EFFECT OF AREA ON COLOR HARMONY IN INTERIOR SPACES

A Ph.D. Dissertation

by
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June 2015

To my parents

EFFECT OF AREA ON COLOR HARMONY IN INTERIOR SPACES

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

by

SEDEN ODABAŞIOĞLU

In Partial Fulfilment of the Requirements for the Degree of
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in

THE DEPARTMENT OF
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İHSAN DOĞRAMACI BİLKENT UNIVERSITY
ANKARA

June 2015

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 Doctor of Philosophy in Interior Architecture and Environmental Design.

Assoc. Prof. Dr. Nilgün Olguntürk
Supervisor

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 Doctor of Philosophy in Interior Architecture and Environmental Design.

Prof. Dr. Halime Demirkan
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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 Doctor of Philosophy in Interior Architecture and Environmental Design.

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Assist. Prof. Dr. Elif Güneş
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Approval of the Graduate School of Economics and Social Sciences

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Prof. Dr. Erdal Erel
Director

ABSTRACT

EFFECT OF AREA ON COLOR HARMONY IN INTERIOR SPACES

Odabaşıoğlu, Seden

Ph.D., Department of Interior Architecture and Environmental Design

Supervisor: Assoc. Prof. Dr. Nilgün Olguntürk

June 2015

The main aim of this study is to examine the effect of area on color harmony in interior spaces. Area in color harmony is the relative amount of different color areas represented as a proportion on which color harmony depends. Colors in the color scheme of an interior space are usually not applied in equal proportions of surface areas and considering the complex relations of colors in interior spaces, it is important to search for the principles of color harmony and area effects in interiors. The secondary aim of the study is to investigate how the term color harmony was defined and the link between color harmony and related terms used to define it. The related terms that are used to define color harmony can explain why a color scheme is evaluated as harmonious. In this study, three primary (red, blue, yellow) and three secondary (green, purple, orange) colors of Itten's color wheel were studied in a simulated office interior with three-color schemes emphasizing different proportional use of each color. There were four color combinations, each consisting of six images differing in areas of the constituent colors. Firstly, participants evaluated the harmony content of the images by comparing them in pairs. Secondly, they evaluated each image regarding the thirteen terms related to color harmony. Findings indicated that area had an effect on color harmony for two of the color combinations (warm and cool color schemes). However, there were no strong but rather moderate and weak correlations between color harmony and the terms.

Keywords: Color Harmony, Three-Color Combinations, Experimental Color Harmony, Interior Space.

ÖZET

İÇ MEKANLARDA ALANIN RENK UYUMU ÜZERİNE ETKİSİ

Odabaşıoğlu, Seden

Doktora, İç Mimarlık ve Çevre Tasarımı Bölümü

Tez Yöneticisi: Doç. Dr. Nilgün Olguntürk

Haziran 2015

Bu çalışmanın başlıca amacı iç mekanlarda alanın renk uyumu üzerine etkisini incelemektir. Renk uyumunda alan, renk uyumunun bağlı olduğu bir oran olarak temsil edilen, farklı renk alanlarının göreli miktarıdır. Bir iç mekanın renk şemasındaki renkler, genellikle, yüzeylere eşit oranlarda uygulanmamaktadır ve iç mekanlarda renklerin kompleks ilişkileri de göz önünde bulundurulduğunda iç mekanlarda renk uyumu ve alan etkilerinin ilkelerini araştırmak önemlidir. Çalışmanın ikincil amacı ise renk uyumunun nasıl tanımlandığını ve renk uyumu ve onu tanımlamaya ilişkin kullanılan terimler arasındaki ilişkiyi araştırmaktır. Renk uyumunu tanımlamaya ilişkin kullanılan terimler, bir renk şemasının neden uyumlu olarak değerlendirildiğini açıklayabilir. Bu çalışmada, Itten'ın renk çemberindeki üç ana (kırmızı, mavi, sarı) ve üç ara (yeşil, mor, turuncu) renk, her rengin farklı oranlarda kullanıldığı üçlü-renk şemalarıyla, modellenmiş bir ofis mekanında incelenmiştir. Dört adet renk kombinasyonu ve her bir kombinasyon için kendisini oluşturan renklerin farklı alanlara uygulandığı altı görüntü bulunmaktadır. Öncelikle, katılımcılar görüntülerdeki renk uyumunu onları çiftler halinde karşılaştırarak değerlendirmişlerdir. İkinci olarak, katılımcılar her bir görüntüyü renk uyumuyla ilgili on üç terime ilişkin olarak değerlendirmişlerdir. Çalışma sonuçlarına göre, iki renk kombinasyonunda (sıcak ve soğuk renk şemaları) renk uyumunda alan etkisi bulunmuştur. Fakat, renk uyumu ve terimler arasında güçlü bir korelasyon yerine orta ve zayıf korelasyonlar bulunmuştur.

