and virtual environments from the spatial point of view under different lighting conditions. In this study, visually same office environments were created in real environment (RE) as well as in virtual environments (VE) in order to be able to observe only the perception between the two environments. The experiment was conducted in full-scale office environment and virtual environment by using Unity 3D program with participating of sixty people. These environments were appraised under 4000K (cool white light) and 6500K (daylight) lighting color temperatures. An office room in Bilkent University and Environmental Design building was used to carry out the

experiments. The participants were asked to experience the environments firstly, later on they were as requested to answer the previously prepared questionnaire with semantic differential scale. As a result of this study one can say that the perceptions of both environments RE and VE were similar to some extend in more than half of the 12 adjective pairs under both color temperature. Adjectives such as usual-unusual, dynamic-static, spacious-confined and harmonious-discord demonstrated significant differences for both environments. Moreover, participants perceived real environment more spacious, usual, harmonious and less dynamic than virtual environment under both lighting conditions. Only the functional-nonfunctional and formal-informal adjective pairs behaved significantly different under 4000K and 6500K respectively. There were no significant effects of color temperatures in real and virtual environments.

Keywords: Color Temperature, Office Environment, Real Environment, Spatial Perception, Virtual Environment,

ÖZET

FARKLI AYDINLATMA KOŞULLARINDA GERÇEK VE SANAL OFIS ORTAMININ MEKAN ALGISI ÜZERİNE KARŞILAŞTIRMALI BİR ÇALIŞMA

Kuş, Büşra

İç Mimarlık ve Çevre Tasarımı Yüksek Lisans Programı

Tez Danışmanı: Dr. Öğr.Üyesi Semiha Yılmazer

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Bu çalışmanın amacı, gerçek ve sanal ofis ortamının insanlar üzerinde yarattığı algıyı farklı renk sıcaklıkları altında karşılaştırmalı olarak incelemektir. Bu araştırmada görsel olarak aynı gerçek ve sanal ortam, bireysel ofis ortamı üzerinden değerlendirilmiştir. Altmış katılımcıyla yapılan deney, tam ölçekli ofis düzeneği ile gerçek ortamda ve görsel olarak aynı düzeneğin Unity 3D programı kullanılarak üçüncü boyuta çıkarılmış haliyle sanal ortamda gerçekleştirilmiştir. Bu iki ortam, 4000K (soğuk beyaz ışık) ve 6500K (günışığı) renk sıcaklıkları altında değerlendirilmiştir. Bilkent Üniversitesi İç Mimarlık ve Çevre Tasarımı Bölümü' ndeki ofis odası, deney koşullarına uygun hale getirilerek kullanılmıştır. Gerçek ve sanal ofis ortamlarını tecrübe eden katılımcılara, mekan algısını değerlendirmek için anket çalışması yapılmıştır. Ankette, zıt kutuplu on iki sıfat çifti anlamsal farklandırma methodu ile katılımcılara sorulmuştur. Bu çalışmanın sonuçlarına göre; her iki renk sıcaklığı altında da

gerçek ve sanal ortamdaki algı, 12 sıfat çiftinin yarısından fazlası için benzerlik göstermiştir. Her iki renk sıcaklığında da anlamlı farklılık gösteren sıfat çiftleri şunlardır; alışılmış-alışılmışın dışında, dinamik-statik, ferah-sıkışık ve uyumlu-uyumsuz. Ayrıca katılımcılar iki renk sıcaklığı içinde, gerçek ortamı daha ferah, uyumlu ve alışılmış, sanal ortamı ise daha dinamik olarak algılamışlardır. İki sıfat çiftine –fonksiyonel-fonksiyonel olmayan (4000K) ve resmi-resmi olmayan (6500K)- farklı renk sıcaklıklarının altında farklı reaksiyon göstermişlerdir. Katılımcıların cevapları doğrultusunda, 4000K (soğuk beyaz ışık) ve 6500K (günışığı) mekan algısı üzerindeki etkisi bir değişken olarak kaydedilmemiştir.

Anahtar Sözcükler: Gerçek Ortam, Mekan Algısı, Ofis Ortamı, Renk Sıcaklığı, Sanal Ortam,

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I dedicate this thesis to my parents, Semiha & İsmail Kuş.

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CHAPTER 1

INTRODUCTION

The world and life standards are improving on daily basis due to the rapid developing in technology. Virtual reality is one of the technology branches which is included in such fast improvement. Maybe the humans could not change the world, but at least they are capable of changing the environment (Orer, 2016). Environment can be also changed itself based on some factors. Normally, humans cannot have a full control over the environment as the external factors have influence on it as well. Recently, it became possible to have a full control on the environment by using the virtual reality (VR) control. VR does not only provide the control but it also opens the gates for other experiences beyond the imagination. For instance, it gives the chance to try impossible or fatal experiences such as bird eye fly which was not possible to attempt before such technology (Mudliyar, Ingale, Bhalerao & Jagtap, 2014). Since it is easily adaptable to variant situations, VR can take a part in several fields of our daily life.

The fast technology improvement closes the gaps between virtual and real environments. With the support of realistic headsets such as HTC Vive it was possible to approach the reality in some cases, even in the absence of some senses like smell or touch which is considered as a proof on the capability of VR to be as similar as reality world. It is accepted fact by experimental and scientific communities that VR can be more beneficial in terms of cast, applicability, wildly and also it is easy to control external factors (Mudliyar et. al.,2014). Since the external factors can be easily controlled, this thesis focuses more on internal factors. The side of psychology in VR became a trend topic in this field. It has started to be investigated with the real interpretation of EMMA project (Alcaniz, Banos, Botella, Rey, 2003). Psychology side of VR, gain importance and become an acceptable variable in virtual environment. In this research, spatial perception was selected as a psychological effect. Moreover, these effects were analyzed in both the real environment (RE) and the virtual environment (VE) under color temperatures of 4000K (cool white light) and 6500K (daylight). Lately, a comparative studies between real and virtual environments were carried out. Nevertheless, a few of them were concentrated on the visual appearances of spatial perception. For that reason, this thesis aimed to identify the similarities and differences between real and virtual environments -the virtual one was created as a simulation of real one- in terms of spatial perception.

1.1. Aim of the Study

Spatial perception and color temperatures are the starting points of this study to specify the differences between the real and virtual environments. Individual office environment is selected as an experimental environment as it is easier to control such environment and due to individual space itself, which means there is no human interaction to affect. The selected variables are investigated with the experimental study. Contributions of this dissertation into literature, will be beneficial and eased the understanding of spatial perceptions in selected environments.

1.2. Thesis Structure

This thesis consists of five main chapters. First chapter, the introduction states the rising virtual reality technology and its features as a tool in several work areas. Later on, the differences and similarities between virtual and real environments were addressed within the same chapter. The aim of this study was discussed in the paragraph that followed the introduction. The aim of the study is followed by the structure of this thesis.

The literature review was explained in details in the second chapter. Since the environment is the core topic of this studies, two different types of environments (real and virtual environments) were subject to detailed literature review. The examined variables were also addressed within the same chapter. Additionally, the

effect of these variables was investigated as well in order to observe whether they have the same effect on the same environment.

In chapter 3, the experimental setup was addressed in detail in chapter 3. After aim of the study, research questions was indicated and experiment details were stated to clarify. Beginning with experimental setup, specifying the sample group, then the procedure of the experiment. Continuing with the design of the experiment. After that, the statistical analysis was stated at the end of the chapter.

Chapter 4 was named as a discussion. In discussion part, results of the research and information that were gathered from the literature were discussed. Some implementations were made in the light of these information.

Chapter 5 is the last chapter of thesis in which a brief summary of the study and sentences of conclusion were written. The limitation of this study and some future suggestions were discussed in the same chapter.

CHAPTER 2

SPATIAL PERCEPTION

Spatial perception described as a general-purpose representation of the environment that surrounding the humans (Witt et.al, 2007). It is not possible to associate space with the only one sense organ, space perception come into existence with combination of senses like visual, auditory and time perception (Alexandre & Tavaras, 2010). Because of its quality of spatial perception, it considered as a supra-modal identity. Space perceptual divided into topic defined by distal properties in other name properties of architectural elements like distance, size and shape (Franz, 2005). The influential perspectives of space are psychophysiological dimensions of perceived spatial experience that provoke individual moods, feelings, preferences and attitudes. Personal interpretation of spatial perception shape with the context of culture, imagination, memory or previous emotional judgements (Naz et. el., 2017). To better understanding of spatial perception, definition of perception has to be done clearly than the major component of spatial perception which are vision and light have to be described at first.

2.1. Spatial Perception

Perception has several definitions and theories due to the conceptual framework of a structure. Its several definitions and theories, perception is commonly defined as a mental registration of sensory stimuli (Salvendy, 2013). Senses like sight, hearing, smell, taste or touch enable the humans to generate signal or stimuli from their surroundings (Rey et. al., 2004; Salvendy, 2013). Perception process consists of three sequential steps. Such process begins with the recognition -being aware of- which is followed by organizing step like gathering and storing and it is ended up with interpreting this sensory information by binding it to knowledge (Hendee & Wells, 1997; Salvendy, 2013). Perception goes beyond stimuli and it is based on sensations. Therefore, sensations are considered to be easier comparison to perception and it is part of humans' objective tools. They tend to be identical or at least similar for all humans. However, perception rely on the individualities and their past experience, which makes vary from human to another (Gibson, MacLeod & Pick, 1974).

For instance, a feeling of warmness and smoke smell which can be sensed by human senses, when they both are combined together in a perception, they might be interpreted into a fire (Gibson, MacLeod & Pick, 1974). Since the perception process starts with the stimulus and continued with the related sense of it, it is considered that senses and stimulus are the prerequisites for the existence of perception. Each sense of the human responsible for some stimulus. Despite of the figure below, generally, the human sensory channels gather under the three most affective channels. These channels have named as a visual related to eye, auditory that connected to ears and lastly haptic is concerned with the sense of touch (Kim et al., 2004).

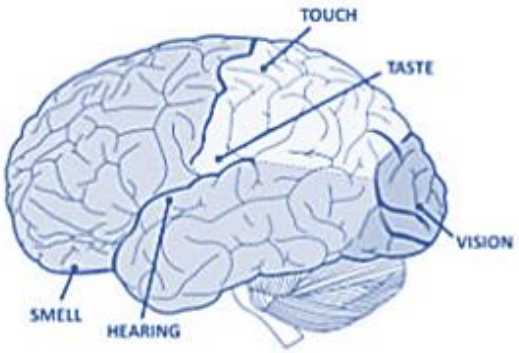
SENSE		
Vision	30%	
Touch	8%	
Auditory	2%	
Taste / Smell	< 1%	

Figure 1: Percentage of neurons in brain devoted to each sense (Billinghurst & Thomas, 2017).

As a subjective process, the perception is influenced by three major factors which can be classified to perceiver based factors, target based factors and situation based factors that has shown in Figure 2 (Pierce & Gardner, 2002).

Perception can be shaped based on the physical structure of a stimulus. Yet, it is likely to have higher efficiency, when the sensorial organs work integrated. Most of the time these organs work under the complementary content (Alexandre & Tavaras, 2010). Vision and audition are the most well understood types of perceptions (Mazza, 2009).

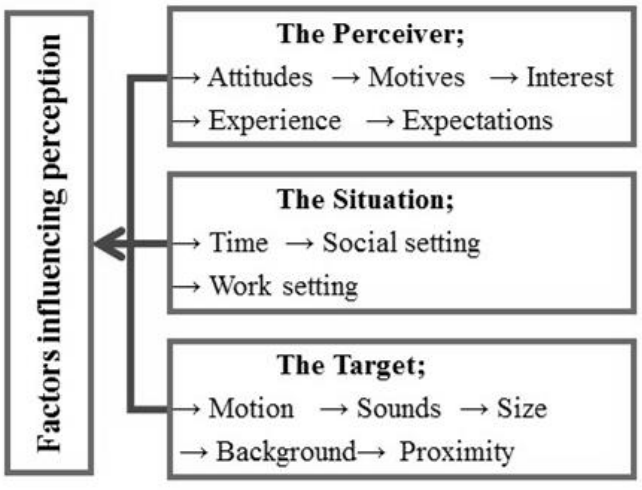


Figure 2: Factors that influencing perception.

Flynn and his colleagues conducted a study about the effect of white light with different properties on individuals' perception. Findings indicated that lighting is a measurable factor for individuals' perception against to visual field. (Flynn, Spencer, Martyniuk & Hendrick, 1973; Flynn, Hendrick, Spencer & Martyniuk, 1979) In addition to light, the effects of surface color on the perception of space have also been a subject of study (Odabasıoglu, 2015). For example, Oberfeld, Hecht and Gamer (2010) found that lighted ceilings and walls made the height of the room seems to be bigger than reality, while lighted floors has no significant impact on the perceived height (Oberfeld, Hecht & Gamer, 2010).

2.1.1. Vision

The most acceptable answer for the question of what is vision for, is that the purpose of the visual system is to generate and estimate a representation or a definition of the world around the human. Obviously, representation is not counted as a single image in the mind, it rather serves a beneficial function about the content of the world to be perceived (Kubovy, Epstein & Gepshtein, 2013). Vision is counted as the first component of the human sensorial system and it is obtained through the human brain rapidly (Alexandre & Tavaras, 2010). Nearly all kinds of animal including human rely on their vision -at first impression- to assist them in interacting with their environments. In daily basis activities, like finding way around, looking for food and many other activities, require the perception of various features of spatial layout of the visible environmental properties such as sizes, distances and/or shapes (Franz, 2005). This aspect of perceptual activity can be referred to the perception of visual space. The representative view of the vision function remains in the minds. Vision

function according to Marr, is explained as “discovering from images what is present in the world” (1982). The most various source of information in the environment is represented by vision (Aznar & Da Silva, 2005). In 1993, Huertas and his co-workers claimed that vision is a pre-eminent perceptual system, as it provides a wide surrounding to be perceived simultaneously in the existing environment.

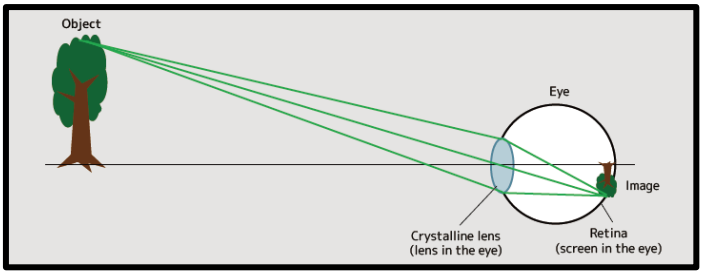


Figure 3: Optical system of human eye.

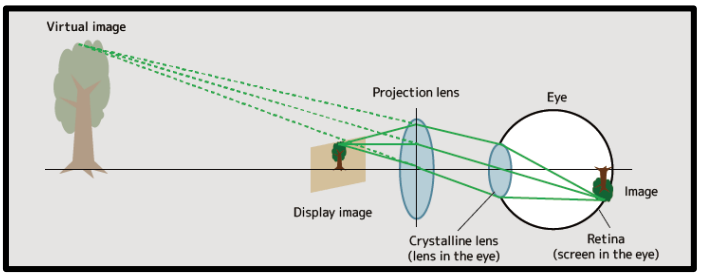


Figure: 4: Optical vision process of HMD.

The optical system of an eye does not contain the psychological and perceptual parts of individual vision (M.LaValle, 2017). Human visual system begins to operate when the luminous stimulation is detected by a sensitive neuron, the retina which is the first sensorial receiver (Alexandre, Tavaras, 2010). Retina is not static and normally it is not under full control of the human. Receiver transforms the stimulation into physical appearance (Alexandre, Tavaras, 2010). This transformation is directed to the related part in the human brain. In this way, the characteristics of information such as color, size or distance have started to come into existence (Alexandre, Tavaras, 2010).

Lenses causes the main differences between real and virtual in terms of vision. To become closer to the perception and sight of human eye, lenses are indispensable even if it has negative sides also. At the same time, they help to increase level of presence mostly, but rarely, distortions that caused by lenses, can be in high level depends on application (see Figure 5). That time manner, distortions can induce a headache or vertigo (Erskine, 2017).

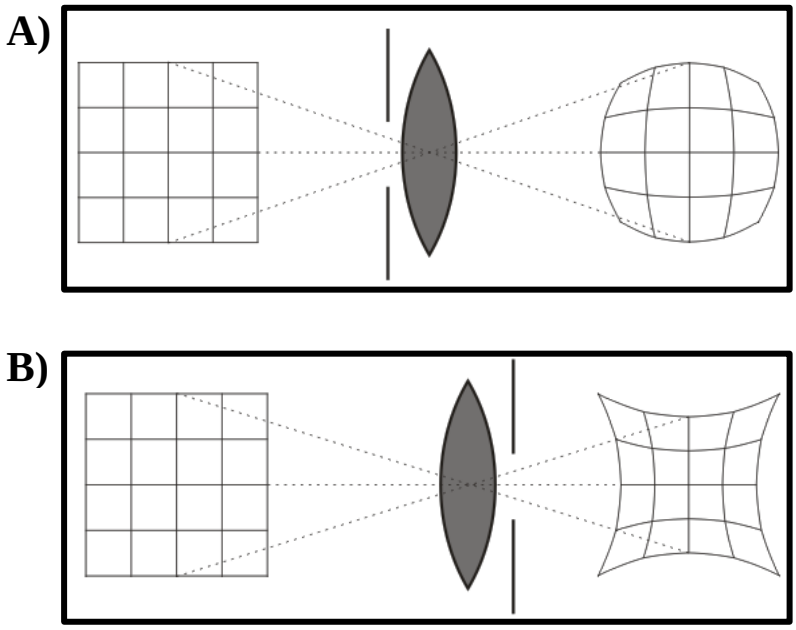


Figure 5: Illustration of image distortions on HDM (Smus, 2019).
-A: pincushion, B: barrel distortion-

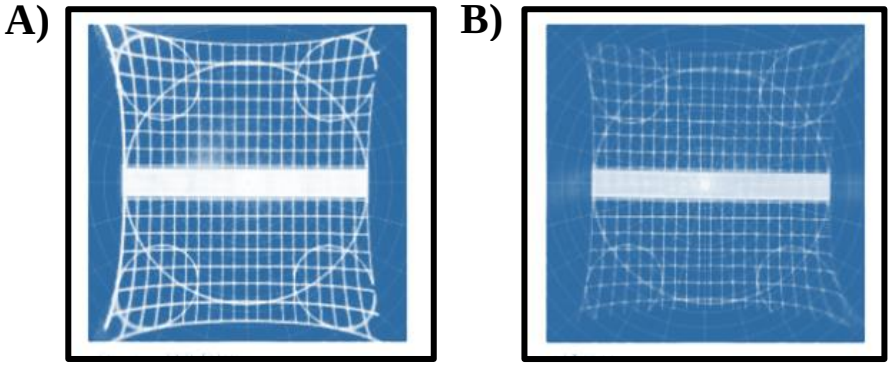


Figure 6: Example of distortion in different HMD.
-A: Oculus Rift, B: HTC Vive-

Moreover, vision provides utility providence to the human without any physical contact with the stimuli (Aznar & Da Silva, 2005). Vision can be considered as the core topic, when comparison is the main purpose of the question due to its ability to (Aznar & Da Silva, 2005);

- Notice the stimulus at a certain distance without physical contact,
- Handle both the animated and unanimated structures,
- Deal with multiple scales of spatial resolution,
- Integrate the phenomenon of time and space at the same time,
- Decide the characteristic of concerned stimulus with the help of brain,
- Lead to perceivers' actions and behavior in the environment,
- Differentiate between properties of the objects.

Visual sense is one of the most essential channel to perceptiveness towards surroundings and for virtual environment as well due to its remarkable contribution in terms of believability (Kim et al., 2004). Visual channel of sensory system is one of the most channels which is subject to study especially in virtual reality scenes (Kim et al., 2004). As is seen in Figure 7, visual simulations are taken and transferred into 3D graphics and thanks to the human machine interface, all data are transmitted to the brain. In virtual environment, the process starts and continues as same until second step, then instead of human-machine, HMD and vision system are situated in step three lastly ends up when transmission process is completed.

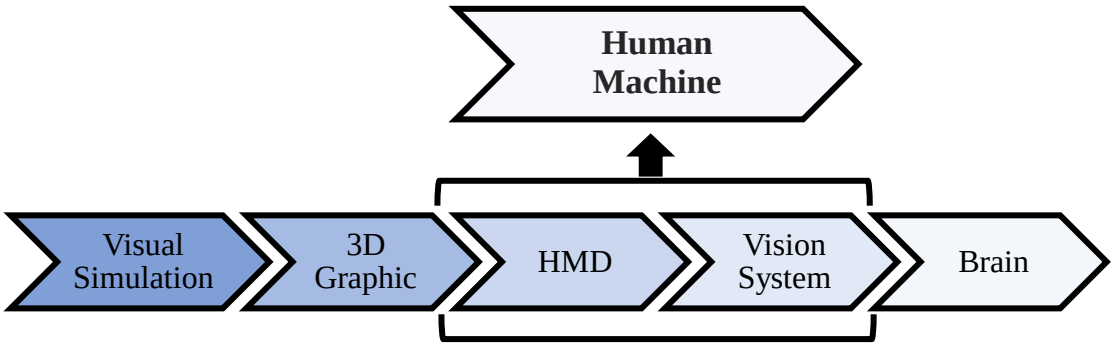


Figure 7: The process of human and virtual visual perception (Billinghurst & Thomas, 2017).