Anahtar Kelimeler: Renk Uyumu, Üçlü-Renk Kombinasyonları, Deneysel Renk Uyumu, İç Mekan.

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CHAPTER 1

INTRODUCTION

Color is in every part of our lives. It is in everything we see: In a flower, in the feather of a bird or in fabric. Colors we see around us are not isolated single colors, they work together creating interrelated visual appearances and perceptions. For example, when we look at nature we see the blue sky, the green and brown of trees, green grass, gray rocks and the different colors of flowers all working together in harmony. This relationship of colors leads many people to question how colors work together, how they interact and how they can be harmonized.

Color is an important tool for artists and designers. It is a powerful element of design such as interior design, graphic design, industrial design and fashion design. Designers and artists, while selecting colors, consider that color may have an effect on the psychology and physiology of people. Another consideration for artists and designers is to select colors that are harmonious and work well together, regarding aesthetics. Harmony, defined as “the pleasant effect made by parts being combined into a whole” (Longman dictionary of contemporary English, 1991), is one of the principles of art and design.

The selection of a color scheme is dependent upon the skills and experience of artists and designers. Consequently these color schemes may differ between individuals and may even be related to the psychology of the artists or designers in question. Artists may use harmonious colors in their works by selecting them intuitively. However, in design, selection of harmonious colors objectively may please a wider range of users. Establishing principles in color harmony should help designers by creating a useful and accurate tool for selecting the most pleasing color combinations for the users. In order to find out these principles many research studies have been done and there is an excessive number of color harmony theories and models (see Chapter 2) (Birren, 1969a,1969b; Chevreul, 1987; Chuang and Ou, 2001; Goethe, 1970; Granger, 1953; Itten, 1973; Moon and Spencer, 1944a; 1944b, 1944c; Nemcsics, 2007, 2008, 2009a, 2009b, 2011, 2012; Nemcsics and Takacs, 2013a, 2013b; Ou, Chong et al., 2011; Ou and Luo, 2003, 2006; Ou, Luo et al., 2011; Polzella and Montgomery, 1993; Szabo, Bodrogi and Schanda, 2010; Wang, Ou and Luo, 2007) but there is a marked lack of consensus in the literature regarding color harmony (see Chapter 2).

It is important to investigate color harmony in relation to interior design because interior designers intend to use harmonious colors in spaces in order to please their users. Colors in the color scheme of an interior space are usually not applied in equal proportions over surface area and considering the complex relationships between colors in interior spaces, it is important to search for the principles of color harmony and area effects in interiors. There have been studies that have stressed the effects of area on color harmony of color chips (see Chapter 2.4) (Granger, 1953; Moon and Spencer, 1944c; Wang, Ou and Luo, 2007) and plates (see Chapter 2.5) (Nemcsics and Takacs, 2013b) but the effect of area on color harmony has not been studied in interior spaces.

1.1 Aim of the Study

The main aim of this study is to examine the effect of area on color harmony in interior spaces. Area in color harmony is the relative amount of different color areas represented as a proportion on which color harmony depends. Studies investigating color harmony in interior spaces (see Chapter 3) (Ou, Chong et al., 2011; Shen, Chen and Hsu, 1996; Shen et al., 2000) are few in number and these studies overlook the effect of area. However, area in color harmony is an important factor in interior spaces since colors usually are applied in different proportions in interiors. In this study, three primary (red, blue, yellow) and three secondary (green, purple, orange) colors of Itten's color wheel were studied in a simulated office interior with three-color schemes emphasizing different proportional use of each color.