2.1.2. Light

Light is the last element that needs to be addressed in order to have a clear understanding of the spatial perception. Basically, light is the word that refers to the visible portion of the electromagnetic spectrum (IESNA, 1993). Without light, it is not possible to see and perceive what is happening in environment (Manav & Yener, 1999). Every individual has different demands, cultural, beliefs and educational background which have influence on his/her emotional reactions and responses to the light quality (Yücetaş, 1997). However, light has no ideal values, some other factors should be controlled in order to achieve better light quality. These quality categorized into two segments, visual and non-visual or in some other sources, they can be named as physical and psychological effects (Van Bommel, 2006). The visual effects contain color temperature, brightness or color rendering, while the non-visual effects of light contain emotional responses, health or mood of individuals. In Figure 8, there is some kind of interrelationship between visual-nonvisual effects and emotions that (Van Bommal, 2006).

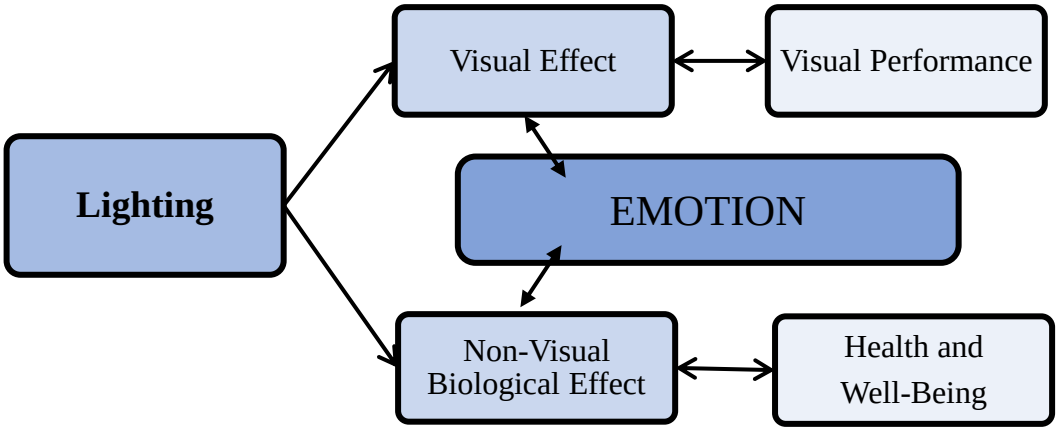


Figure 8: The relationship between lighting and its effects (Van Bommal, 2006)

For a good lighting and space quality, designers, architects and engineers should pay attention to both the psychological and physical factors when designing a light. Most of the studies observe the emotional effect of the lighting quality. In one research which is published in 2017, there is a chart which shows the percentage of lighting effect according to previous studies (Kočanovs, Kočanova & Bogodistaja, 2017). As it seen in the following chart, the emotional effects of lighting have bigger influence than the physical effects. According to Bogodistaja and his associates (2017) emotional effects consist of several components which are perception, mood, sense of safety and comfort.

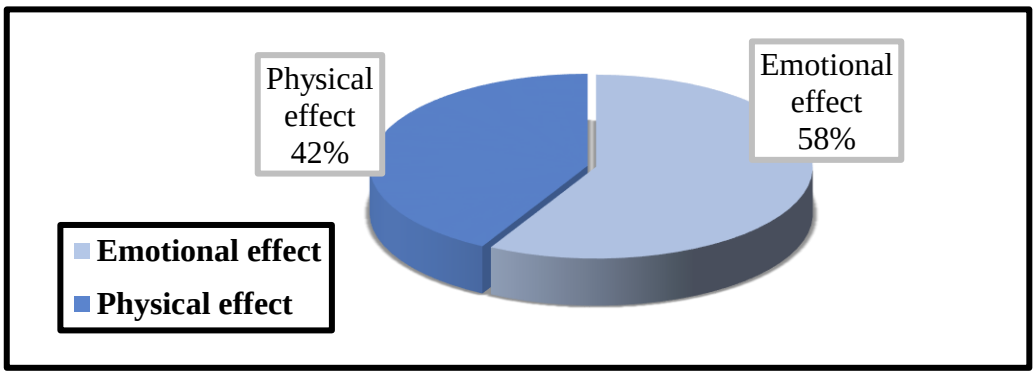


Figure 9: Ratio of the physical and emotional effects of lighting (Kočanovs et. al., 2017).

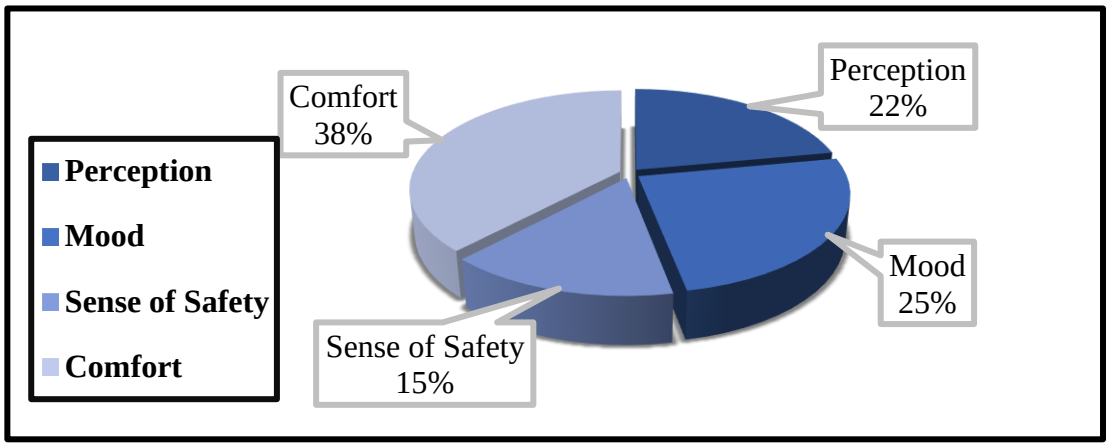


Figure 10: Ratio of the emotional effects of lighting components reviewed studies (Kočanovs et. al., 2017).

Perception has been examined in a detailed way at the head of the chapter. Basically, comfort refers to pleasant feeling of being relaxed and for that article which is cited showed the comfort as a major component of the emotional impact of light. The sense of safety has the lowest share in this chart (Kočanovs et. al.2017).

There are some main physical lighting factors that must be given attention while designing light, such as general lighting illuminance, illuminance distribution, color rendering properties and color temperature (Nakamura, Karasawa 1999). According to American National Standard (1987), lighting quality is one of the primarily aspect of lighting and color temperature is one of the most important components of light quality for the human perception, as it provides comfort and effective visual environments. (Veitch et. al., 1998; Katsuura, 2000; Samani, 2012). The concept of color temperature basically depends on the relationship between the temperature and the radiation emitted by a theoretical standardized material termed as ‘black body radiator’ cooled down to a state in which all molecular motion has ceased (Abramowitz & Davidson, 2018). Color temperature can be defined as a value of the

absolute temperature of a black body radiator chromaticity that matches the one of the light source (Rea, 2000). In the case of the lamps and sources that can only approximate the chromaticity of a black body, the corrected term correlated color temperature is applied through a calculated chromaticity (Abramowitz & Davidson, 2018). The color temperature expresses the warmness or coolness of a light source like yellowish white, bluish white, or neutral in appearance, not the spectral energy distribution or the physical temperature (Egan & Olgyay, 2002).

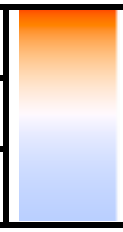
ColorTemp. < 3300K		**Warm** (reddish white)
3300 < Color Temp. < 5300		**Intermediate** (white)
5300 < Color Temp.		**Cool** (bluish white)

Figure 11: Color Temperature Classes from Commission International de I'Eclairage (CIE technical report, 2004) and CIBSE (Boyce et al., 1989).

In the last chart, color temperature is divided into three main categories (warm, intermediate, cool) according to their temperature (see Figure 11). According two of the most recognized light organizations, CIE and CIBSE, warm light lays between 0K-3300K, while color temperatures between 3300K - 5300K are expressed as intermediate. Any other color temperature value that is greater than 5300K refers to cool light (Boyce et. al., 1989; CIE technical report, 2004). Some other literatures were more specific regarding the values of color temperatures. IESNA had more specific values and names about color temperatures that is shown in Table 1, which belongs to fluorescent lamps, they also stated the proper color rendering indexes (Kaufman, 1984**)**.

Table 1: Values of color temperature and CRI of an ordinary fluorescent lamp from IESNA (Kaufman, 1984).

Fluorescent Lamps	Color Temperature (K)	CIE general Color Rendering Index
Warm White	3020K	52
Warm White Deluxe	2940K	73
White	3450K	57
Cool White	4250K	62
Cool White Deluxe	4050K	89
Daylight	6250K	74

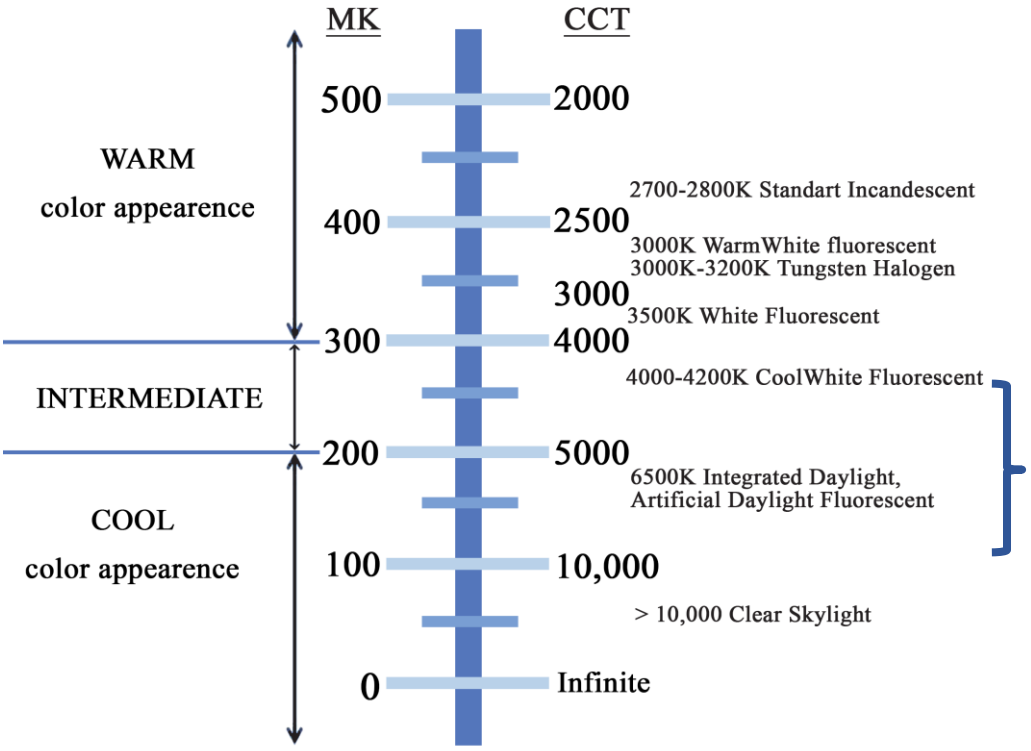


Figure 12: Color temperatures and familiar light sources from CIBSE (Boyce et al., 1989).

Several studies have been discussing the lighting and the relationship between light conditions and their impact of different physical and visual traits, the results were restricted though. For instance, color temperature (Öztürk , Yılmazer & Ural, 2011),

color temperature and illuminance together (Fleischer, Krueger & Schierz, 2001; Manav 2007), lighting arrangement (Manav & Yener, 1999), spectral power distribution (Fotios & Levermore, 1999) and illuminance and lighting arrangement together (Durak, et. al, 2007). Additionally, experimental psychological studies have conducted various evidence for the non-visual and psychological impact of light, such as attention (Guisa & Perney, 1974), perceived guilt (Taherzadeh, 2018), time-estimation task performance (Öztürk, Yılmazer & Ural, 2011), communication (Gifford, 1988), mood (Belcher & Kluzny, 1987) performance of various cognitive task and interpersonal behaviours (Baron et. al. 1992) mood and decision making (McClaughan, Aspinall & Webb, 1996; Kürkçü, 2017) and self-reported quality of life (Sörensen & Brunnström, 1995).

Since color temperature is one of the studied subjects in this thesis, Kruithof Curve should be shortly explained. In 1941, Kruithof has published his first curve concerning the illuminance level and color temperature (Kruithof, 1941). The Kruithof Curve later on became the base of the majority of successor light quality studies. In 2015, Cuttle mentioned that "probably the most reproduced curve in the history of light" (Cuttle, 2015). Kruithof linked the color temperature of the light source to a range of illuminances that it was found to be 'pleasing' (Ashdown, 2015).

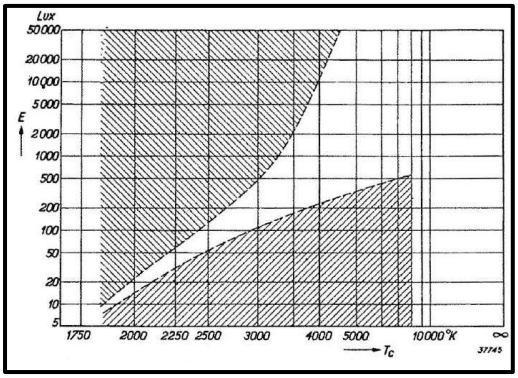


Figure 13: First version of Kruithof Curve (Ashdown, 2015)

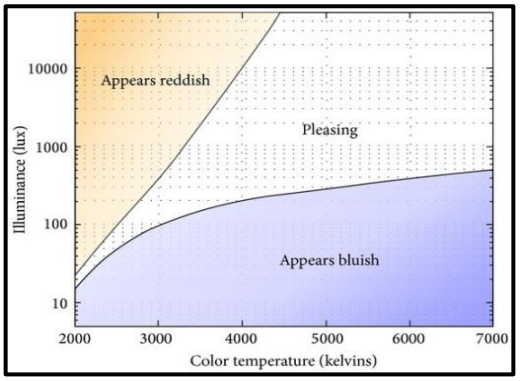


Figure 14: Modern version of Kruithof Curve (Fotios, 2016)

In early researches, results were significantly different from one another. Baron et. al. (1992) figured out that participants was felt to be more relieved and pleased towards an experimental room when they were exposed to warm colored temperature than cool colored temperature or under the low temperature rather than high illuminance. However, Boyce and Cuttle (1990) stated that color temperature has no effect on the subjective impression.

In 2013, an article was published that focuses on effects of light's color temperature on visual comfort, task performance and alertness on office workers (Shamsul, Sia, & Karmegan, 2013). Their aim was to identify the effects of three different light's color temperature which are warm white light (WWL = 3000K), cool white light (CWL = 4000K) and artificial daylight (DL = 6500K). Noticeable increase was observed in subjective alertness level and computer-based performance under the daylight condition. The typing performance in terms of speed was significantly better under the CWL when it was compared to WWL and DL. In spite of that, minimum error was made in typing performance under the DL, followed by CWL and WWL. CWL was the one preferred the most and selected as the most comfortable light by workers (Shamsul, et. el. 2013).

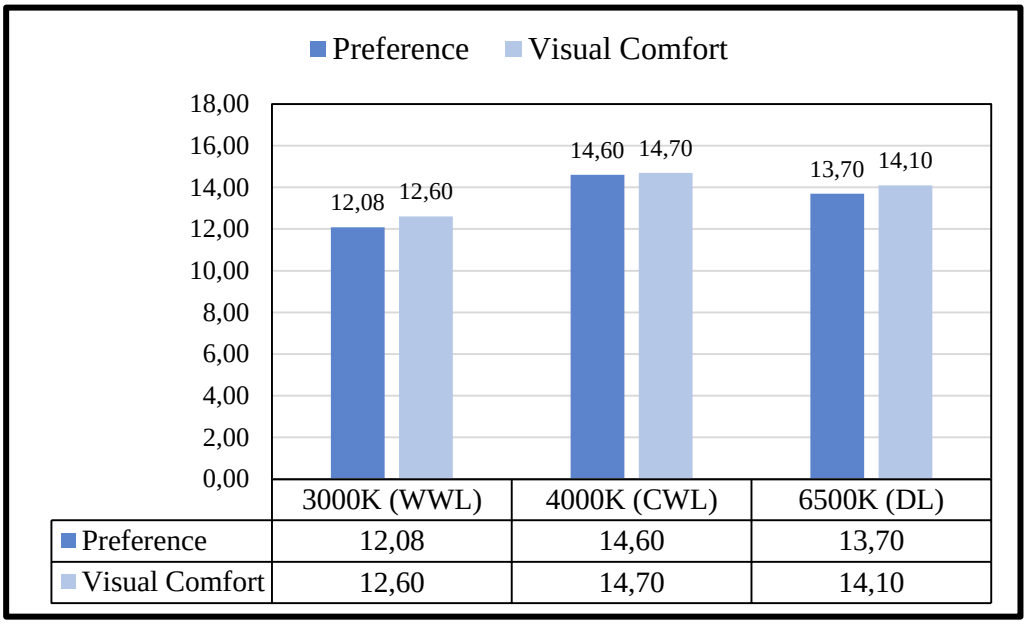


Figure 15: Comparison of preferences and visual comfort score (Shamsul, et. el. 2013).

Another study from International Color Conferences 2018, Yılmazer and her team investigated the effects of color temperatures on color task performance and users' mood. Two color temperature was used and 100 participants was attended. (2700K and 4000K). Participants showed better total accuracy under 4000K (cool white light) in comparison to 2700K (warm white light). In terms of mood, participants mood was affected in a positive way under 4000K (Yılmazer, et al., 2018).

2.2. Spatial Perception in Real Environment (RE)

The initial and traditional approach towards spatial perception (visual space perception) described that perceiver has internal representation of physical environment, in other words visually perceived space or visual space, and then try to form an estimate of this visual space properties (Loomis, da Silva, Fujita & Fukusima, 1992; Örer, 2016). While measuring the properties, they use numerous personal variables like knowledge and experience. Therefore, perception of interior

space is psychological process at the same time it is learned, selective, dynamic, interactive and individual. (Lee & Aronson, 1974; Bloomer, 1990). Spatial perception is investigated under different categories such as auditory or visual perception (Atlı, 2010; Acun & Yılmazer, 2015),

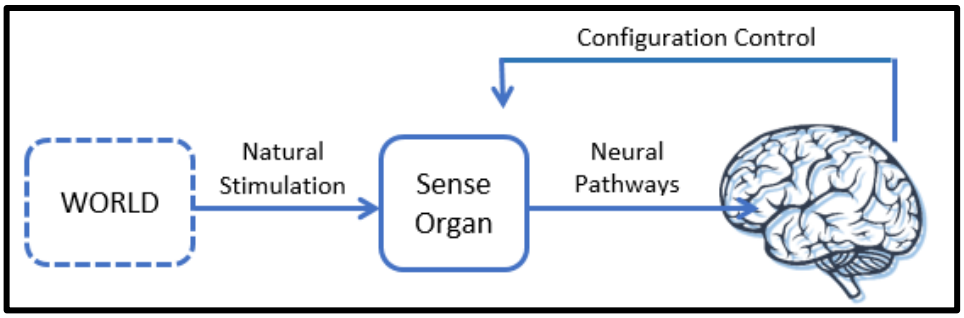


Figure 16: Human perception process in real (M.LaValle, 2017)

It is not possible to associate space with only one sense organ. As it was said, the space perception comes into existence with combination of senses like visual, auditory and time perception (Alexandre, Tavaras, 2010). Due to this quality of spatial perception, it considered as a supra-modal identity. Powerful multisensory stimulus proved that human senses are connected and act together harmoniously. But the general rule human sensation has tendency to be dominated by the sensation type which ensures the most reliable and extra detailed information about the surroundings (Eimer, 2004). For this reason in spatial perception, visual perception comes front because vision ensure the most accurate spatial information about the features of space (Eimer, 2004). When the entrance the room, in a highly manner, stimulus has started to perceive in eyes unconsciously. Therefore, the visual field of human eye mainly represents the spatial perception of human. In Figure 19, visual field of human is interchangeable depends on physical factors such like distance or angle (Pérez, Rueda & Orduña, 2018).