The secondary aim of the study is to investigate how the term color harmony is defined and the link between color harmony and related terms used to define it. The term 'color harmony' is defined differently by different authorities, and in experimental studies researchers prefer to use one of these definitions in order to inform evaluators. However, it is also important to know how evaluators define color harmony and on what basis they evaluate a color scheme as harmonious. The related terms that are used to define color harmony can explain why a color scheme is evaluated as harmonious.

Research questions of the study are:

1. Is there a general pattern of color harmony which differs depending on the proportions of colors used in interior spaces?
2. Is there a relationship between color harmony and the related terms used to define it?
3. Is there a relationship in between the related terms used to define color harmony?

1.2 General Structure of the Thesis

This thesis consists of six chapters. After an introductory first chapter, the following two chapters review related literature. In the second chapter, basic definitions and concepts related to color are elaborated on, a definition of color harmony is provided and theories and attributes of color harmony are examined.

The effect of area on color harmony and the relationship between color harmony and color preference are analyzed. In addition, the second chapter explores color harmony research using experimental evaluation methods and contains detailed information on measuring color harmony, color harmony based on three color appearance attributes, and color harmony for two-color and three-color combinations. The third chapter comprises information on color harmony in interior spaces.

The fourth chapter describes the experiment with its aim, research questions, hypotheses and methodology. The methodology of the experiment, detailed information on the sample group, experiment room and procedures are provided. The fourth chapter also includes findings of the experiment.

In the fifth chapter, the findings are discussed in relation to the relevant literature. The sixth chapter features the major conclusions of the study and suggestions for further research. Some of the visual and written materials related to literature and experiment are included in the appendices.

CHAPTER 2

COLOR HARMONY

2.1 Basic Definitions and Concepts of Color

It is necessary to understand the basic terminology of color and its dimensions for discussing color harmony. *Color*, as Pile (1997) defined it, is a characteristic of light or surfaces that the human eye can perceive. Colors are basically divided into three types: primary, secondary and tertiary colors.

Primary colors are those that cannot be obtained by mixing other colors. The primary colors of light and pigments/dyes are different. The former's primary colors are red, green, blue and the latter's primary colors are red, yellow, blue (Pile, 1997). *Secondary colors* are those that are obtained by mixing of two primary colors. The secondary colors of light are yellow, cyan and magenta whereas the secondary colors of pigments and dyes are green, purple and orange

(Pile, 1997). Additionally, there are *tertiary colors* that are obtained by mixing primary and secondary colors such as a mixture of red and orange (Pile, 1997).

Colors have three dimensions which are hue, value (lightness or brightness) and chroma (saturation or intensity). *Hue* is the quality that gives a chromatic color its name such as red or yellow and refers to a pure color. As Pile (1997: 33) defined, hue is “a term for the position of a color along the band of the spectrum” that is based on the wavelengths of the light energy creating these colors. Munsell (cited in Birren, 1969b: 18) defined hue as “the quality by which we distinguish one color from another, as a red from a yellow, a green, a blue, or a purple”.

Value is the quality indicating how much a pure color includes black or white. It is the degree that a color reflects light (Pile, 1997). Light colors, including white, reflect much of the light falling on them and dark colors, including black, reflect little light. Munsell (cited in Birren, 1969b: 20) defined value as “the quality by which we distinguish a light color from a dark one”. Related to the value of a color, tints and shades of it are obtained. *Tints* are light values of a color obtained by adding white whereas *shades* are dark values of a color obtained by adding black. In addition, *tones* are between tints and shades.

Chroma, *saturation* and *intensity* are the terms for the purity of a color (Pile, 1997). It is the measurement of weakness and strength of a color (Birren, 1969b). A pure color becomes desaturated, or of a lowered chroma, when it is added white, black, or gray. Another option to make a pure color desaturated is to add a color away from that color in the spectrum (Pile, 1997).

Regarding their hue content, colors are divided into two categories as achromatic and chromatic colors. *Achromatic colors* are black, white and gray and *chromatic colors* are the ones other than these colors. Considering their positions on the spectrum and the perception of the viewers, colors are categorized as warm and cool. *Warm colors*, which are red, orange and yellow, are the ones near the red end of the spectrum and *cool colors*, which are green, blue and violet, are the ones near the violet end of the spectrum. Related to its red or blue content, violet may be perceived as warm or cool (Pile, 1997). In addition to achromatic and chromatic colors there is also a term, *monochromatic colors*, used for color schemes which consist of all the colors (tints, shades or tones) of a single hue.

It is also important to define the orderly relationships between colors. Hues appearing on opposite sides of a color circle are called *complementary colors* (see Figure 1). The mixture of a complementary pair produces a gray color or a similar tone having a weaker chromatic hue (Pile, 1997). According to Marx (1983) there are three different meanings of complementary colors:

a. Subtractive complementary colors are the colors that, when they are mixed (paints or inks) produce a gray or neutral color.
b. Optical complementary colors are ones that appear to gray when they spin on a Maxwell disk.

c. Afterimage complementary colors are a color and its afterimage seen when the color is stared at and removed.

Hues appearing adjacent to each other on the color wheel are defined as *analogous colors* (see Figure 1). *Triad colors* are three equally-spaced colors on a color wheel forming an equilateral triangle or an isosceles triangle (see Figure 2). According to Itten’s color wheel, the combination of red, blue and yellow is one example of a triadic color triangle. There are also modified triads which are made up of three colors having one color between each on a twelve-color wheel such as on Itten’s color wheel (Leland, 1998; Leland, 2008) (see Figure 1). Tetradic colors are four equally-spaced colors on a color circle forming a square or a rectangle and consist of two complementary pairs (see Figure 2). Blue, green, red and orange are of the examples of tetradic colors on Itten’s color wheel.

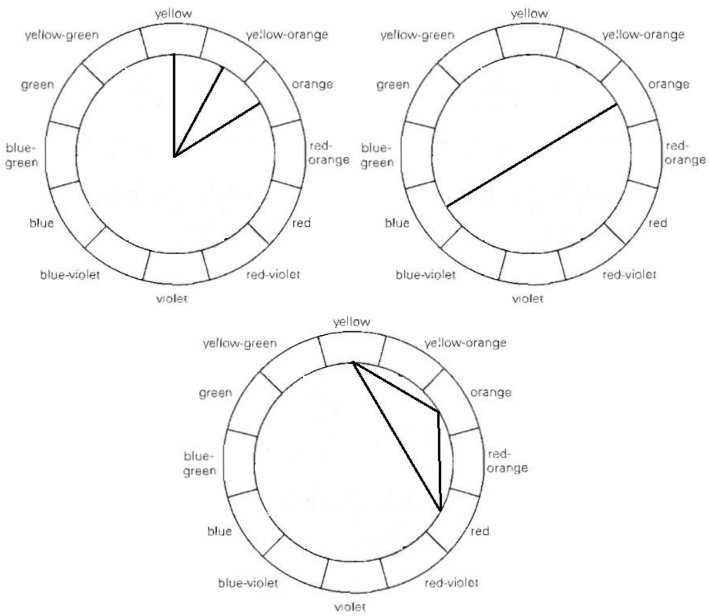


Figure 1. Analogous, complementary colors and modified triads (Adapted from Birren, 1970: 21).

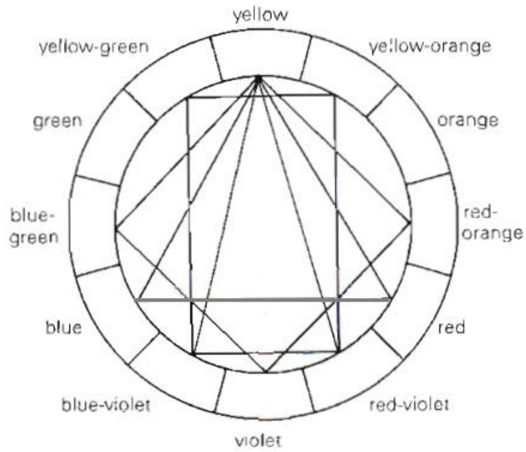


Figure 2. Triads and tetrads on Itten's color wheel (Birren, 1970: 21).