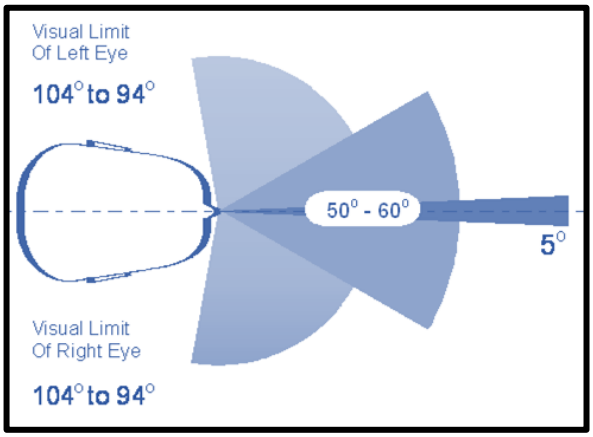


Figure 17: Horizontal visual field of human eye (Billinghurst, Thomas, 2017)

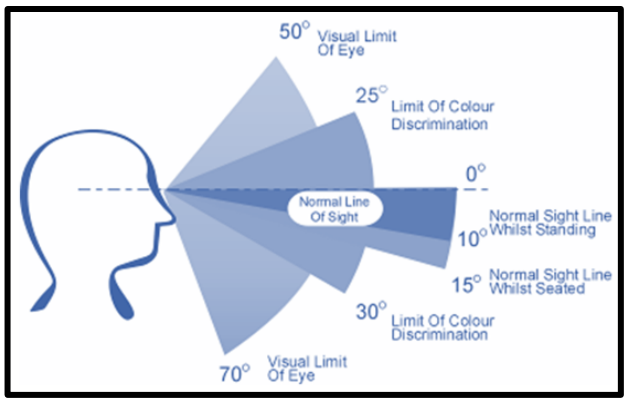


Figure 18: Vertical visual field of human eye (Billinghurst & Thomas, 2017)

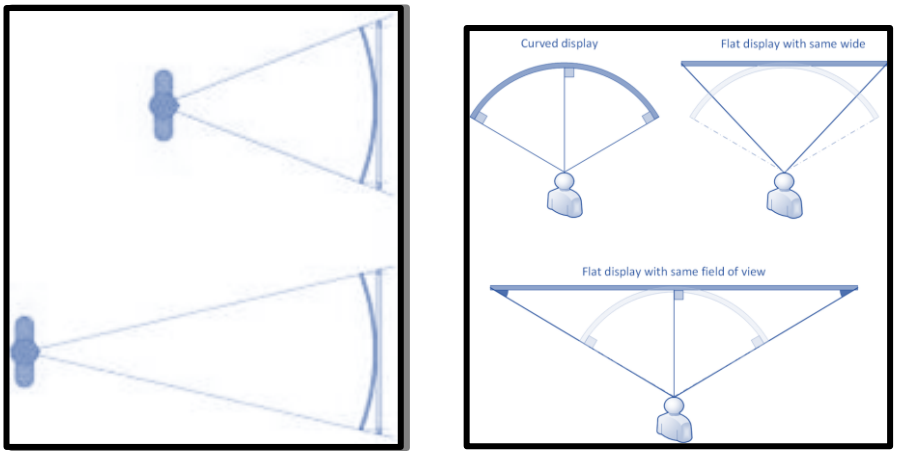


Figure 19: Distance and angle in human visual field (Pérez, Rueda & Orduña, 2018).

Environmental factors are highly related with the evaluation of its perception. And, the proper use of these environmental factors physically, possible to change individual spatial perceptions like enhance the feeling of satisfaction.
Evaluation of environmental quality in architecture has contained both qualitative and quantitative factors. Proportion, size, distance and scale are counted as quantitative statements, meanwhile qualitative statements are related to environmental side of environment. In environmental psychology, to make correct assessment towards environments, some basic models were developed. Most of the times, these kind of models have been used with semantic differentiate scales for the most influential valuation of space. Beside semantic differentiate scale, opposite adjective pairs have been established as descriptors of environmental aspects. (Naz et. al. 2017). According to many studies there are some components of a environment that help us while perceiving and evaluating the environment by evoking humans' emotional responses. (Knez & Enmarker, 1998; Knez & Kers, 2001; Manav, 2007). Color and light are most influential quantitative factors that probably affect individuals' perception of an environment (Knez & Enmarker, 1998; Knez & Kers, 2001). Perceptual awareness of this aspect individual first enters the space, before the eyes has time to adapt to the condition (Jaglarz, 2011).

Visual perception of a room size and proportions that occur under the impact of individual subjectiveness, visual memory, quality and features of light like glare, brightness, intensity and color perception (Jaglarz, 2011). There are many theories about the understanding of spatial phenomena. And the studies have still ongoing, since the varied content of spatial perception.

2.3. Spatial Perception in Virtual Environment (VE)

Cambridge Dictionary defined virtual reality (VR) as ‘’computer, images and sounds that make you feel an imagined situation is real’’ (2018). This definition does not cover the whole concept of virtual reality, where in there are some missing parts. Comprehensive description of virtual reality was written Steven M. Lavalle’s book Virtual Reality in 2017;

> *‘’Inducing targeted behavior in an organism by using artificial, sensory stimulation while the organism has little or no awareness of the interference.’’*

M Lavalle also had made an elucidator description between reality and virtuality, where he indicated that, real world can include instant experiences of users in physical world, while virtual world can refer to sense of targeted or designed experiences in any world that could be real, imaginary, future or past (M LaValle, 2018). VR become a very powerful technology that assure people to make differences in human lives by stimulating human senses in an artificial way and human bodies could be manipulated to accept other versions of reality (M LaValle, 2018; Kim et al., 2004).

The main rise of virtual technology was started in parallel with worldwide spread of smartphone industry. This is due to the fact that smartphones are more qualified and developed than older times in terms of high resolution and price especially among college community and young generations who give more attention to this growing technology. Because it provides uncommon and new experiences with fresh ideas in

different fields such as art, entertainment, social network and academic fields. Mobilization of VR technology and portable headsets provide compelling VE experience and ease its accessibility among students (Özgen, 2017). VE has gained importance among different industries like medical, automotive, military, advertising, education and other several industries. Nevertheless, VE has particularly highly developed in design field, where in it opened the gates for a new technology that can be utilized for design researches and practical fields (Özgen, 2017).

Before the passing to next topic, and in the light of previously mentioned information, virtual environment could reveal the features of 5 matters (Mudliyar et. al, 2014);

1) Changes regarding the work that can be reconfigured easily in software.
2) Besides natural environment, unlimited and unnatural environments can be created to provide impossible or deadly experiences – e.g. bird eye fly- which would not be possible to achieve in the real.
3) Interactive and adaptive.
4) Human sensory motor systems and their senses are utilized more than before.
5) People can feel sense of presence in the synthetic & artificial environment.

As a subjective concept, perception displays the differences of several various perspectives that change from individual to another. The more diverse environment can be induced the more various perception can be realized. As is mention above,

since the concept of virtual environment is interactive and adaptive, human senses are used efficiently and at the time of experience in artificial environment not only one sense but multiple sensory channels play a part (Kim et al., 2004).

Real and virtual environment cannot be perceived as an exact same. Because, even if they are identical visually, other sense which are affective in perception, can be felt differently (M.LaValle, 2017). In previous pages, perception towards real environment was addressed. In order to make meaningful and acceptable comparison between two environments, perception and vision in virtual environment were analyzed. In title of vision, normal optical eye was examined not eye analyzed with virtual glasses. In virtual reality headsets, lenses are located to display the screen farther than reality (M.LaValle, 2017)

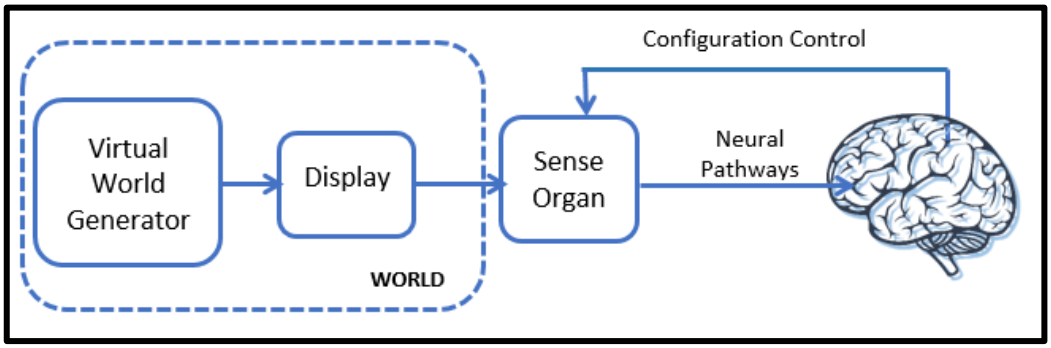


Figure 20: Perceptual process in VE (M.LaValle, 2017).

Human bodies and systems that have been living in natural environments since the beginning of the world, are not accustomed to virtual reality system. But with the help of senses and some other external factors, biological mechanism of human could be stimulated and adapted towards virtual environment (M LaValle, 2017). However, human bodies can react negatively in some cases. These negative reactions could cause some diseases like fatigue or headache. As an explanation of these reaction,

experts argue the over-worked and muzzy brain (M LaValle, 2017). In general, it is well-known as VR sickness. The most common VR sickness is motion sickness (Erskine, 2017). It occurs when the vestibular system of human does not work efficiently. Vestibular system is located in the inner ear of human and it enables the human to maintain balance, coordination, and awareness of spatial orientation. ("Vestibular system | anatomy", 2018). Normally, motion sickness develops when the vestibular systems send message to the brain of moving body which is contradicting to the information comes from the eyes. Therefore, it might cause dizziness, sweating and vomiting (Erskine, 2017).

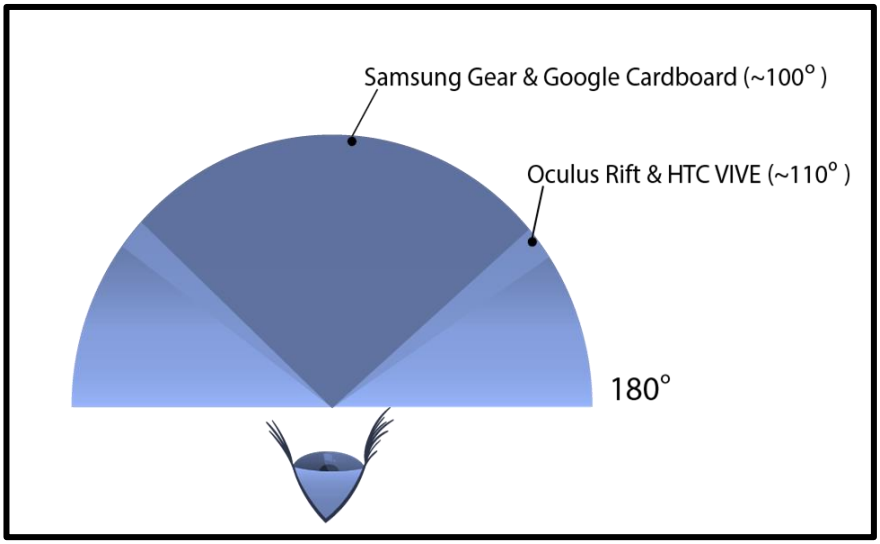


Figure 21: Vision field of HDM

Perception in VE is the concept that developers do not give too much of attention due to its psychological concept. In real environment and humans daily routine perception process comes to existence unconsciously. For instance, when an individual see a friend, it does not require any effort from the individual to recognize

him/her immediately, while but the perception process has already started long time before (Daniel & Meitner 2000; M.LaValle, 2017).

In order to understand perception in VE, firstly it needs to understand how human perceives the real environment (RE). Perception in RE seems as it appears and it is completed by itself without any effort (Stahre, 2009). Because human does that every moment unconsciously. On the other hand, in VE, there are some information and cues that can lead, assist or manipulate the human perception (Stahre, 2009). For the next chapter, previous studies about comparative studies between real and virtual environment will be analyzed.

2.4. Previous Comparative Studies Between Real Environment and Virtual Environment

Before the examination of previous studies in literature, Table 2, can be beneficial for understanding of previous studies objectives easier.

Table 2: Comparison between human eye and HDM (Billinghurst & Thomas, 2017)

<table>
<tr><th></th><th colspan="2">HUMAN EYE</th><th colspan="2">HTC VIVE</th></tr>
<tr><td>FOV</td><td>200^0 x 135^0</td><td rowspan="2">  </td><td>110^0 x 110^0</td><td rowspan="2">  </td></tr>
<tr><td>Stereo Overlap</td><td>120^0</td><td>110^0</td></tr>
<tr><td>Resolution</td><td colspan="2">30,000 x 20,000</td><td colspan="2">2,160 x 1,200</td></tr>
<tr><td>Pixels/inch</td><td colspan="2">>2190 (100mm to screen)</td><td colspan="2">456</td></tr>
<tr><td>Update</td><td colspan="2">60 Hz</td><td colspan="2">90 Hz</td></tr>
</table>

According to the M.LaValle, Real and virtual world cannot be perceived as an exact same. Because, even if they are identical visually, other sense which are affective in perception, can be felt differently (2017). However, some researchers such as Danford and Willems (1975), Flynn and his coworker (1977) or Daniel and Meitner (2000) (as cited in İmamoğlu, Şenyapılı and Demirbaş, 2009) stated in their studies that representatives of physical environments may result in similar outcomes like real environments.

In 1993, Henry and Furness made comparison between real and virtual environment about appreciation of room dimensions and object orientation judgements in real environment with three different conditions which was using only monitor, a head mounted display (HMD), without head tracking and lastly using HDM with head tracking. Their result indicated that in virtual environment, participants underestimated the size of environments compared to participant in real environment condition. Investigators interpreted this situation in a way that HMD provided only restricted field of whole environment, and the borderlines of HMD distort the objects more than the center. These two mentioned factors dispose to demonstrate the environment smaller than its actual size (Henry & Furness, 1993).

In 2003, other comparative experiment was performed in Virtual Laboratory. This study attempted to measure environmental factors thought the perception with five categories –ambiance, evaluation, arousal, privacy and security- using twenty nine bipolar adjective pairs. Semantic differential scale was applied for adjective pairs. As a statistical analysis, factor analyses was used (Kort, Ijsselsteijn, Kooijman & Schuurmans, 2003). Apart from arousal, results demonstrated significant differences

in all other categories between RE and VE. In addition to that, participants evaluated RE more positively than VE for four other categories.

Researches which are interested in making a comparison of scenes in monoscopic (2D) and stereoscopic (3D) indicated that some minor differences have been recognized in how they are perceived. as a conclusion of such study, the 3D was perceived to be more realistic than 2D (Cauwerts and Bodart 2011). Stereoscopy did not demonstrate any considerable impact when comparing the subjective interpretations of emotion and perceived presence (Cauwerts and Bodart 2011).

The differences in perceptions between real and virtual environments have been studying for the last decade. In 2013, Bruder and Steinicke, focused on perception of time during walking movement with head-mounted display (HMD). As a result of this research, they recorded no significant differences between real and virtual environments in terms of perception (Steinicke & Bruder, 2013). Similar study was conducted in 2015 by Heydarian and his research team. This study focused on a comparison between real and virtual environments in terms of perception, performance and presence. Results revealed that participants act similarly in both environments with no significant differences (Heydarian et al., 2015).

In 2017, Anderson and his co-worker aimed to compare perception of users in real and virtual environment under the same physical condition. Most challenging part of this study was the utilizing of day light. Result stated that high level of perceptual accuracy did not point out any significant differences. Besides, participants felt high incidence of presence in virtual environment and there was no any significant impact

on physical symptoms on participants after using HDM. In the light of these findings, investigators noted that proffered experimental method appears promotive for usage of virtual environment instead of real environment in terms of considered five dimensions of perception in daylight spaces (Chamilothori, Wienold & Andersen, 2018).

In 2017, a research was conducted about virtual environment space quality by Naz and her research group. They sought an answer the question of that ‘to what extent emotional response in a simulated environment is affected by the same parameters of real environment?’ Result of the experiment demonstrated that perceivable emotional aspects of real spaces could be generated into virtual spaces as a stimulation of design attributes (Naz, Kopper, Ryan P. & Nadin, 2017).

CHAPTER 3

EXPERIMENTAL STUDY

3.1. Aim of the Study

After the entrance of virtual reality (VR) into human life, any field that might be somehow connected to the VR is continually changing due to the rapid advancing of VR technology (Botella et. al., 2004). Moreover, VR has become more of an issue for the architecture and design fields mainly in terms of experiencing environments which are unconstructed. Architects are trying to integrate VR in life. To do so, spatial perception – which is the essential factor to integrate VR in life – has to be taken into account. The spatial perception is human oriented factor. Thus, it might change immediately when the human enters an environment (Jaglarz, 2011).

The aim of this study is to make comparison between real environment (RE) and virtual environment (VE) in terms of spatial perception. To make such comparison, two office environments – identical by appearance- were created. One of these two

office environments was in the real environment (RE), while the other one was in a virtual environment (VE). Spatial perception was investigated comparatively in the two environments as a priority. As a later stage, the effects of different color temperatures -4000K (Cool White Light), 6500K (Daylight)- were evaluated in the existence office environments

3.1.1. Research Questions

In order to attain the aim of this study, the following research questions were constituted;

Q1: What are the differences between full-scale real and virtual office environments in terms of spatial perception?

Q2: Are there any impact of color temperatures -4000K-6500K- in created environments according to aspects of spatial perception?

3.2. Methodology

3.2.1. Sample

The sample group included graduated as well as undergraduate university students who participated voluntarily in the experiment. The experiment was carried out in Interior Architecture and Environmental Design Faculty of Bilkent University, Ankara. The sixty participants were divided into two, main sample groups equally and disorderedly. In total, participants were consisted of 24 males and 36 females.

The mean value of the participants' age was 24.71 and their ages varied between 19 and 31 years old.

Every participant spent one minute to experience the environment individually. The experiment was conducted using the repeated measures design system in which the same sample group was tested repeatedly – two times- in order to prevent individual differences such as age, characteristic, gender and cultural background of participants. Also to prevent it, order of conditions was presented in an equal selection. For that purpose, participants divided into two randomly, the half of participants experienced Real Environment (RE) first, while other half experiencing the Virtual Environment (VE) initially. Then the order of participant replace, by this mean, in both experimental environment, an equal number of participants experienced the experiment at first order without being on familiar with environments.

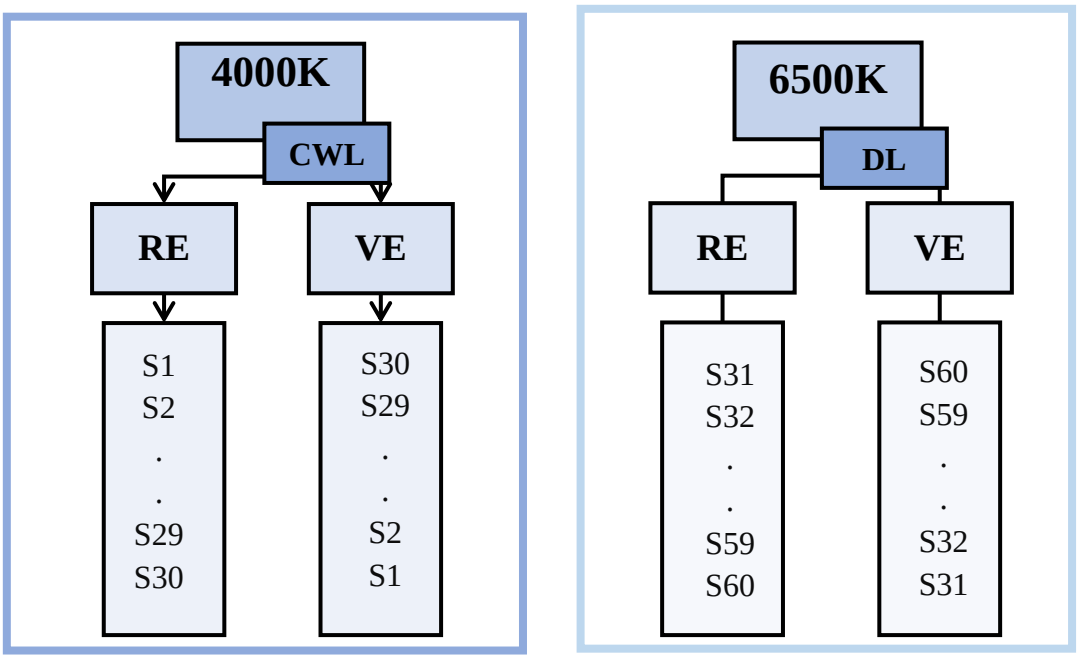


Figure 22: Order of experiment's sample groups

3.2.2. Experimental Set-up

Experiment of the study was prepared in two different environments which were the real environment (RE) and the virtual environment (VE) under two different color temperatures; 4000K (CWL) and 6500K (DL). Two environments were prepared in order to guarantee the rooms layouts in terms of visually same appearance.

While the experimental environments were prepared, both environments must be taken into consideration to create identical environments. The experimental set-up was prepared. It was a full-scale office room in which the RE experiment will be carried out. This room was designed as if it was real private office environment with dimensions of; 4.00m length, 4.10m wide and a height of 3.20m (Figure 23, 24, 25).