The term mentioned above, a*fterimage,* is the ghost-like image that appears after a stimulating color is taken away (Holtzschue, 2006). It is an effect that an inverted or retained image continues to appear in one's vision after the original stimuli is removed. For instance, staring intensely at a red image will produce a green image if the gaze is turned onto a white surface. This kind of afterimage, in which apparent colors are shifted to their complementary, is called negative afterimage (Kuehni, 2005). As Kuehni (2008) stated, a well-known example of negative afterimage is the American flag in reverse color (see Figure 3). A person can see the image of the flag with its original colors, if he/she looks at a white surface after staring at the white dot on the center of this image for some time. There are also positive afterimages, in which the perceived color of objects remains nearly unchanged in the images (Kuehni, 2005). Positive afterimage can be seen, for instance, by looking at a light bulb shortly and then turning off the light (Byrne and Hilbert, 1997). When the light is turned off, one continues to see the previous scene for a very short period of time. As Byrne and Hilbert (1997) stated, short and intense flashes produce positive afterimages whereas longer-duration stimuli cause one to see negative afterimages.

Figure 3. Image of an American flag in reverse colors (Kuehni, 2008: 90).

Since it will be mentioned in chapter 2.2, it is also important to give the definition of the color order system, color space, color solid and color atlas. *Color order system* is the term used for a system that systematically arranges color experiences (Kuehni and Schwarz, 2008) (see Figure 4 and Appendix A). *Color space* is a frame of three-dimensional axis that defines the dimensions and divisions of these dimensions of a color solid (Kuehni and Schwarz, 2008) (see Figure 4). *Color solid* is the occupied color space with symbols of colors that have a volume (Kuehni and Schwarz, 2008) (see Figure 4). Finally, *color atlas* is a systematic collection of color chips or color prints consisting of a large range of possible colors of a color system (Kuehni and Schwarz, 2008) (see Figure 4).

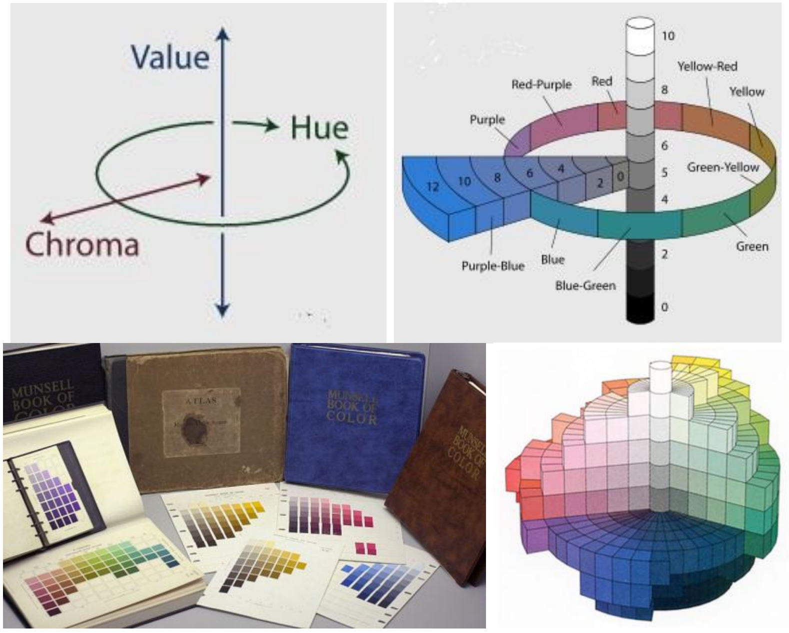


Figure 4. In clockwise order, the Munsell color system, color space, color solid and color atlas.
(http://munsell.com/color-blog/time-for-a-munsell-revival/)
(http://www.naturephotographers.net/articles0809/ab0809-1.html)
(http://en.wikipedia.org/wiki/Munsell_color_system)