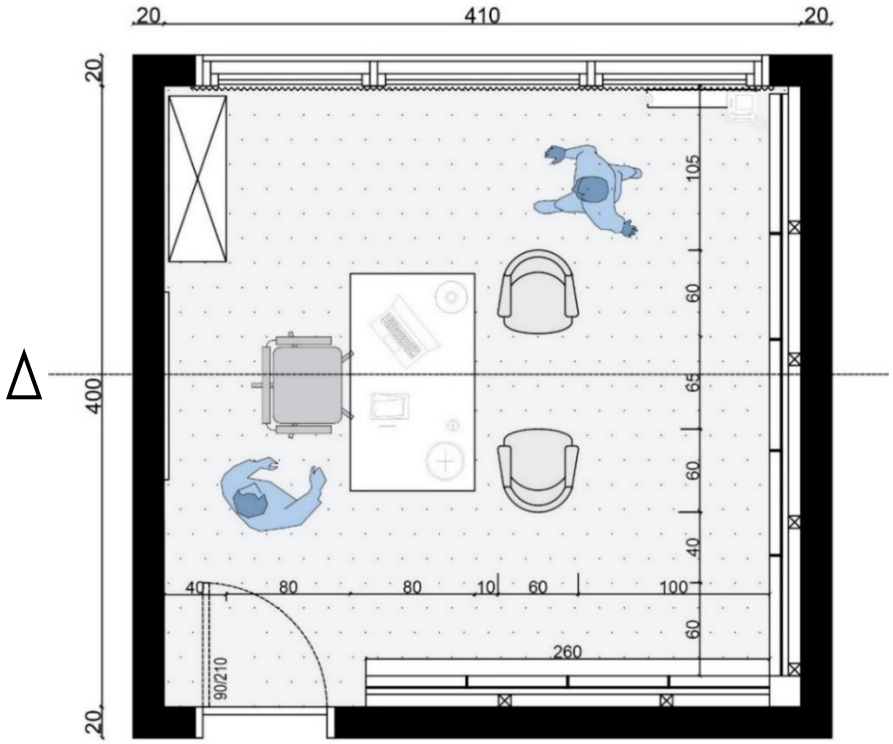


Figure 23: Plan of the test room (not to scale).

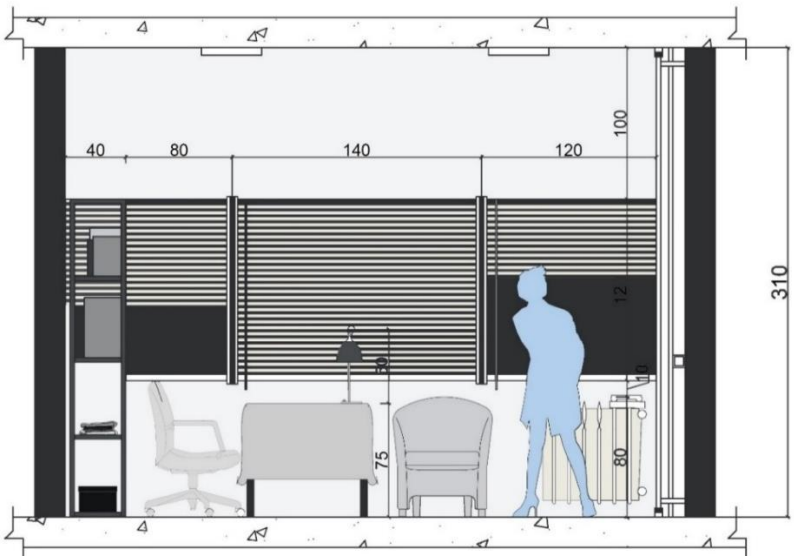


Figure 24: Section of the test room (not to scale).

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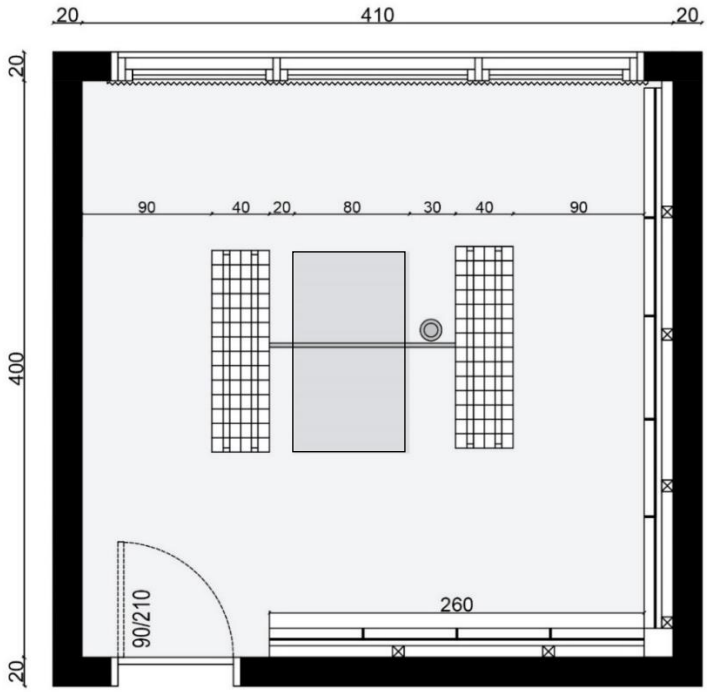


Figure 25: Reflected ceiling of the test room (not to scale).

In order to eliminate daylight condition, windows were covered with black board in the manner that only the artificial light was analyzed. In order to minimize, the undesirable impacts of color, all furnishing elements and three dimensional elements

were selected and used achromatically or covered with achromatic colors. In addition, the materials' color and texture in the office environment were chosen to generate matt and smooth surfaces that were far from specular reflection and glare.

As seen in the reflected ceiling plan (Figure 25), there are two fluorescent lighting fixtures that are embedded in the middle of the ceiling and existence sighting has appropriate distances to satisfy the expected illuminance levels (300-500 lux) which were decided by IESNA for office lighting (1993). Each one of existing lighting fixtures included two fluorescent lamps (four fluorescent lights in total).

The construction period of VE was started while RE was proceeding and VE required multiple steps to accomplish. First of all, AutoCAD drawings were transferred into a 3D Max program and harmonized into a three dimensional form without skipping any details. But the 3D Max program and HMD (head mounted display) did not match in terms of program compatibility. The project which was drawn by using 3D Max, had to be optimized in the Unity3d program. The firm of SIMTEK Stimulation and Information Technologies in Hacettepe Teknokent transferred 3D Max file into the Unity3d. To experience the virtual part of the experiment, the empty room had to be founded in an indoor environment which has a same dimension as the RE room. The laboratory was used during vacant times in order to eliminate noise factor (Appendix B).

Tracking is one of the most common barriers in VR headsets due to the eternal desire to enhance it continuously which enables us to experience a better virtual reality (MLaValle, 2017).

Table 3: Specification of lighting fixtures. ("LUMILUX T8 | OSRAM Lamps", 2019)

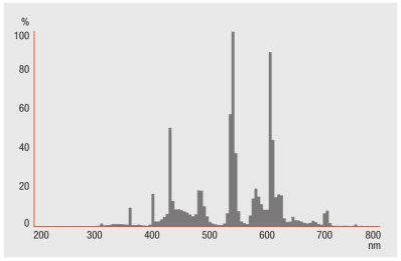
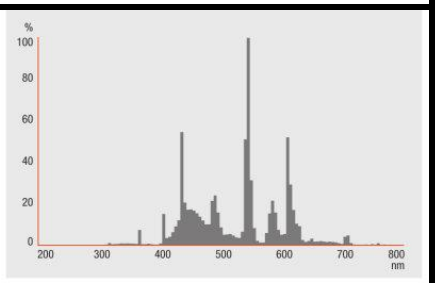
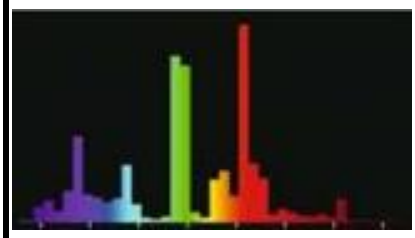
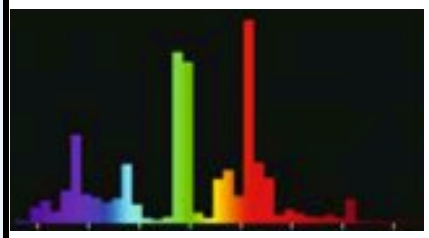
4000K **(Cool White Light)**		**6500K** **(Daylight)**
Cool White Light	**Light Name (in OSRAM)**	Cool Daylight
Fluorescent lamps,	**Light Type**	Fluorescent lamps,
T8 36W/840	**Light Code**	T8 36W/865
≥80	**CRI**	≥80
36 Wattage	**Nominal Wattage**	36 Wattage
3350 lm	**Luminous Flux**	3350 lm
	**Spectral Power Distribution**	
	**Color Spectra**	

Figure 26: RE under 4000K (CWL) -left- and 6500K (DL) -right-

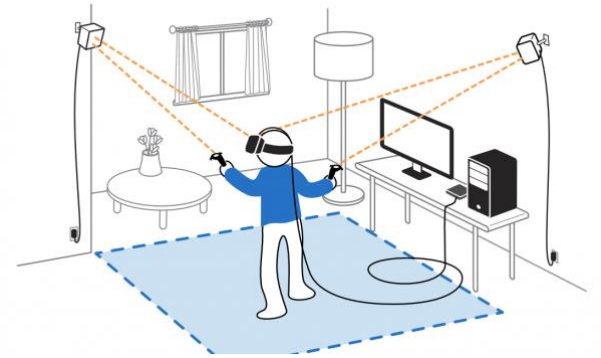
Figure 27: VE under 4000K (CWL) -left- and 6500K (DL) -right- (see appendix B)

3.2.3. Instruments

Two types of headset were used for the realistic experience of virtual (VE), camera-based implementation (Oculus Rift) and laser-based implementation (HTC Vive). According to implementations, although both of them are close to each other and high technology, there are some nuances that are important, Oculus Rift is more comfortable and practical for gamers, contrary to that, HTC Vive is offering more realistic and immerse experience to users. In a word, if the subject is desired to more realistic virtual environments and feeling of high presence, the best headset choice is HTC Vive for academic researches for now. Due to the fact that it was better at

resolution and sound quality, it gives more reliable results. In Table 4, technical information was given about HTC Vive ("VIVE™ | Virtual Reality System", 2018).

Table 4: Specifications of the HTC Vive Headset from their website ("VIVE™ | VIVE Virtual Reality System", 2018).

HTC VIVE HEADSET	
Screen	Dual AMOLED 3.6'' diagonal
Resolution	1080 * 1200 pixels per eye (2160 * 1200 pixels combined)
Refresh Rate	90 Hz
Field of View	110 degree
Safety Features	Chaperone play area boundaries and front-facing camera
Sensors	SteamVR Tracking, G-sensor, gyroscope, proximity
Connections	HDMI, UB2.0, stereo 3.5 mm headphone jack, power, bluetooth
Input	Integrated microphone
Operating System	Windows 7 SP1, Windows 8.1 or later, Windows 10
Image of HMD	
Configuration of HDM	

3.2.4. Procedure

Participants performed the experiment individually and orderly (Figure 28). Some students who have claustrophobia had difficulties while experiencing VE because of the virtual reality headsets mechanism. Right before the participant started to perform, the conductor gave specific information and expectations about the experiment. In the beginning, the participant's demographic information was noted. The second step was experiencing the environment and it was expected that they should have an experience of one minute in the environment. Participants were free to do anything they want but only to touch was forbidden. While they were experiencing the environment, one observer noted their path that they were followed during the experiment. After one minute experience, they left the experiment environment and continued to answer questions which were helping to evaluate their perceptions towards to environments. That, with open ended questions their comparative opinions were interrogated toward RE and VE.

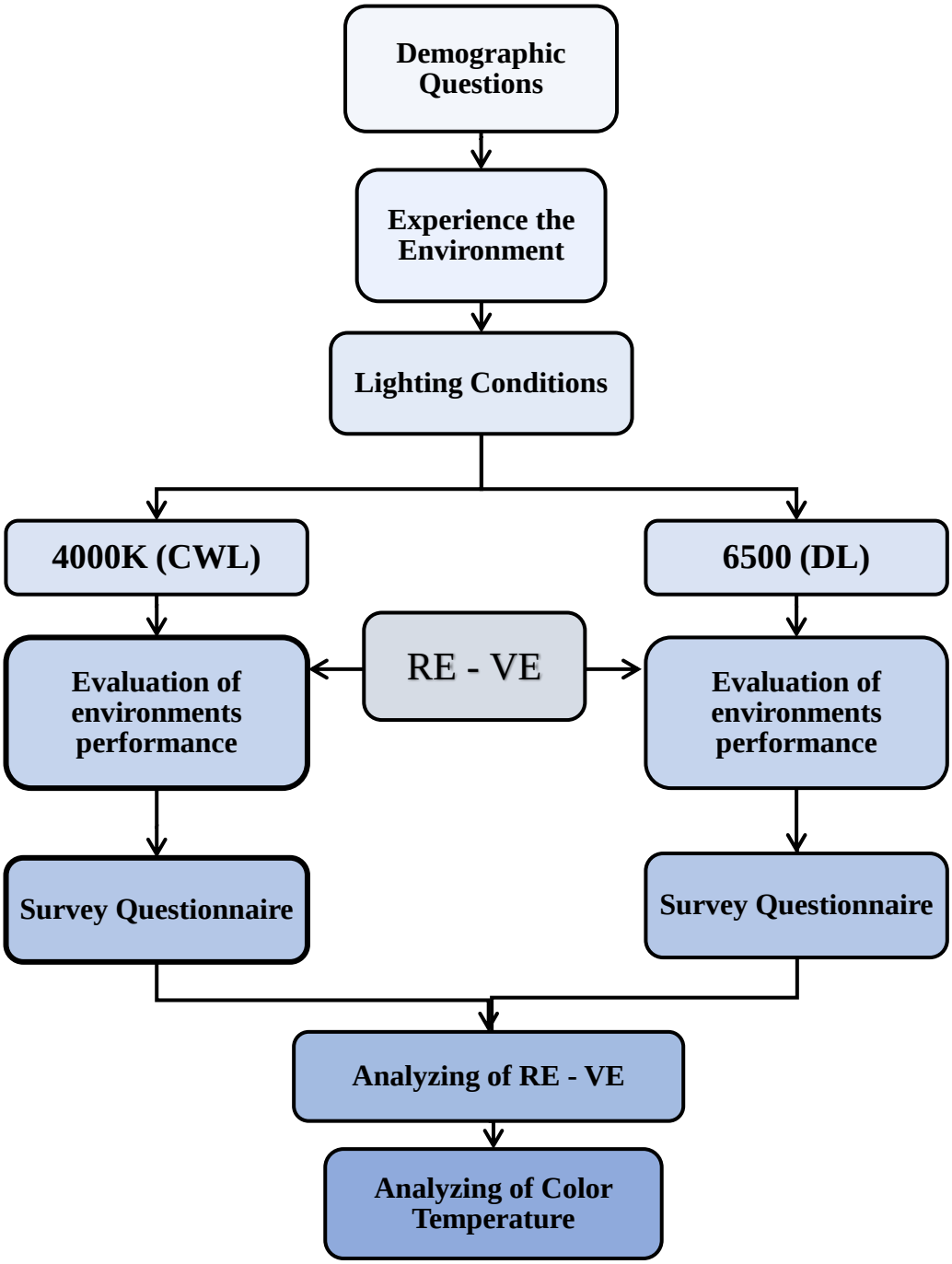


Figure 28: Schematic illustration of the experimental procedure.

3.2.5. Questionnaire

Questionnaire of the experiment consists of two kind of questionnaire method which were semantic differential scale by using 12 bipolar adjective pairs - dynamic-static, spacious-confined, formal-informal, usual-unusual, harmonious-discord, pleasant-unpleasant, attractive-unattractive, satisfying-unsatisfying, relax-tense, comfortable-uncomfortable, functional-nonfunctional, organized-disorganized with Five-Likert point and open ended questionnaire about spatial perception towards environments. And participants were expected to fill out the survey by themselves.

The purpose of this study is to reach individuals' preference about the spatial perception of two different environments. For that purpose, the study was prepared according to the basis of environmental appraisals; personal impressions and interpretations of spaces (Öztürk, Yılmazer and Ural, 2011). To measure perception towards environments were evaluated with the semantic differential measurement technic with 5-Likert system by using the set of bipolar adjective pairs. According to the Osgood (1952), Semantic Differential Method is used to measure the meaning of events, objects and concepts (Snider and Osgood, 1969). Kasmar (cited in Nasar, 1992) indicated that, if an individual wants to describe a physical environment, they need a proper scale for it. For that reason, the Lexicon of Environmental Descriptor Method was invented and developed by him. In literature, there are many studies that were carried out to improve Semantic Differential Method as a tool to comprehend individual impressions about environments from the point of lighting, acoustic, and so on (Flynn, Hendrick, Spencer & Martynik 1979). While the determination process of adjective pairs, literature retrieval was done and previous studies were analyzed.

Studies that were related to personal impression about interior office environment were chosen to construct questionnaires. Then the adjective pairs -dynamic-static, functional-nonfunctional, usual-unusual, harmonious-discord, spacious-confined, pleasant-unpleasant, attractive-unattractive, satisfying-unsatisfying, relax-tense, comfortable-uncomfortable, formal-informal, organized-disorganized- were translated into Turkish with the help of the dictionary and previous studies (Öztürk, et. al. 2011). After that part of questionnaire, three open ended questions were prepared about personal impressions or interpretations of participants towards to experienced environments. Both part of questionnaire was applied after participants experienced the environment. When they completed both phase of experiment, three open ended questions were asked them to make comparison and express their observations, opinions and comments about environments. As a first question their general opinions was asked. Then if there is any complains about environment, asked them to verbalize that complains. Last question, asked them to suggestions to make environments in a better quality (see Appendix A).

3.2.6. Statistical Analysis

Statistical Package for the Social Science (SPSS 23.0) is the software used to analyze the acquired data. These statistical analyses were stated with reference to the research questions of study (see Chapter 3.1.1). Shapiro Wilk-W, the most reliable normality test was implemented in this study to address the differences between RE and VE (SPSS base 13.0 user's guide, 2004). By implementing such testing method, the P value of the acquired data became measurable. If the P value of data set is less than

0,05, it can be interpreted that the data was not distributed normally due to using nonparametric tests for analyzing the differences between RE and VE.

Wilcoxon Sign-Rank is a testing method that can be classified under nonparametric tests which is used to compare two sets of data. The core feature of the Wilcoxon test that the sample group is repeated. Therefore, this testing method was implemented separately to understand the differences between the two environments under different color temperatures. (SPSS base 13.0 user's guide, 2004). Factor Analysis was used to evaluate the differences between the two color temperatures, 4000K (cool white light) and 6500K (daylight). The results were not sufficiently meaningful though (SPSS base 13.0 user's guide, 2004). Therefore, the t-test was conducted to specify the differences between color temperatures of lights instead of factor analysis. Since the sample group was not remained same, the type of t-test was selected as independent (SPSS base 13.0 user's guide, 2004). Then, to make sure about t-test outcomes and learn more about variables, multilinear regression analysis was run.

3.3. Results

The results consist of statistical analyses and its findings. The objective of this paper work focused mainly on addressing the core differences between RE and VE under two different lighting conditions. The results were classified under to subheadings. One subheading meant to address the differences between RE and VE. The other subheading discussed the influence of using two different color temperatures, 4000K and 6500K.

3.3.1. Comparison of Spatial Perception in Real and Virtual Environment

To make comparison between environments, at first sample group, it was handled in respective order (See Figure 22). Spatial perception in real environment (RE) was examined under two different color temperatures of light. In total, four different environments were created for the experiment. While test variables were evaluated, must be considered about sample groups and their order. It needed to be certain that only one variable was able to change which was the evaluated parameter. Otherwise, results have meaningless values or not reliable. For that aim, environments were examined under both condition separately. Since the sample group was the same, the Wilcoxon Sign Test was used for these related samples. Both environments exhibited significant differences from each other. However, one can say that almost same differences between RE and VE were observed under the two color temperatures. Under the color temperature of 4000K, value table demonstrated significant differences for adjective pairs of dynamic-static (p=0,000), functional-nonfunctional (p=0,037), usual-unusual (p=0,000) and harmonious-discord (p=0,001) and lastly, spacious-confined (p=0,002). On the other hand, the rest of pairs such as pleasant-unpleasant (p=0,782), attractive-unattractive (p=0,834), satisfying-unsatisfying (p=0,713), relax-tense (p=0,682), comfortable-uncomfortable (p=0,212), formal-informal (p=0.059), and organized-disorganized (p=0,939) did not exhibit significant difference in diverse environments (see Table 5). Participants perceived VE more dynamic, functional than RE, while RE was perceived more spacious, usual and formal than RE.