2.2 Definition of Color Harmony

Color harmony has been a focus of interest for many researchers since Goethe (1970) published *Farbenlehre* in 1810. For two centuries, ‘color harmony’ has attracted interest in aesthetics from both philosophical and scientific perspectives. Many theorists have defined color harmony with the principles they posited based on their experiences to create harmony in colors. These principles were ‘completeness’ for Goethe, ‘complementary/analogous’ for Chevreul, ‘order’ for Ostwald, ‘balance’ for Munsell (cited in Ou and Luo, 2006).

As can be inferred from the different principles posited by different theorists, color harmony “is a viable and abstruse concept described differently by different authorities” (Burchett, 2002: 30). Polzella and Montgomery (1993) defined color harmony as the ‘suitability’ of juxtaposed colors. Whereas Judd and Wyszecki (1975: 390) defined color harmony as: “When two or more colors seen in neighboring areas produce a pleasing effect, they are said to produce a color harmony”. Color harmony definitions similar to this definition, combining harmony with the emotion pleasantness, can be seen in various studies as stated below.

Granville (1987) defined color harmony as the color usage that pleases people. Chuang and Ou (2001: 30) explained the term harmonious as “that which pleases the viewer” or “that which is perceived as harmonious”. Additionally, Burchett (2002: 28) suggested “colors seen together to produce pleasing effective response are said to be in harmony”.

Moreover, color harmony was recently defined by Schloss and Palmer (2011: 551) as “how strongly an observer experiences colors in the combination as going or belonging together”. This definition of color harmony has a similarity with the definition of Polzella and Montgomery (1993) related to the suitability of juxtaposed color. It removes the link between the emotion of pleasantness and color harmony but still includes subjectivity that harmony is related to the experience of the observer.

Considering the definition of harmony, defined as “the pleasant effect made by parts being combined into a whole” (Longman dictionary of contemporary English, 1991), color harmony can be defined as the pleasant effect made by colors seen together. However, in this thesis, the definition of color harmony was obtained from the participants of the experiments who evaluated the harmony content of the color combinations. It was important to know the definition of color harmony in their minds since they were the decision-makers. According to their answers, color harmony can be defined as a balanced combination of colors that has a positive and pleasing effect in relation with the proportion, configuration, similarity and tone of the colors. This definition, obtained from a number of subjects, covers many of the theories and definitions of color harmony explained above and in Chapter 2.3.

2.3 Theories of Color Harmony

The concept of color harmony and how it can be obtained has been a question interesting many people. Artists may choose harmonious colors for their works intuitively but designers should select harmonious colors for the users of their products more systematically. Artists have created harmony and their rules for obtaining it are related to their art experience. However, researchers, who work on color, have searched for the so-called ‘laws of color harmony’ to describe the relationship between the psychological experience of color harmony and the physical attributes of color (Chuang and Ou, 2001).

According to Heddell (1988), color harmony theories can be categorized into two as the ones which are based on complementary colors and the ones that are based on commonality such as ‘equal hue’, ‘equal chroma’ or ‘equal value’. On the other hand, Ou and Luo (2006) divided color harmony studies into two categories: the ones that are based on an orderly arrangement of colors and the ones that are based on the interrelationship between colors. Studies of Ostwald (1969a), Munsell (1969b), Itten (1973) and Nemcsics (2007, 2008, 2009a, 2009b, 2011) can be placed in the first category since these studies assumed that harmonious color combinations can be created when the colors are selected systematically from a hue circle or from a particular path in an ordered color space. Studies of Goethe (1970), Chevreul (1987), Moon and Spencer (1944a, 1944b, 1944c) and Chuang and Ou (2001), Ou and Luo (2006) can be placed in the second category since these studies assumed that harmonious color combinations can be created when the colors are complementary or analogous either in hue, lightness or chroma.