Table 5: Comparison between RE and VE (Wilcoxon Sign)

		Mean		P
	ADJECTIVES	**RE**	**VE**	**RE - VE**
4000K (Cool White Light)	Pleasant – Unpleasant	2,90	2,87	,782
	Attractive – Unattractive	2,10	2,03	,834
	Satisfying- Unsatisfying	3,07	3,17	,713
	Dynamic-Static	2,30	3,73	**,000**
	Relax – Tense	2,57	2,60	,682
	Comfortable- Uncomfortable	2,87	2,50	,212
	Organized – Disorganized	3,37	3,33	,939
	Functional - Nonfunctional	2,80	3,37	**,037**
	Formal – Informal	3,90	3,20	,059
	Usual – Unusual	3,37	1,60	**,000**
	Harmonious - Discord	3,80	2,33	**,001**
	Spacious - Confined	2,73	1,80	**,002**

To perform a reliable comparison between RE, Wilcoxon Sign-Rank test was applied one again for the color temperature of 6500K (daylight). Significant differences for adjective pairs were reported between two created environments (see Table 6). Dynamic-static (p=0,000), spacious-confined (p=0,001), formal-informal (p=0.003), usual-unusual (p=0,000) and harmonious-discord (p=0,005). On the other hand, the rest of pairs such as pleasant-unpleasant (p=0,623), attractive-unattractive (p=0,867), satisfying-unsatisfying (p=0,696), relax-tense (p=0,598), relax-tense (p=0,598), comfortable-uncomfortable (p=0,419), functional-nonfunctional (p=0,191) and organized-disorganized (p=0,844) did not exhibit significant difference in diverse environments. Participants perceived VE more dynamic and less usual, informal, harmonious and spacious than RE.

Table 6: Comparison between RE and VE under 6500K (Wilcoxon Sign)

		Mean		P
	ADJECTIVES	**RE**	**VE**	**RE - VE**
6500K (Daylight)	Pleasant – Unpleasant	2,77	2,87	,623
	Attractive – Unattractive	2,00	2,00	,867
	Satisfying- Unsatisfying	3,00	3,13	,696
	Dynamic-Static	2,30	3,97	**,000**
	Relax – Tense	2,53	2,63	,598
	Comfortable- Uncomfortable	2,67	2,47	,419
	Organized – Disorganized	3,30	3,30	,844
	Functional - Nonfunctional	3,00	3,40	,191
	Formal – Informal	3,73	2,77	**,003**
	Usual – Unusual	3,37	1,33	**,000**
	Harmonious - Discord	3,53	2,33	**,005**
	Spacious - Confined	2,77	1,73	**,001**

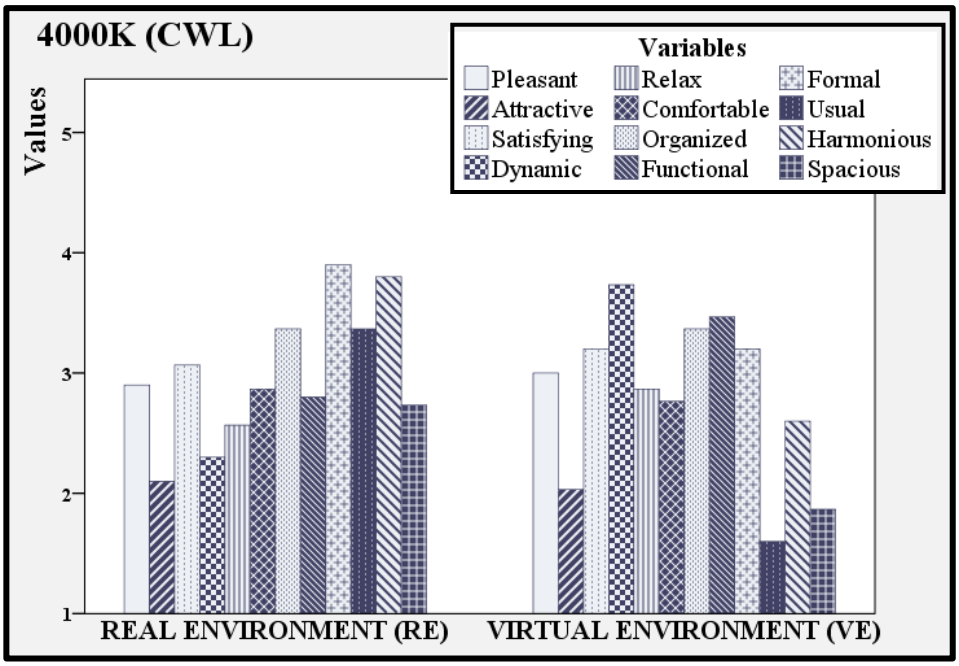
To sum-up, significant differences between RE and VE were observed by the participants for five adjective pairs. Even if the sample group did not remain the same, these differences were perceived almost similar under the two applied lighting conditions. Only the pair of functional-nonfunctional in 4000K and formal-informal in 6500K did not show similarity in differences. The participants perceived VE more dynamic and functional than RE. On the other hand, RE was described to be more usual, harmonious and spacious (see Table 7).

Table 7: Summary of comparison between RE and VE under

4000K (CWL)	Adjective Pairs	6500K (DL)
No significant. differences	**Pleasant – Unpleasant**	*No significant differences*
No significant differences	**Attractive – Unattractive**	*No significant differences*
No significant differences	**Satisfying- Unsatisfying**	*No significant. differences*
More dynamic in VE	**Dynamic-Static**	**More dynamic in VE**
No significant differences	**Relax – Tense**	*No significant differences*
No significant. Differences	**Comfortable- Uncomfortable**	*No significant. differences*
No significant differences	**Organized – Disorganized**	*No significant differences*
More functional in VE	**Functional - Nonfunctional**	*No significant differences*
No significant differences	**Formal – Informal**	**More formal in RE**
More usual in RE	**Usual – Unusual**	**More usual in RE**
More harmonious in RE	**Harmonious - Discord**	**More harmonious in RE**
More spacious in RE	**Spacious - Confined**	**More spacious in RE**

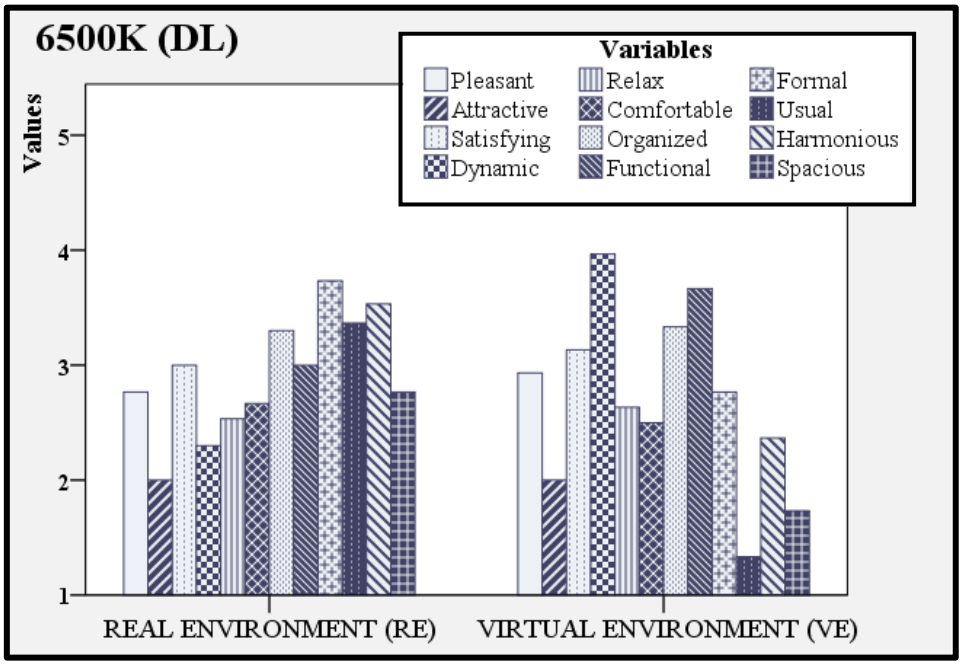
The mean values exhibited that the RE was perceived more positively than VE under the both lighting conditions (Figure 29). Nevertheless, this positive perceiving of RE was less noticeable under the 4000K lighting condition. Figures 29 shows the participants rating of 4000K over 6500K, especially in VE. Even though significant differences were the same in the two environments, VE showed more fluctuating differences more than RE.

A)



1: Not at all **2**: A little **3**: Moderately **4**:Quite a bit **5**: Exteremely

B)



1: Not at all **2**: A little **3**: Moderately **4**:Quite a bit **5**: Exteremely

Figure 29: Mean values of environments under 4000K (A) and 6500K (B).

Last part of questionnaire included open-ended questions. In these questions, their opinion, interpretations, complaints and suggestion were questioned towards experienced environment. According to participant's responses, frequency distribution bar chart was shaped. First question was asked them, their general opinions about the office environments. To make it easier, they were free to use adjectives that they wanted. As it seen in Figure 30, eleven variables were occurred and they varied depend on the environment. Three of these variable were aheaded of answers. First one was realistic, besides real environment, some participants perceived the virtual environment as like real. It means that, feeling of presence was high. Eighteen of participant had difficulty to move, but reason is not sickness or vertigo, they did not feel safe when their eyes were closed even though they saw and know that the room was empty. Three factor which are safe, challenging and afraid to move were related to blindness.

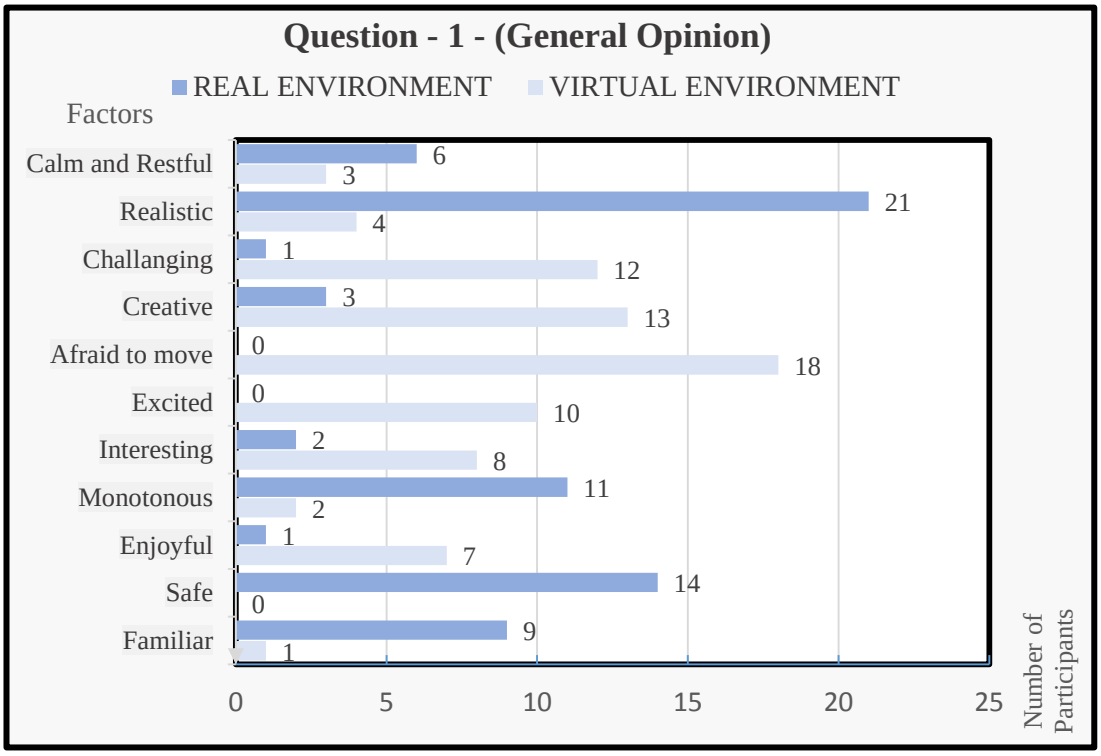


Figure 30: Frequently Distribution table of open ended question -1-

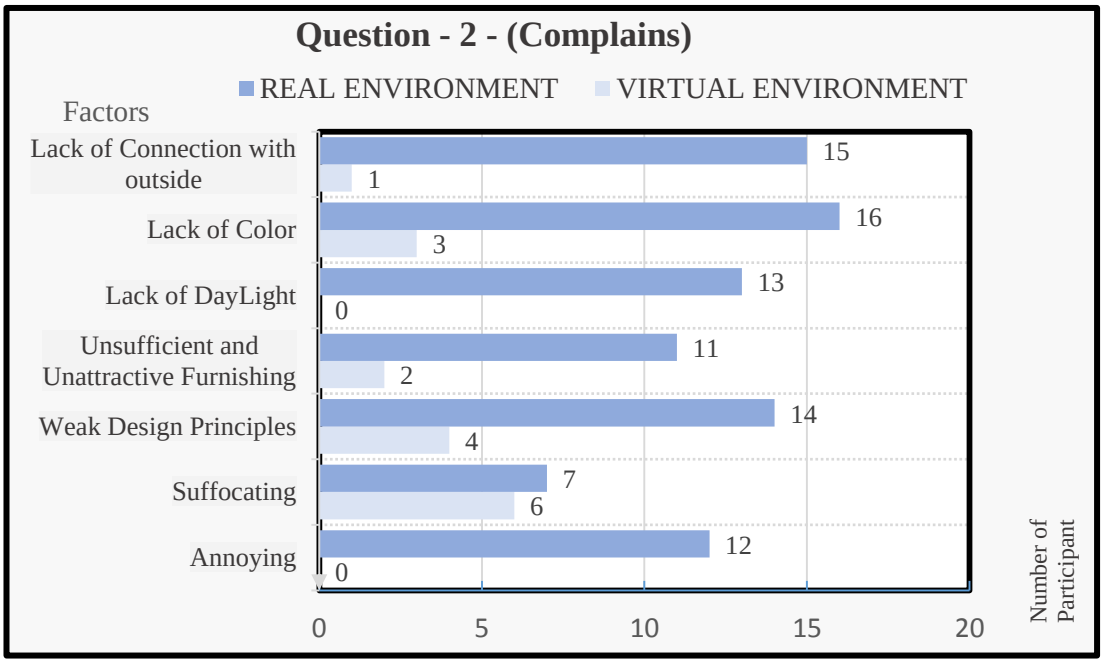


Figure 31: Frequently Distribution table of open ended question -2-

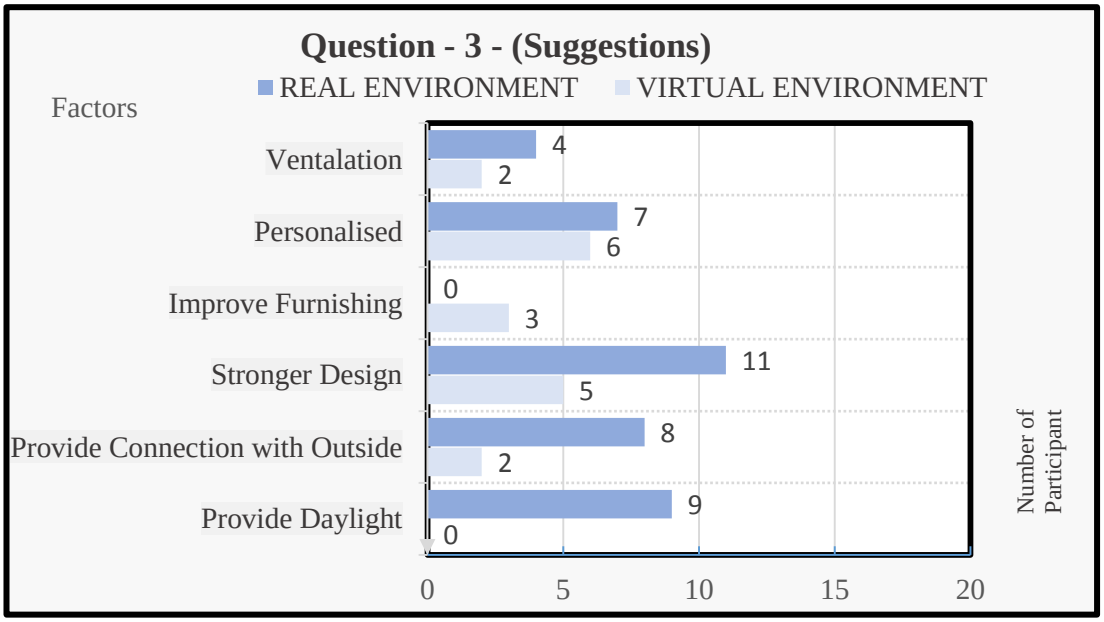


Figure 32: Frequently Distribution table of open ended question -3-

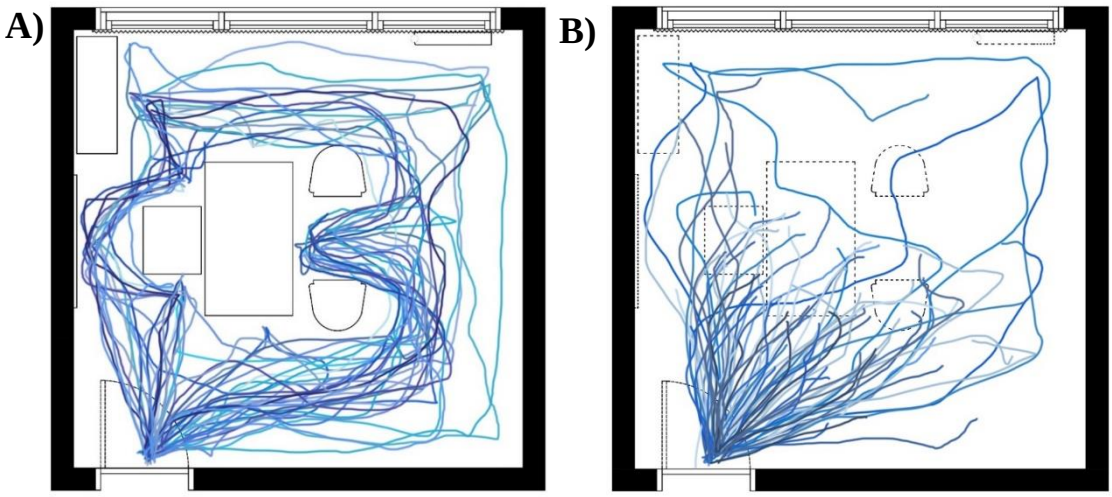


Figure 33: Pathway that they followed during the experiment
(A. Real Environment – B. Virtual Environment)

3.3.2. Effects of Color Temperature in Real and Virtual Environment

To make an interpretation of possible effects of color temperature on created environment, Factor Analysis was conducted. Since sample group were changed with the color temperature, non-parametric tests which makes comparison between two or more variables were not be able to appropriate for that situation.

Since the KMO values was greater than 0.60 and Bartlett's test results were meaningful (p=.000), it was possible to conduct the factor analysis.

In order to realize a fiducial inference two parameters have been considered;

- Accumulative variance with total percentage over 60%
- If the Egan value is greater than one, the SPSS is taken as a factor while grouping.

Effects of color temperature was examined with factor analysis. Since the KMO values of color temperatures (4000K= 0.613, 6500K= 0.618) were greater than 0.60 and Bartlett's test results were meaningful (p=.000), it was possible to conduct the factor analysis for this data set.

Table 8: KMO and Bartlett's tests for both color temperature.

KMO and Bartlett's Test		4000K	6500K
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**,613**	**,618**
Bartlett's Test of Sphericity	Approx. Chi-Square	160,401	171,899
	Sig.	**,000**	**,000**

As a common extraction method for factor analysis, principal component was uses for the both color temperature of light. Due to variables were correlated with each other and the number of participant was not in high standards according to the number of variables, direct Oblimin Method was selected as a Rotation Method. In total variance table, variables were classified into four different factors automatically according to their Eagan values under the color temperature of 4000K. Factor 1 includes adjective pairs of usual-unusual, harmonious-discord, dynamic-static, spacious-confined and organized-disorganized with the 18% of the total variance. Factor 2; formal-informal, comfortable-uncomfortable and relax-tense with a 16% of total variance but the adjective pairs of formal-informal was uploaded into factor 1 too. The interpretation of data was depended on the data sets, however, values were too close, best solution was not to count this variable as a component of that factor. Pleasant - unpleasant, satisfying- unsatisfying and functional-nonfunctional that lay under factor 3 and factor 4 were not sufficient to build a factor, since at least three variables are required to consider a factor (SPSS base 13.0 user's guide, 2004). The

antithesis of attractiveness was already included in the two factors and the values were close to each other. It means that either attractiveness had common features for both condition or it was not clear enough to respond. Usual-unusual and spacious-confined were uploaded to the component. The pair of usual-unusual was acceptable, whereas, the value of spacious-confined were closer. Thus if the pair of spacious-confined were eliminated, according to Cronbach Alfa, the reliability of the analysis would increase. The same problem was valid for the pair of organized. After the all corrections and controls only three pairs –harmonious-discord, usual-unusual, dynamic-static- left.