Additionally, O’Connor (2010) divided the approaches to color harmony into three categories. The first category defines color harmony as a universal phenomenon and assumes it is created and predicted with a mathematically-derived proportion and order. This first category includes the theories of Newton, Ostwald, Munsell, Moon and Spencer, and Chuang and Ou since these theories proposed that color harmony was based on proportional and orderly arrangement of colors (O’Connor, 2010). In the second category, including the theories of Goethe, Chevreul, Munsell, and Itten, color harmony is aligned with the notion of balance and equilibrium associating the physiological balance in the human visual system with color harmony (O’Connor, 2010). According to these theories in the second category (Goethe, Chevreul, Munsell, and Itten cited in O’Connor, 2010), color harmony required the balance of contrasting or complementary colors. The third category includes the theories of Itten, Munsell, Hard and Sivik, wherein color harmony is defined as groups of colors that are similar in hue and chroma (O’Connor, 2010). These theories in the third category indicated that there was a link between analogous colors and color harmony (Itten, Munsell, Hard and Sivik cited in O’Connor, 2010).

It is important to know how color harmony theories emerged and how they were developed through time. Generally, the concepts of color harmony have been designated by artists but from a scientific point of view and as a basis of modern understanding of color and light, color harmony theory dates back to the time that Newton explored the color spectrum in the late 1660s (Gage, 1995). Subsequently various color harmony theories were developed by different authorities. A brief summary of these theories is given in Table 1 and further information is given in the following pages.

Table 1. Summary of color harmony theories.

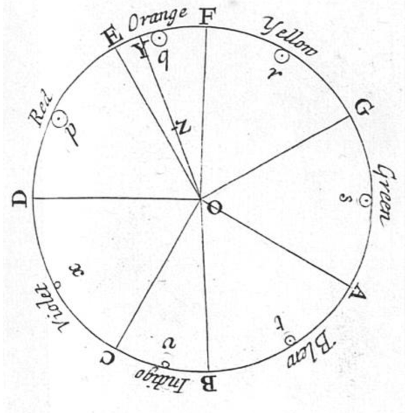
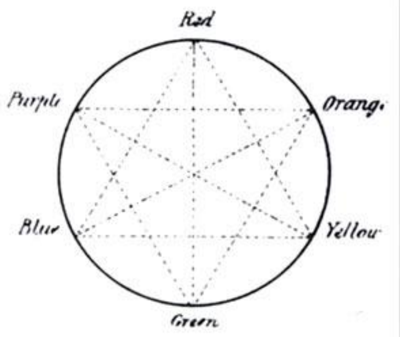
	Theory	System	Example	Area
NEWTON 18th century	Color harmony was associated with the orderly steps between seven hues on his color circle. Seven hues were correlated with musical notes (analogy between aural and visual harmonies).	 (https://commons.wikimedia.org/wiki/File:Newton's_color_circle.png)	Gold and indigo are harmonious. Red and blue are discord.	X
GOETHE 19th century	Color harmony was created if colors were selected from the both sides of his hue circle which he divided hues into two sides as positive and negative. (completeness of complementary colors)	 (Goethe, 1970: 184)	Yellow and Red-blue Blue and Red-yellow Red and Green are harmonious.	X

Table 1 (cont'd),

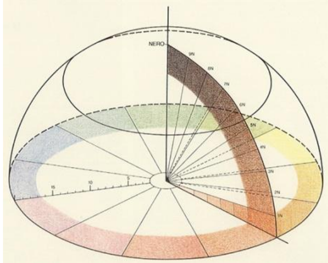
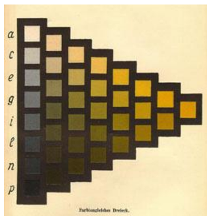
	Theory	System	Example	Area
CHEVREUL 19th century	Identified two types of color harmonies: the harmony of *analogous* colors and the harmony of *contrasts*.	 (http://www.colorsystem.com)	Harmony of contrast colors: Red-Green, Blue-Orange, Light-Dark, etc. Harmony of analogous colors: Redish orange- Red, Greenish blue-Blue, etc.	X
OSTWALD 20th century	Color harmony was equal to *order*. Two primary orders: 1) Equal value (equal white and equal black) of different hues (3, 4, 6, 8, 12 steps from the selected hue on the hue circle) 2) Different values of the same hue (monochromatic triangle) Additionally: 3) Gray harmonies: Achromatic colors arranged by equal intervals Simple intervals: a, c, e, or g, i, l Double intervals: a, e, i or g, l, p Triple intervals: a, g, n or c, i, p	 (http://www.daicolor.co.jp/english/color_e/color_e01.html)	1) 12 steps (complementary color pairs): Yellow- Blue, Red-Seagreen, etc. 8 steps (triads): yellow-purple- turquoise, etc. 2)  (http://www.colorsystem.com) 3)  (http://www.colorsystem.com)	X