Table 9: Factor Analysis of 4000K; Total Variance

4000K (Total Variance Explained)						
Component	**Initial Eigenvalues**		**Extraction**		**Rotation**	
	Total	**Variance**	**% Variance**	**Cumulative %**	**% Variance**	**Cumulative %**
1	**2,334**	19,448	19,448	19,448	18,093	18,093
2	**2,024**	16,866	16,866	36,314	16,074	34,168
3	**1,582**	13,182	13,182	49,496	14,955	49,122
4	**1,274**	10,613	10,613	60,109	10,987	**60,109**
5	,984	8,197				
6	,868	7,231				
7	,709	5,906				
8	,664	5,531				
9	,518	4,313				
10	,444	3,698				
11	,373	3,108				
12	,229	1,906				

Extraction Method: Principal Component Analysis.

Table 10: Factor Analysis of 4000K; Pattern Matrix by using Oblimin Method

4000K (Cool White Light)				
Pattern Matrix[a]	Component			
	1	2	3	4
Usual – Unusual	,709			,326
Harmonious - Discord	,657			
Dynamic-Static	,631			
Spacious - Confined	~~-,629~~		~~-,390~~	
Organized – Disorganized	~~,541~~			~~,350~~
Comfortable- Uncomfortable		~~,898~~		
Relax – Tense		~~,870~~		
Formal – Informal	~~,342~~	~~-,465~~		
Pleasant – Unpleasant			~~,784~~	
Satisfying- Unsatisfying			~~,747~~	
Functional - Nonfunctional				~~,792~~
Attractive – Unattractive			~~,557~~	~~,576~~

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 8 iterations.

In order to reach fiducial inference, the percentage of cumulative total variance was 64% and the 6500K had four factors too which were values of Egan was higher than one. Factor 1, included usual-unusual, harmonious-discord, formal-informal, dynamic-static and organized-disorganized adjectives with 21% of total variance. Even if four factors were occurred according to Egan value, only factor one met the requirement of composing factor. And the rest of the adjective pairs; relax-tense, attractive-unattractive, comfortable-uncomfortable, functional-nonfunctional, satisfying-unsatisfying and pleasant-unpleasant were not had to necessity qualifications to form a factor.

Table 11: Factor Analysis of 6500K; Total Variance

6500K (Total Variance Explained)						
Compon	Initial Eigenvalues		Extraction		Rotation	
	Total	% Variance	% Variance	Cumulative %	% Variance	Cumulative %
1	2,577	21,479	21,479	2,577	21,479	21,479
2	2,127	17,727	39,206	2,127	17,727	39,206
3	1,711	14,262	53,468	1,711	14,262	53,468
4	1,339	11,159	64,627	1,339	11,159	**64,627**
5	,895	7,459	72,086			
6	,742	6,185	78,271			
7	,643	5,362	83,633			
8	,545	4,544	88,178			
9	,462	3,850	92,028			
10	,383	3,188	95,216			
11	,326	2,720	97,936			
12	,248	2,064	100,000			
Extraction Method: Principal Component Analysis.						

Table 12: Factor Analysis of 6500K; Pattern Matrix by using Oblimin Method

6500K (Daylight)				
Pattern Matrix[a]	Component			
	1	2	3	4
Usual – Unusual	,818			
Harmonious - Discord	,701			
Formal – Informal	~~,656~~		~~,401~~	
Dynamic-Static	-,626			
Spacious - Confined	,520			
Organized – Disorganized	,474			
Relax – Tense		~~,897~~		
Comfortable- Uncomfortable		~~,856~~		
Functional - Nonfunctional			~~,891~~	
Attractive – Unattractive			~~,567~~	~~,410~~
Pleasant – Unpleasant				~~,848~~
Satisfying - Unsatisfying				~~,730~~
Extraction Method: Principal Component Analysis. Rotation Method: Oblimin with Kaiser Normalization. a. Rotation converged in 13 iterations.				

When the two pattern matrixes of 4000K and 6500K were compared to each other, the 6500K was more meaningful than the 4000K. Only one factor was created for each lighting condition. Three mutual adjective pairs - usual-unusual, harmonious-discord and dynamic-static- were used for the both light conditions. Yet, two additional adjective pairs - spaciousness and organized- were included in the 6500K. As it seen in Table 11-13, in both color temperature, although four factors were arisen from the total variance, only first factor was be able to remained same. 4000K had five variables - usual-unusual, harmonious-discord, dynamic-static, spacious-confined, organized-disorganized - into Factor 1. Color temperature of 6500K contained six variables which was the same for five variable of 4000K and also formal-informal.

By making interpretation from Table 2, since all variable were same except formal-informal and the same variable that was attractiveness was uploaded into two factors, these mentioned environments did not demonstrate significant differences. Moreover, when the real and virtual environments were examined, significant pairs among RE and VE were almost same pairs in 4000K and 6500K. Thus, there were no significant differences of color temperature while considering and analyzing the real and virtual environment.

As it seen in tables, factor analysis was not clustered meaningly. The interpretation of Figure 34 was not be made in levelly, healthy and reliable. Therefore, to determine the significant effects of color temperature, independent t-test was applied instead of factor analyses.

	4000K (Cool White Light)	6500 (Daylight)
FACTOR I	Usual - Unusual	Usual - Unusual
	Harmonious - Discord	Harmonious - Discord
	Dynamic-Static	Dynamic-Static
		Spacious - Confined
		Organized - Disorganized

Figure 34: Variables that belongs to Factor 1

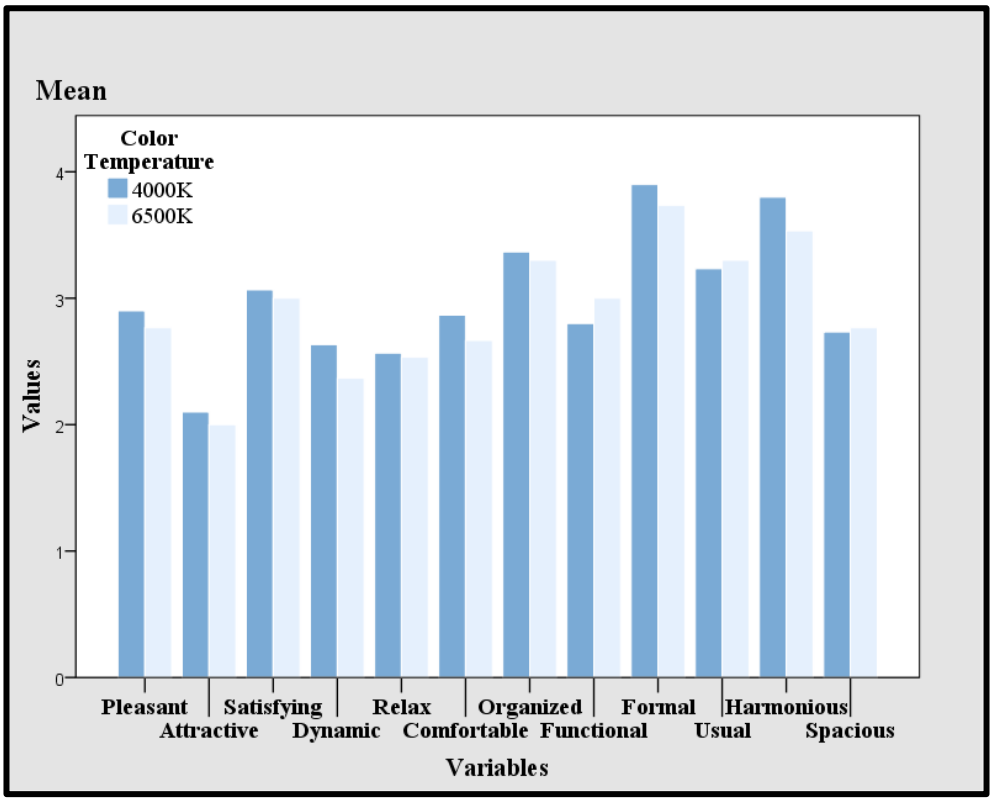
The recommended color temperature of office environment is 4000K according to IES (Illuminating Engineering Society). Therefore, it is more reasonable to consider the color temperature of 4000K as a control group, and the interpretation was made according to that (Kaufman & Christensen, 1987). Nevertheless, the results of independent t-test displayed no significant differences between the two color temperatures, 4000K (CWL) and 6500K (DL) in real environment (RE). As shown in Table 13, all the p values which are bold face values, were greater than the significant level (0.05). Although, no significant level was demonstrated in the RE, the mean values of the bar chart were generally higher –in positive manner- in 4000K than in 6500K. Only three adjective pairs in 4000K were not perceived as positively as in 6500K.

Table 13: Independent T-Test between 4000 K (CWL) and 6500 (DL) in RE .

REAL ENVIRONMENT (RE)	CT	N	Mean	Mean Differences	P
Pleasant – Unpleasant	4000K	30	2,90	,133	**,620**
	6500K	30	2,77		
Attractive – Unattractive	4000K	30	2,10	,100	**,653**
	6500K	30	2,00		
Satisfying- Unsatisfying	4000K	30	3,07	,067	**,853**
	6500K	30	3,00		
Dynamic-Static	4000K	30	2,63	,267	**,229**
	6500K	30	2,37		
Relax – Tense	4000K	30	2,57	,033	**,872**
	6500K	30	2,53		
Comfortable-Uncomfortable	4000K	30	2,87	,200	**,426**
	6500K	30	2,67		
Organized – Disorganized	4000K	30	3,37	,067	**,785**
	6500K	30	3,30		
Functional - Nonfunctional	4000K	30	2,80	-,200	**,382**
	6500K	30	3,00		
Formal – Informal	4000K	30	3,90	,167	**,576**
	6500K	30	3,73		
Usual – Unusual	4000K	30	3,23	-,067	**,822**
	6500K	30	3,30		
Harmonious - Discord	4000K	30	3,80	,267	**,338**
	6500K	30	3,53		
Spacious - Confined	4000K	30	2,73	-,033	**,891**
	6500K	30	2,77		

As it is shown in the graph, participants realized no significant differences when the lighting conditions changed in RE (Figure 36). Nevertheless, nine adjective pairs out of twelve had slightly higher mean values under 4000K (CWL). In other words, one can say that 4000K light condition was perceived more positively more than 6500K (DL). The pairs of functional-nonfunctional, usual-unusual and spacious-confined

presented higher levels under 6500K (Figure 36). In real environment, attractiveness showed the lowest values for both color temperatures, while the functional-nonfunctional adjective pair recorded the highest values in the same environment.



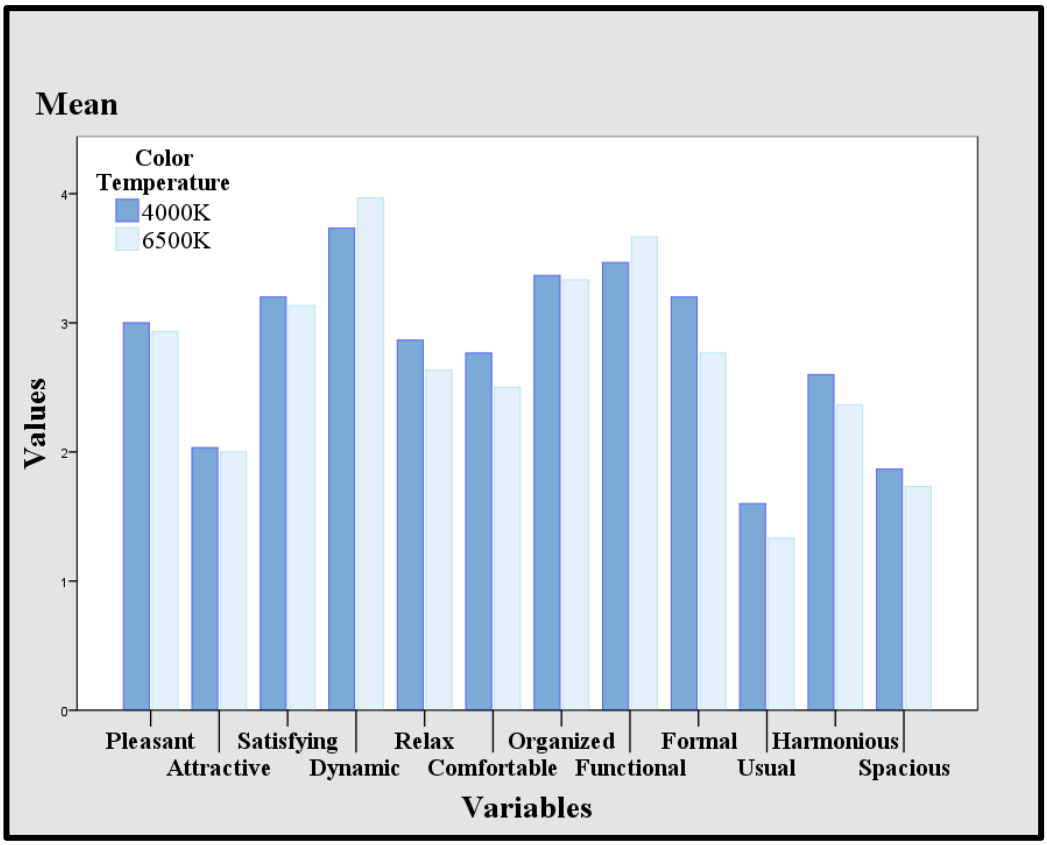
1: Not at all	**2**: A little	**3**: Moderately	**4**:Quite a bit	**5**: Exteremely

Figure 36: Mean values of variables under 4000K and 6500K in RE .

Results of virtual environment, the color temperature of light did not show any significant differences. All the p values in table 13, were higher than 0.05. Graphic (Figure 37) shows that participants perceived the 6500K significantly more dynamic in VE. Usual-unusual is the adjective pair with the least mean values under the two lighting conditions in VE.

Table 14: Independent T-Test between CWL and DL in virtual environment.

VIRTUAL ENVIRONMENT	CT	N	Mean	Mean Differences	P
Pleasant – Unpleasant	4000K	30	3,00	,067	**,729**
	6500K	30	2,93		
Attractive – Unattractive	4000K	30	2,03	,033	**,895**
	6500K	30	2,00		
Satisfying- Unsatisfying	4000K	30	3,20	,067	**,778**
	6500K	30	3,13		
Dynamic-Static	4000K	30	3,73	-,233	**,329**
	6500K	30	3,97		
Relax – Tense	4000K	30	2,87	,233	**,503**
	6500K	30	2,63		
Comfortable- Uncomfortable	4000K	30	2,77	,267	**,458**
	6500K	30	2,50		
Organized – Disorganized	4000K	30	3,37	,033	**,913**
	6500K	30	3,33		
Functional - Nonfunctional	4000K	30	3,47	-,200	**,496**
	6500K	30	3,67		
Formal – Informal	4000K	30	3,20	,433	**,169**
	6500K	30	2,77		
Usual – Unusual	4000K	30	1,60	,267	**,260**
	6500K	30	1,33		
Harmonious - Discord	4000K	30	2,60	,233	**,499**
	6500K	30	2,37		
Spacious - Confined	4000K	30	1,87	,133	**,664**
	6500K	30	1,73		



1: Not at all	**2**: A little	**3**: Moderately	**4**:Quite a bit	**5**: Exteremely

Figure 37: Mean values of variables under 4000K and 6500K in VE

The outcomes from the t-test exhibited that the different color temperatures had no significant effect on the spatial perception. However, a Regression Analysis was carried out in order to have insight into the effect of the adjective pairs, and to know which adjective in every adjective pair had more influence than the other.

The impact of color temperature was observed separately for each environment. Real environment was tested with linear regression first. As it shown in Table 15, the significant level had an upper value of 0.971. Therefore, it can be understood that there is no noticeable relation between dependent and independent variables, which means that the light condition was not an effective factor while perceiving the environment. since, this thesis has multiple independent factor, multiple regression

model was applied, in which the adjusted R square demonstrates the variable percentage of the Total Variance. The adjusted R square with value of -0,156 shows that the color temperature had only an impact of 15% on spatial perception from the total variance. Even if the regression value were not significantly different, the adjective pairs were examined one by one and their contribution to the total variable could be observed by looking at the significant levels in table 16. Since all values are upper than ,05, thus there was no noticeable effect of any adjective pairs for color temperature. As an addition, the values of column B demonstrated the contribution percentage of the adjectives into the dependent variable.

Table 15: Summary regression values in VE

Model		**Adjusted R Square**	**F**	**Sig.**
1	Regression	**-,156**	,359	**,971[b]**

Table 16: Coefficient table of regression in RE

Model		Unstandardized Coefficients		
		B	**Std. Error**	**Sig.**
	(Constant)	2,360	1,202	,056
	Pleasant – Unpleasant	-,065	,103	**,533**
	Attractive – Unattractive	-,046	,105	**,661**
	Satisfying- Unsatisfying	-,011	,083	**,894**
	Dynamic-Static	-,004	,129	**,974**
	Relax – Tense	-,003	,103	**,978**
	Comfortable- Uncomfortable	-,088	,088	**,324**
	Organized – Disorganized	-,061	,090	**,504**
	Functional - Nonfunctional	,073	,112	**,520**
	Formal – Informal	-,031	,075	**,679**
	Usual – Unusual	,025	,089	**,782**
	Harmonious - Discord	-,071	,073	**,334**
	Spacious - Confined	-,008	,104	**,940**

The same values were controlled in the virtual environment as well. Since the significant level was ,836, it is not possible to mention that the color temperature has any effect on the spatial perception in virtual environment. Similar to real environment, none of the adjective pairs recorded any significant differences. The adjusted R square was calculated in order to reach the effective percentage of color temperature on spatial perception. The value of R squared (,90) shows that the color temperature has an effect of only 9% on spatial perception(see Table 17)

Table 17: Summary regression values in VE

Model		Adjusted R Square	**F**	**Sig.**
1	Regression	**-,090**	,594	**,836[b]**

Table 18: Coefficient table of regression in VE

Model		Unstandardized Coefficients		
		B	**Std. Error**	**Sig.**
1	(Constant)	1,822	,805	,028
	Pleasant – Unpleasant	-,022	,119	**,855**
	Attractive – Unattractive	-,030	,112	**,790**
	Satisfying- Unsatisfying	,138	,191	**,473**
	Dynamic-Static	,016	,117	**,893**
	Relax – Tense	-,046	,117	**,698**
	Comfortable- Uncomfortable	-,104	,087	**,241**
	Organized – Disorganized	,024	,082	**,767**
	Functional - Nonfunctional	,050	,068	**,463**
	Formal – Informal	-,100	,063	**,119**
	Usual – Unusual	-,153	,099	**,128**
	Harmonious - Discord	-,012	,064	**,853**
	Spacious - Confined	-,002	,079	**,984**

CHAPTER 4

DISCUSSION

In order to have a meaningful and reliable comparison between real environment (RE) and virtual environment (VE), the concept toward environments and core component of these environments have to be understood. All dimensions and tiny details of the two environments have to be taken into account in order to have reasonable interpretation of a psychological phenomenon like perception. This thesis mainly focused on the spatial perception and the lighting effect in terms of color temperature. To have a complete understand of the virtuality concept, the light and vision topics were studied deeply. After then, an experimental study was conducted to study the differences between the two apparently similar environments.

4.1. Spatial Perception in the Real and Virtual Environment

The spatial perception was observed in both environments and under both color temperature of light. The same participants took part in the two experiments of real and virtual environments. Therefore, the sample groups of experiments were classified as repeated sampling method. As a consequence of this method, Wilcoxon Sing Rank test was applied to make comparison between the two environments, and means values were demonstrated in the graphics. Differences and similarities between the two environments were distinguished by the help of the open ended questions. According to test results, the real environment was perceived spacious, harmonious and usual much more than virtual environment under both color temperature (4000K and 6500K). On contrary, virtual environment was perceived more dynamic. Even though, four adjective pairs were perceived the same in terms of color temperatures, another two adjective pairs acted differently under 4000K and 6500K. The 4000K was perceived to be more functional in VE, while 6500K perceived to be more formal in the same environment.

In the Chapter 2.4 , it was mentioned that nowadays virtual environments studies mainly concentrate on the question of ‘Can virtual environment substitute the real environment in research experiments?’ or ‘Can virtual environment supplant by real environment, does it give the same responses with real experience?’. All of them - including this study- had a roughly comparable purpose.

In that research, with addressing the research questions there were no significant differences in the six adjective pairs - pleasant-unpleasant, attractive-unattractive, satisfying-unsatisfying, relax-tense, comfortable-uncomfortable and organized-disorganized. It is highly possible to encounter the same results found in this paper work in other literatures. Since the head mounted display (HDM) system was developed and applied successfully, most of the studies ended with no noticeable differences between real and virtual environments in terms of the subjective impression. Anderson and his coworkers (2018) conducted a study regarding the perception in RE and VE. This study meant to evaluate the subjective impression in five aspects; pleasant, interest, excitement, complexity and satisfaction. The outcomes exhibited that there was a high level of consistency with no significant differences to be mentioned between the both environments (Chamilothori, Wienold & Andersen, 2018). Moreover, another study was done by Naz and her research group (2017) in which they did record no considerable difference between the two environments from the psychological point of view (Naz, Kopper, Ryan P. & Nadin, 2017). Likewise, the time perception during the walk did show almost no differences between RE and VE (Bruder & Steinicke, 2013). Heydarian and his team. (2015) found no difference in his study when he made a comparison between real and virtual environments in terms of perception, and presence. The results revealed that participants act similarly in both environments.

On the other hand, even though there was no significant difference indicated in six pairs out of twelve, the other six adjective pairs acted differently. While the four pairs usual-unusual, harmonious-discord, spacious-confined and dynamic-static differed from one environment to another, the rest of two the pairs formal-informal and functional-nonfunctional were acted differently depends on the lighting condition. Some other studies mentioned about the differences between RE and VE in various aspects of spatial perception. M.LaVella (2017) stated that it is not possible to perceive the two environments exactly the same, even if the RE and VE were designed to be exactly the same in terms of appearance as vision is not the only sense that humans rely on to sense the surroundings. In HDM, spaciousness is one of this aspects that showed differences most of the time, which is valid for this thesis also. Under the both light conditions, real environments (RE) were perceived more spacious than the virtual one (VE). Expectative views from both environments were shown (see Figure 38). Lenses which used in HDM could be the main reason of spaciousness differences between environments. As it was mentioned in literatures, these lenses can cause same damage and distortion especially in vision of space, as such distortion lead to underestimate distances between the origin and the object. Although the technologies have developed, this distortion remains a real challenge for all the HDM.

According to Henry (1993) and Spross (2011) studies, participants underestimated all distances and sizes tremendously in VE and RE as well. In Henrys' work the ratio was %20, but due to technology improving Spross found that this ratio reduced to 15%. The perception in virtual environments (VE) were 8% lower than reality (Henry, 1992). Similarly, the qualitative factors were perceived relatively bigger, brighter, and more interesting in RE than VE (Spross, 2011). This paper work endorses the findings of these studies as the RE was perceived more spacious than VE in this thesis as well.

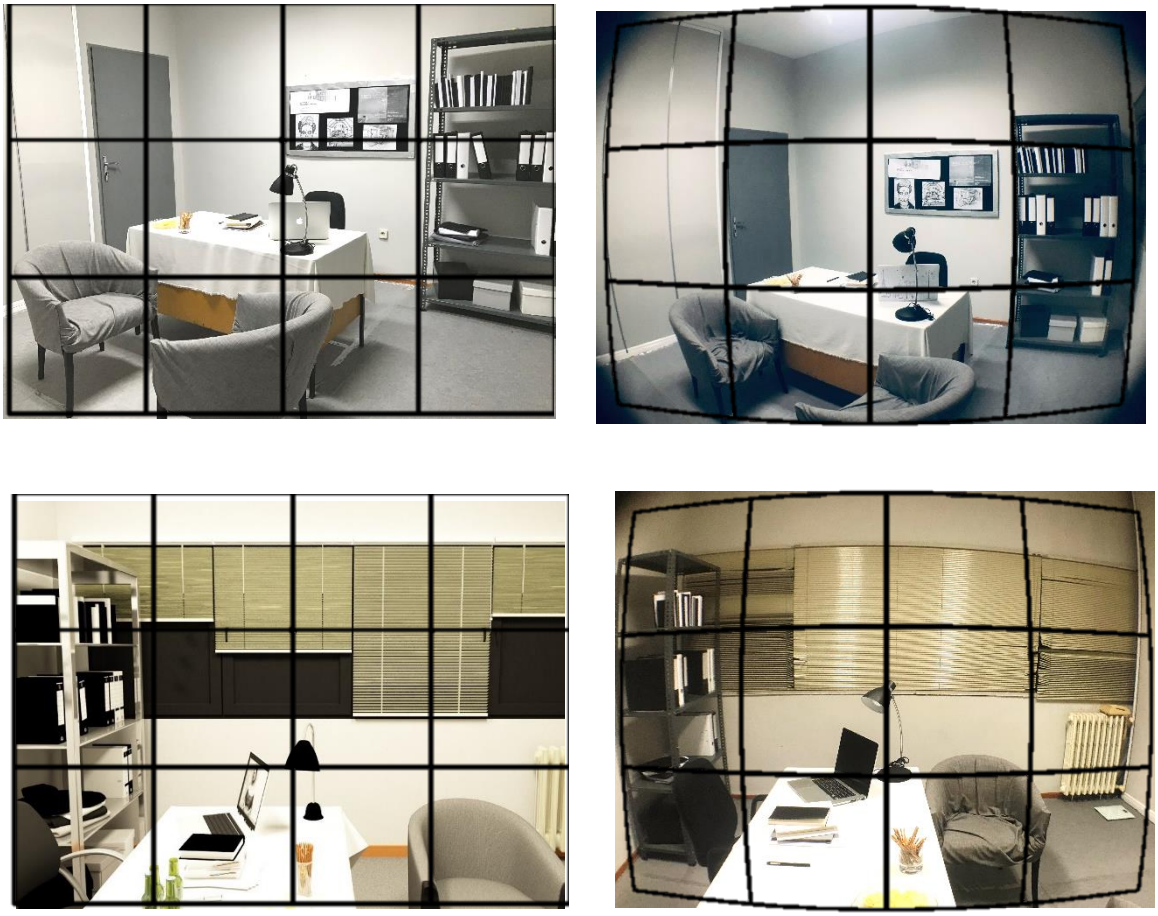


Figure 38: Possible lens distortions for the experiment of this thesis RE view -left-, VE view –right-

Usual-unusual, dynamic-static and harmonious-discord adjective pairs indicated differences between RE and VE under both color temperature. The participants perceived RE more usual and harmonious than the VE, whereas, they found virtual one more dynamic than the virtual environment.

In literature, no studies which were directly related to pairs of usual and harmonious were not found, however, some information from literature lead to some interpretations about those pairs. Özgen (2018) mentioned that young generation prefers HDM technology due to it is capability to offer new and dynamic experiences, new concepts, and to experience the imaginary and unusual world that they built themselves with no burdens. All these reasons were stimulating enough for young generation to try such technology (Özgen, 2018). As an added concern, apart from natural environment, unlimited and unnatural environments can be created to provide impossible or deadly experiences – e.g. bird eye fly- which would not be possible to achieve in the reality (Mudliyar, et. al., 2014).

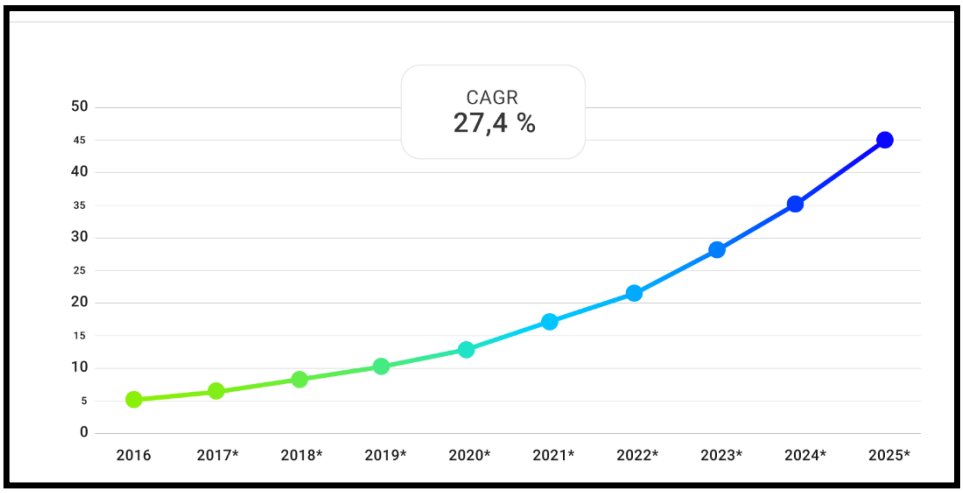


Figure 39: Gaming marketing throughout the years

Additionally, video games were phenomenal among college students and as all know, the appearance of virtual reality was based upon video games. The knowledge about virtual reality were taken from it and the game industry still counted as number one for virtual system (see Figure 30). In that kinds of games, generally presence level was high and action has priority in order to enjoy. Participants may associate the games with the research experience. That could be the reasonable factor for choosing VE as a more dynamic. When all of these information gathered together, it is more reasonable to assume that VE was perceived more attractive, dynamic and it presents abnormal experience especially to college students. VE was perceived more dynamic and unusual than RE. Based on these literature, it is reasonable to assume that VE would be more attractive than the RE for college. Yet, the attractiveness did not show significant differences.

Rest of the adjectives; pleasant-unpleasant, attractive-unattractive, satisfying-unsatisfying, relax-tense, comfortable-uncomfortable and organized-disorganized did not exhibit noticeable differences under both color temperature of light. The pair of functional-nonfunctional was perceived differently only under the 4000K (CWL). In contrary, formal-informal adjective pair was perceived differently only under the 6500K (DL). It can be said that no significant differences regarding the evaluation of both environments. In 2003, another comparative experiment was performed in Virtual Laboratory (Kort, Ijsselsteijn, Kooijman & Schuurmans, 2003). This study attempted to measure environmental factors assessing the perception with five categories –ambiance, evaluation, arousal, privacy and security- using 29 bipolar adjective pairs. Semantic differential scale was applied for adjective pairs. As a statistical analysis, factor analyses was used. According to factor analysis, all factors

were clustered with meaningful relationships in RE, whereas, they did not exhibit similar behavior in VE. As interpretation of that, VE did not perform any better than in RE. Adjective pairs of attractive-unattractive, pleasant-unpleasant, relax-tense and organized-disorganized (ordered-chaotic) were the common pairs that did not indicated any differences between environments for both this thesis and mentioned study. In addition to that, when the mean values were compared in RE and VE, participants evaluated RE more positively than VE for the majority of the adjectives pairs. This results were endorsed by the findings of the Kort and his team. They also indicated that RE was evaluated more positively than VE in all factors depending on mean values of adjective pairs. For a visual explanation, Figure 34 was used. These values were observed under 6500K. Although some exceptions such as dynamic and functional were perceived more positively in RE environment than in VE.

The first open ended question was; "what is your opinions about these office environments?" (Figure 33). They were permitted to express their thought the way they wanted. When the frequently distribution table was examined, it was figured out that the answers were generally not common for both environments which can be a sign of differences between RE and VE. The most given answers were addressing the reality and ordinary in RE, whereas for the VE, the answer was revolving around the safety issues. Kort and his team came out with similar results concerning safety. The challenging safety factors such as fear to move could be due to virtual blindness. However, participants' eyes were open and they were aware of the surroundings, the real worlds obstacles caused them fear.

As a second question, their complains were questioned. Even though RE were evaluated positively in comparison to VE, surprisingly, most of complains were

about RE. According to Kort and his team, these differences could be based on the experimental realism in the VE and the quality of simulation (Kort et. el. 2003). Their outcomes were endorsed by the open ended answer of this study. Lack of daylight and insufficient design and layout were the primary concerns of the answers. However, the achromatic color scheme was the most given complain. In 2011, Öztürk, Yılmazer and Ural made a study about chromatic and achromatic color schemes in office environments. According to their results, the chromatic scheme in office environment were found more pleasant, attractive, dynamic and satisfying than the achromatic one (Öztürk, Yılmazer, Ural, 2011). Eventually, the participants were asked to express their suggestions regarding the both environments. Their common prominent suggestions related to personalizing the environment and its design.

As it is discussed in the first open ended questions, the most mentioned subject was safety which was proved by the path plans analysis. The participants did not feel any certainty about it. As can be seen from the path plans, the participants strolled all around the room in RE (see Figure 33), while their movements were more limited in VE, which could be due to the virtual sicknesses or suffering from vertigo or queasiness.

4.2. The Effects of Color Temperature in the Real and Virtual Environment

The psychological effects of light were undeniable (Veitch, Newsham, 1998; Van Bommel, 2006; Knez, Enmarker, 1998; L. Mccoll & A. Veitch, 2001). There are many aspects of light which affecting the human psychology. Color temperature was one of these essential and effective aspects. The effect of a specific color temperature

of lighting elements used to vary greatly in the past from one study to another. But the effects of color temperature in virtual environment were not take place near the top. In that thesis, although three different tests –factor analysis, independent t-test, multilinear regression- were conducted for specifying effectiveness of color temperatures on real and virtual environments (RE and VE), effectiveness level were founded very weakly, therefore their impacts on environments were not significantly shown. Depends on regression test, in RE, effects of color temperature had 15% on the spatial perception, meanwhile, in VE, it decreased to the 9% (see Table 15-17)

As it was mentioned in previous paragraph, none of adjective pairs were indicated as an effective variable for perceiving the environments. In real environment, Boyce and Cuttle (1990) stated that color temperature has no effect on subjective impression. After than Gifford made a study in 1994, and he also search the differences between warm white light-cool white light and full spectrum fluorescent, he noted that as a conclusion, there was no any difference between color temperature of lighting element on cognitive performance, mood and attractiveness. Moreover, he added that if the difference would exist, it would be weak. In 2013, Shamsul, Sia and Karmegan attempted to observe the visual comfort of the participants when they were exposed to lights with different color temperatures; WWL (3000K) – CWL (4000K) – DL (6500K). They figured out that the participants preferred the WWL the least as it was less comfortable for them. Moreover, they recorded no considerable differences between CWL and DL. Khan (2016) and his co-workers performed experiment in which a comparison between three diversified surrounding in terms of light phenomenon was addressed. Their findings were in line with the outcomes of dissertation. Virtual environment (VE), exhibited similar behavior to

real environment (RE) in Khan experimental study, when the functional utilitarian elements were taken into consideration (Khan et. al., 2016).

There were possible reasons for effectiveness of color temperatures on spatial perception. Knez and Kers (2001) mentioned that exposure time could be an effective state measurement. The point is that the participants should stay in environments at least couple of hours in order to be able to observe and interpret whether the variables have any sort of effect on the environments. Such long exposure time is not recommended for applying in VE. Since, it would cause side effects such as sickness issues. Billger and Wastberg made several researches on the physical quality of light within RE and VE. According to one of their initial works in 2006, they reported that significant differences were recognized between the two environments. Since then, the color rendering technology has improved greatly (Billger & Wasberg, 2015). They conducted the exact study again in 2015, and they stated that regardless the basic improvement on light, results did not change. One of the main issues that they faced in their studies was the incorrect implementation into VE due to inefficient software. Slater and coworker also came out with similar conclusions when he stated that the issue of making a proper illumination comes mainly from technical reasons (Slater, Sadagic, Usoh & Schroeder, 2000). Illumination was also one of the main issues that had to be handled in this dissertation. Although all features were applied, light intensity did not approach the required values due to the used software.

Most of the searched literature studies meant to observe more the physical quality of light rather than its psychological manner. Therefore, this dissertation attempted to

study the color effect of lighting from a psychological point of view. The outcomes exhibited no considerable psychological differences among several color temperatures in RE and VE.

CHAPTER 5

CONCLUSION

The effects of different environments on spatial perception were investigated in full-scale experimental office environment and head mounted display (HMD) system comparatively. In addition to that, different color temperatures were analyzed in a manner of spatial perception. Experiment was conducted in four different environments;

- RE in 4000K color temperature
- RE in 6500K color temperature
- VE in 4000K color temperature
- VE in 6500K color temperature

Spatial perception is a psychological process which starts in the eyes and go through the brain and arisen from subjective impression and it may turn into physical responses under some conditions (Salvendy, 2013). Thus, it is a changeable that

depends on conditions and might differ from a person to another (Pierce & Gardner, 2002). Since the perception is a subjective concept, the perception evaluation process of all details has a high importance. Therefore, all details were attempted to be applied correctly for both environmental conditions, when the environments were constructed.

The results of the study indicated that real (RE) and virtual environments (VE) exhibited significant differences in four adjective pairs out of twelve under both color temperatures. Nevertheless, in each color temperature one adjective pair behaved differently. Dynamic-static, usual-unusual, spacious-confined and harmonious-discord are the pairs that changed according to the examined environment. RE was perceived more spacious, harmonious, unusual and less dynamic than VE in both color temperature. Functional-nonfunctional and formal-informal are the two pairs that acted differently, when the lighting condition was changed from 4000K (CWL) to 6500K (DL) or vice versa. For instance, functional-nonfunctional displayed significant difference under 4000K, whereas, it showed almost no difference under the condition of 6500K. Formal-informal adjective pair acted completely opposite, where in it showed no considerable difference under the 4000K light condition, while it was totally different under the 6500K. The remaining six adjective pairs recorded almost no differences between RE and VE, under both color temperature.

Generally, the environmental appraisal used to be the commonly used method to measure the spatial perception (IJsselsteijn, et. al. 2003; Öztürk, Yılmazer & Ural, 2011; Spross 2011; Chamilothori,, et. al. 2018). These appraisal values were

reevaluated in order to demonstrate the differences between 4000K and 6500K color temperatures.

As an added concern, the factor analysis results of the two lighting conditions - 4000K and 6500K- were similar to each other. Although, this paper work could achieve its objectives, it faced some core limitations such as transferring the light conditions to the virtual environment. Due to engineering issues, the “Lighting Condition” was not stimulated correctly.

Most of the comparative studies between RE and VE on perception were mainly focusing on the kind of perception that has a control group or exact numerical values to compare (e.g. distance estimation by Henry and Furness (1993) and time perception by Bruder and Steinicke (2013). On the other hand, when the evaluation was done with the aspect of spatial perception, since the control group or exact numerical values do not exist, other environmental factors were gained importance and should be taken into account. It was attempted to be control as much as stable. Therefore, all details were attempted to be applied correctly for both environmental conditions, when the environments were constructed.

According to Knez (2001), when the light perception is investigated to improve the light power, some exposing factors should be controlled over. Noise and air temperature of the area are two of these factors that need to be controlled over. Keeping these factors under control during the experiment provides more reliable results. Enander and Hygge (1990) stated that the ideal degree is 21C and the ideal

level of noise is 45 dbA in Holmberg study. (1993). For the future studies, these variables will be advised to be manageable as much as possible.

As a conclusion, the virtual reality (VR) witnesses a rapid development and obviously it will continue that way. Therefore, it will be subject for more researches that will attempt to address its new aspects. The experiments in other literatures did not examine the effect of the color temperature the way it was examined in this thesis. It can be a starting point for future studies of color temperatures.

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APPENDICES

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Appendix A.
A1. Questionnaire of Experiment in English

SURVEY

This survey conducted for thesis of MFA in Bilkent University and Environmental Design under the topic of *comparative study on spatial perception in virtual and real office environments under different lighting conditions*. (4000K and 6500K)
It will not be used for any different purposes and will not be published.

☐ **REAL** ☐ **VIRTUAL**

☐ **1st Entrance** ☐ **2nd Entrance**

In 1st step, participants must answer personal questions. Then the 2nd step, after spending 1 minute in the experimental environment (without touch anything) they will be expected to respond appropriate level of given adjective pairs and open ended questions.

1. **Personal Questions**

Age:

Gender: ☐ **M** ☐ **F** ☐ **Other**

Department :

Did you use lenses or glasses? **Yes** ☐ **No** ☐

2. **PLEASE ENTER THE EXPERIMENTAL ENVIRONMENT. YOU HAVE 1 MINUTE TO SPEND IN THERE. PLEASE DO NOT TOUCH ANYTHING.**

3. **Perception**

   a. Please evaluate adjective pairs about the perception of environment with considering the rating scale which is giving below.

   1. Not at all 2. A little 3. Moderately 4. Quite a bit 5. Extremely

	1	2	3	4	5	
Unpleasent						Pleasent
Unattractive						Attractive
Unsatisfying						Satisfying
Static						Dynamic
Tense						Relax
Uncomfortable						Comforfi
Disorganized						Organize
Nonfunctional						Functional
Informal						Formal
Unusual						Usual
Discord						Harmonious
Confined						Spacious

b. Please answer the open-ended questions**.**

1. What is your opinions about this office environment?

2. Is there any complaint about perception of this office environment? (lighting, color or heat?)

3. If your answer is yes, what is your recommendation about it?

4. What are similarities and differences between RE and VE?

Thank you for attending the experiment ☺

Appendix A.
A2. Questionnaire of Experiment in Turkish

ANKET

Bu araştırma Bilkent Üniversitesi İç Mimarlık ve Çevre Tasarımı Bölümü Yüksek Lisans programı kapsamında "gerçek ve sanal ofis ortamında farklı renk sıcaklıklarının (4000K ve 6500K) mekan algısı üzerinde etkisinin karşılaştırmalı olarak incelenmesi" başlıklı tez çalışması için yapılmaktadır. Farklı bir amaçla kullanılmayacak ve yayınlanmayacaktır. Katılımınız için teşekkürler.

☐ **GERÇEK** ☐ **SANAL**

☐ **İlk Giriş** ☐ **İkinci Giriş**

Birinci aşamada deney öncesi demografik soruları cevaplanmanız bekleniyor. İkinci aşamada, deney ortamında 1 dakika geçirdikten sonra ortamdaki mekan algınızı uygun dereceyi işaretleyerek ve açık uçlu soruları cevaplandırarak değerlendirmeniz istenecek. (İçerde geçirdiğiniz süre zarfında nesnelere dokunamazsınız).

1. **Kişisel Bilgiler**

Yaş:

Cinsiyet: **E** ☐ **K** ☐ **Diğer** ☐

Bölüm :

Gözlük veya kontak lens kullanıyor musunuz? **Evet** ☐ **Hayır** ☐

2. **DENEY ORTAMINA GİRİŞ YAPABİLİRSİNİZ. İÇERİDE 1 DAKİKA GEÇİRECEKSİNİZ. LÜTFEN HERHANGİ BİR ŞEYE DOKUNMAYINIZ.**

3. **Mekan Algısı;**

   A. Lütfen ortamla ilgili görüşlerini aşağıdaki ölçeği dikkate alarak derecelendiriniz.

Çok az veya hiç 2. Biraz 3. Ortalama 4. Oldukça 5. Çok fazla

	1	**2**	**3**	**4**	**5**	
Hoş Değil						Hoş
İtici						Çekici
Tatmin Etmeyen						Tatmin Edici
Statik						Dinamik
Gerginleştirici						Gevşetici
Rahatsız						Rahat
Düzensiz						Düzenli
Fonksiyonel Değil						Fonksiyonel
Resmi Olmayan						Resmi
Alışılmışın Dışında						Alışılmış
Uyumsuz						Uyumlu
Sıkışık						Ferah

B. Lütfen aşağıda gördüğünüz açık-uçlu soruları cevaplandırınız.

1. Bu ofis ortamı ile ilgili düşünceleriniz nelerdir?

2. Ofis algısıyla ilgili herhangi bir şikayetiniz veya rahatsız olduğunuuz nokta var mı? (ışıklandırma, renk, sıcaklık)

3. Eğer cevabınız evet ise, önerileriniz nelerdir?

4. Gerçek ve sanal ortamdaki farklılıklar veya benzerlikler size göre nelerdir?

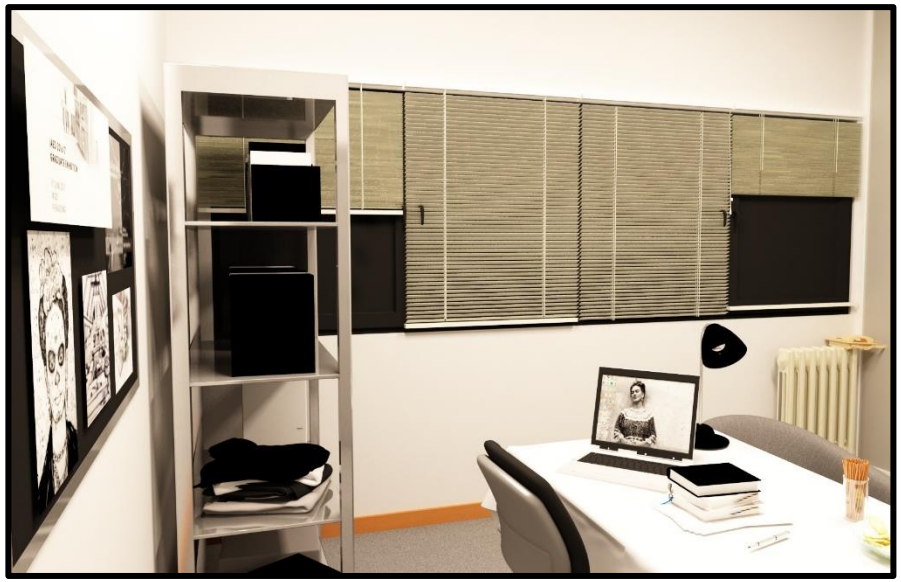
Anketimize katılım sağladığınız için teşekkür ederiz.

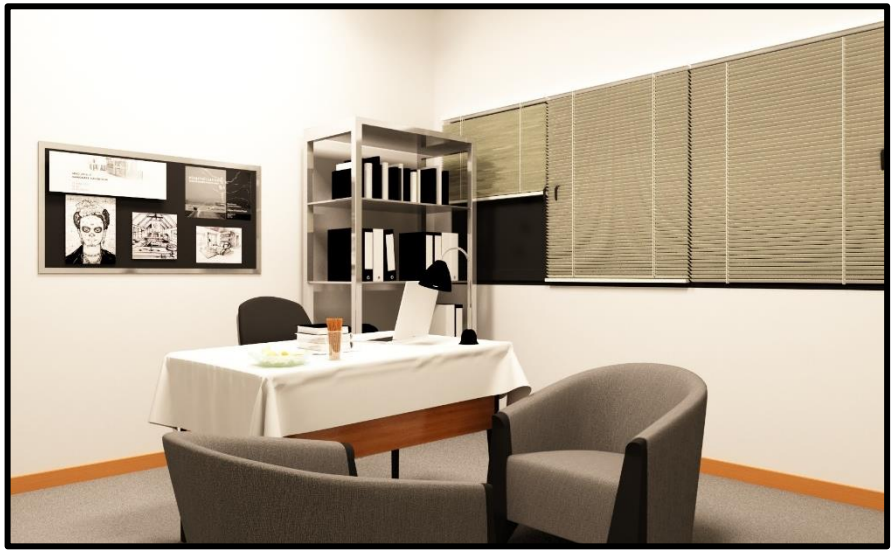
Appendix B.

Photographs of the Experiment Setup and Environment

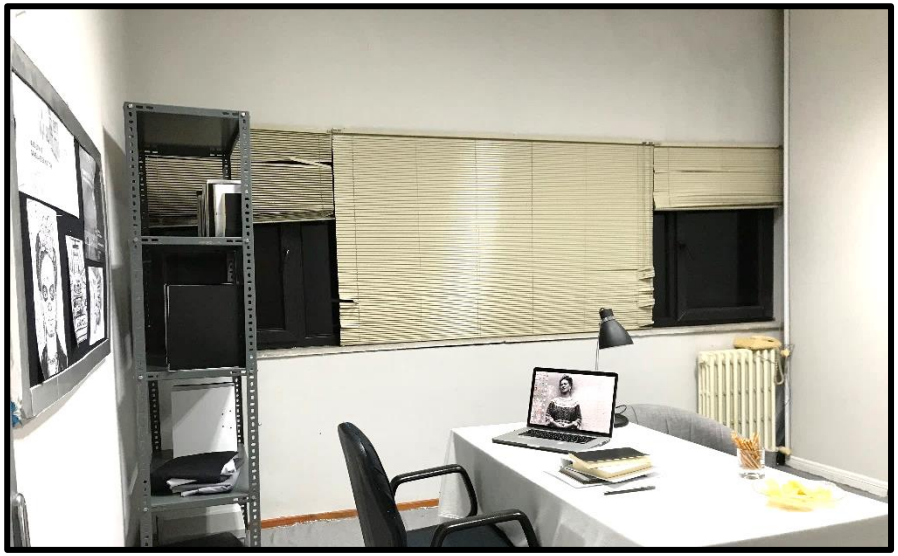
Figure B1. While the virtual part testing

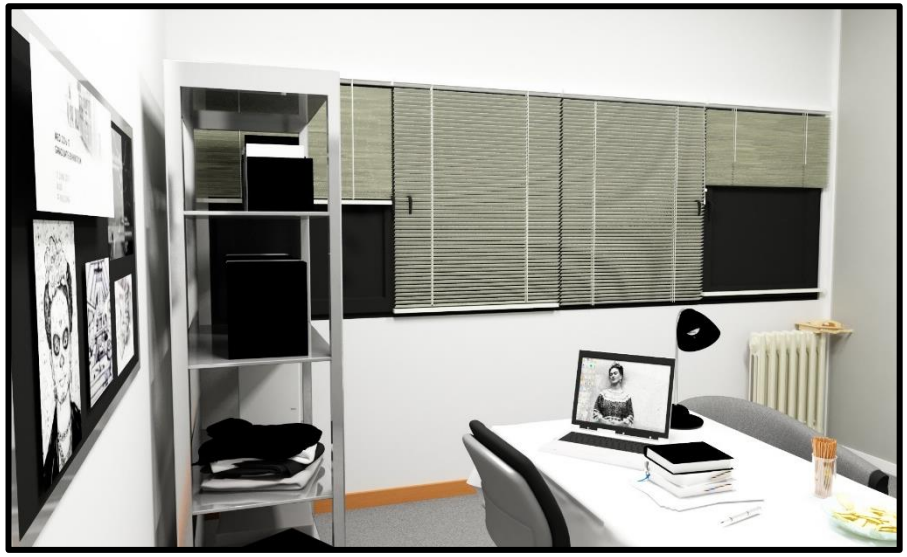
Appendix B1. Real and Virtual Environments under 4000K

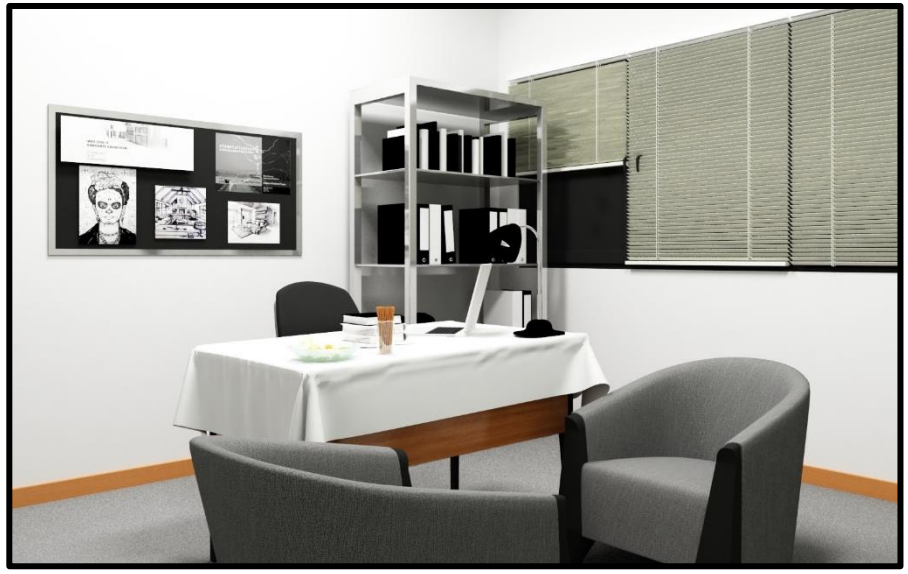




Appendix B2. Real and Virtual Environments under 6500K







Appendix C.
Statistical Analysis

Table C1. Wilcoxon Sign-Rank Test in 4000K

Test Statistics[a]												
	Pleasant Unpleasant	Attractive Unattractive	Satisfying-Unsatisfying	Dynamic Static	Relax Tense	Comfortable Uncomfortable	Organized Disorganized	Functional Nonfunctional	Formal Informal	Usual Unusual	Harmonious - Discord	Spacious Confined
Z	-,276[b]	-,209[b]	-,368[c]	-4,000[c]	-,410[c]	-1,249[b]	-,076[c]	-2,091[c]	-1,891[b]	-3,806[b]	-3,470[b]	-3,165[b]
Asymp. Sig. (2-tailed)	,782	,834	,713	,000	,682	,212	,939	,037	,059	,000	,001	,002

a. Wilcoxon Signed Ranks Test
b. Based on positive ranks.
Based on negative ranks.

Table C2. Wilcoxon Sign-Rank Test in 6500K

Test Statistics[a]												
	Pleasant Unpleasant	Attractive Unattractive	Satisfying-Unsatisfying	Dynamic Static	Relax Tense	Comfortable Uncomfortable	Organized Disorganized	Functional Nonfunctional	Formal Informal	Usual Unusual	Harmonious - Discord	Spacious Confined
Z	-,491[b]	-,042[c]	-,391[b]	-4,333[b]	,528[b]	-,808[c]	-,133[b]	-1,309[b]	-2,989[c]	-4,532[c]	-2,786[c]	-3,382[c]
Asymp. Sig. (2-tailed)	,623	,967	,696	,000	,598	,419	,894	,191	,003	,000	,005	,001

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.
c. Based on positive ranks.

Table C3. Correlation table of regression analysis in real environment

Correlations								
		CT	Pleasant Unpleasant	Attractive Unattractive	Satisfying-Unsatisfying	Dynamic Static	Relax Tense	Comfortable Uncomfortable
Pearson Correlation	CT	1,000	-,094	-,058	-,038	-,010	-,043	-,115
	Pleasant Unpleasant	-,094	1,000	,093	,579	-,159	-,025	-,227
	Attractive Unattractive	-,058	,093	1,000	,442	,381	,062	,056
	Satisfying Unsatisfying	-,038	,579	,442	1,000	,132	-,108	-,324
	Dynamic-Static	-,010	-,159	,381	,132	1,000	,178	,218
	Relax -Tense	-,043	-,025	,062	-,108	,178	1,000	,149
	Comfortable Uncomfortable	-,115	-,227	,056	-,324	,218	,149	1,000
	Organized Disorganized	-,043	-,175	-,235	-,222	-,262	,044	-,084
	Functional Nonfunctional	,094	-,146	,238	,031	,400	,096	,149
	Formal -Informal	-,097	-,050	,152	,091	,112	,204	-,061
	Usual -Unusual	,041	,153	-,187	,059	-,540	-,276	-,401
	Harmonious Discord	-,153	,000	-,145	-,100	-,039	-,057	-,099
	Spacious Confined	,028	-,403	-,113	-,391	-,146	-,084	,088
Sig. (1-tailed)	CT	.	,242	,332	,389	,471	,374	,194
	Pleasant – Unpleasant	,242	.	,245	,000	,117	,425	,043
	Attractive – Unattractive	,332	,245	.	,000	,002	,321	,337
	Satisfying-Unsatisfying	,389	,000	,000	.	,162	,211	,007
	Dynamic-Static	,471	,117	,002	,162	.	,091	,050
	Relax – Tense	,374	,425	,321	,211	,091	.	,131
	Comfortable-Uncomfortable	,194	,043	,337	,007	,050	,131	.
	Organized – Disorganized	,374	,095	,038	,047	,023	,371	,266
	Functional - Nonfunctional	,241	,137	,036	,409	,001	,237	,132
	Formal Informal	,234	,355	,128	,248	,201	,062	,325
	Usual – Unusual	,381	,126	,080	,330	,000	,018	,001
	Harmonious - Discord	,125	,499	,139	,227	,385	,336	,231
	Spacious Confined	,417	,001	,199	,001	,136	,265	,256

Correlations							
		Organized Disorganized	Functional Nonfunctional	Formal Informal	Usual Unusual	Harmonious - Discord	Spacious Confined
Pearson Correlation	CT	-,043	,094	-,097	,041	-,153	,028
	Pleasant – Unpleasant	-,175	-,146	-,050	,153	,000	-,403
	Attractive – Unattractive	-,235	,238	,152	-,187	-,145	-,113
	Satisfying- Unsatisfying	-,222	,031	,091	,059	-,100	-,391
	Dynamic-Static	-,262	,400	,112	-,540	-,039	-,146
	Relax – Tense	,044	,096	,204	-,276	-,057	-,084
	Comfortable,Uncomfortable	-,084	,149	-,061	-,401	-,099	,088
	Organized -Disorganized	1,000	,006	,257	,201	-,069	-,107
	Functional Nonfunctional	,006	1,000	,113	-,494	-,190	-,374
	Formal – Informal	,257	,113	1,000	,100	,133	-,273
	Usual – Unusual	,201	-,494	,100	1,000	-,056	,119
	Harmonious - Discord	-,069	-,190	,133	-,056	1,000	,049
	Spacious - Confined	-,107	-,374	-,273	,119	,049	1,000
Sig. (1-tailed)	CT	,374	,241	,234	,381	,125	,417
	Pleasant – Unpleasant	,095	,137	,355	,126	,499	,001
	Attractive – Unattractive	,038	,036	,128	,080	,139	,199
	Satisfying- Unsatisfying	,047	,409	,248	,330	,227	,001
	Dynamic-Static	,023	,001	,201	,000	,385	,136
	Relax – Tense	,371	,237	,062	,018	,336	,265
	ComfortableUncomfortable	,266	,132	,325	,001	,231	,256
	Organized – Disorganized	.	,482	,026	,065	,302	,212
	Functional - Nonfunctional	,482	.	,198	,000	,076	,002
	Formal – Informal	,026	,198	.	,228	,159	,019
	Usual – Unusual	,065	,000	,228	.	,337	,186
	Harmonious - Discord	,302	,076	,159	,337	.	,356
	Spacious - Confined	,212	,002	,019	,186	,356	.

Table C4. Correlation table of regression analysis in virtual environment

Correlations								
		CT	Pleasant Unpleasant	Attractive Unattractive	Satisfying-Unsatisfying	Dynamic Static	Relax Tense	Comfortable Uncomfortable
Pearson Correlation	CT	1,000	-,046	-,017	-,037	,128	-,088	-,098
	Pleasant Unpleasant	-,046	1,000	,287	,110	-,234	,354	,272
	Attractive Unattractive	-,017	,287	1,000	,307	-,552	,266	-,021
	Satisfying Unsatisfying	-,037	,110	,307	1,000	-,174	,806	,689
	Dynamic-Static	,128	-,234	-,552	-,174	1,000	-,335	,063
	Relax -Tense	-,088	,354	,266	,806	-,335	1,000	,677
	Comfortable Uncomfortable	-,098	,272	-,021	,689	,063	,677	1,000
	Organized Disorganized	-,014	,054	,161	,314	-,173	,199	,166
	Functional Nonfunctional	,090	-,038	,241	,039	,018	-,006	-,115
	Formal -Informal	-,180	-,077	,015	-,260	-,109	-,180	-,247
	Usual -Unusual	-,148	-,280	,068	,151	-,199	-,042	-,186
	Harmonious Discord	-,089	-,227	-,020	,286	-,233	,137	,146
	Spacious Confined	-,057	-,086	-,221	,032	-,028	,022	-,046
Sig. (1-tailed)	CT	.	,364	,447	,389	,164	,252	,229
	Pleasant Unpleasant	,364	.	,013	,201	,036	,003	,018
	Attractive Unattractive	,447	,013	.	,008	,000	,020	,437
	Satisfying Unsatisfying	,389	,201	,008	.	,092	,000	,000
	Dynamic-Static	,164	,036	,000	,092	.	,004	,316
	Relax -Tense	,252	,003	,020	,000	,004	.	,000
	Comfortable Uncomfortable	,229	,018	,437	,000	,316	,000	.
	Organized Disorganized	,456	,342	,110	,007	,094	,063	,102
	Functional Nonfunctional	,248	,386	,032	,384	,446	,483	,190
	Formal -Informal	,084	,281	,456	,023	,204	,084	,029
	Usual -Unusual	,130	,015	,303	,125	,064	,376	,078
	Harmonious Discord	,249	,040	,441	,013	,037	,149	,133
	Spacious Confined	,332	,256	,045	,405	,415	,435	,363

Correlations							
		Organized Disorganized	Functional Nonfunctional	Formal Informal	Usual Unusual	Harmonious - Discord	Spacious Confined
Pearson Correlation	CT	-,014	,090	-,180	-,148	-,089	-,057
	Pleasant - Unpleasant	,054	-,038	-,077	-,280	-,227	-,086
	Attractive - Unattractive	,161	,241	,015	,068	-,020	-,221
	Satisfying - Unsatisfying	,314	,039	-,260	,151	,286	,032
	Dynamic-Static	-,173	,018	-,109	-,199	-,233	-,028
	Relax -Tense	,199	-,006	-,180	-,042	,137	,022
	Comfortable Uncomfortable	,166	-,115	-,247	-,186	,146	-,046
	Organized - Disorganized	1,000	,066	,208	,035	,230	,486
	Functional - Nonfunctional	,066	1,000	,007	,201	,006	-,105
	Formal -Informal	,208	,007	1,000	-,085	-,005	,152
	Usual -Unusual	,035	,201	-,085	1,000	,316	,231
	Harmonious - Discord	,230	,006	-,005	,316	1,000	,052
	Spacious - Confined	,486	-,105	,152	,231	,052	1,000
Sig. (1-tailed)	CT	,456	,248	,084	,130	,249	,332
	Pleasant - Unpleasant	,342	,386	,281	,015	,040	,256
	Attractive - Unattractive	,110	,032	,456	,303	,441	,045
	Satisfying - Unsatisfying	,007	,384	,023	,125	,013	,405
	Dynamic-Static	,094	,446	,204	,064	,037	,415
	Relax -Tense	,063	,483	,084	,376	,149	,435
	Comfortable Uncomfortable	,102	,190	,029	,078	,133	,363
	Organized - Disorganized	.	,308	,055	,395	,038	,000
	Functional - Nonfunctional	,308	.	,479	,062	,480	,212
	Formal -Informal	,055	,479	.	,260	,483	,123
	Usual -Unusual	,395	,062	,260	.	,007	,038
	Harmonious Discord	,038	,480	,483	,007	.	,346
	Spacious - Confined	,000	,212	,123	,038	,346	.