Table 1 (cont'd),

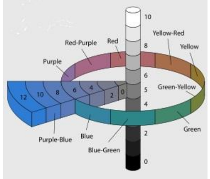
	Theory	System	Example	Area
MUNSELL 20th century	*Balance* was the key for making harmonious color combinations. There are nine principles of harmony (balance) (Birren, 1969b): **1)** Balance of neutral grays **2)** Monochromatic harmonies **3)** Opposite colors of equal chroma that center on middle value N5 (in equal area) **4)** Opposite colors of equal value but of different chroma(weaker chroma larger area than the stronger chroma) **5)** Opposite colors of the same chroma but of different value **6)** Opposite colors of different value and different chroma (darker value or weaker chroma larger area than lighter value or stronger chroma) **7)** Harmony of neighboring hues and split-complements **8)** Harmony of diminishing sequences **9)** Harmony of the elliptical path	 (http://munsell.com/color-blog/time-for-a-munsell-revival/)	**1)** N1-N3-N4-N7 **2)** R 7/5-R 3/5 **3)** R 5/5-BG 5/5 **4)** R 5/10- with a twice larger area of BG 5/5 **5)** R 7/5-BG 3/5, R 8/4-BG 2/4 **6)** R 7/8- BG 3/4 **7)** Neighboring hues: YR 5/5-R 5/5-Y 5/5 Split-complements: R 6/10-B 4/5-G 4/5 **8)** Y 8/9-GY 7/8-G 6/7- BG 5/6- B 4/5- PB 3/4 **9)** Y 7/12- YR 6/8- R 5/4- RP 5/4- P 4/8- PB 3/12- B 4/8- BG 5/4- G 5/4- YG 6/8	√

Table 1 (cont'd),

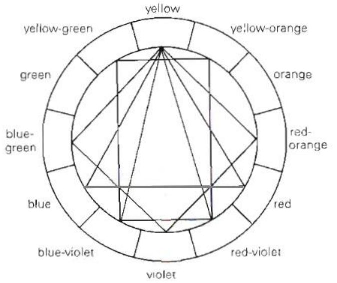
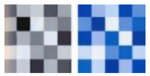
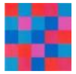
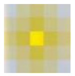
	Theory	System	Example	Area
ITTEN 20th century	Color harmony would be obtained if positions of the colors in his hue circle formed a well-defined polygon, such as dyads, triads, tetrads, and hexads. Seven color contrasts: 1) Contrast of hue 2) Light-dark contrast 3) Cold-warm contrast 4) Complementary contrast 5) Simultaneous contrast 6) Contrast of saturation 7) Contrast of extension	 (Birren, 1970: 21)	**Dyads:** Red-Green, Blue-Orange, etc. **Triads:** Yellow-Red-Blue, Orange-Violet-Green, etc. **Tetrads:** Yellow-Violet-RedOrange-BlueGreen, YellowOrange-BlueViolet-Red-Green, etc. **Hexads:** Yellow-Violet-Orange-Blue-Red-Green, etc. **Seven color contrasts:** 1) Yellow-Red-Blue, Red-Blue-Green, Blue-Yellow-Violet, etc.  2)  3) Yellow-Violet, RedOrange-BlueGreen, etc.  4) Yellow-Violet, Blue-Orange, Red-Green, etc.  5)  6)  7) 	√

Table 1 (cont'd),

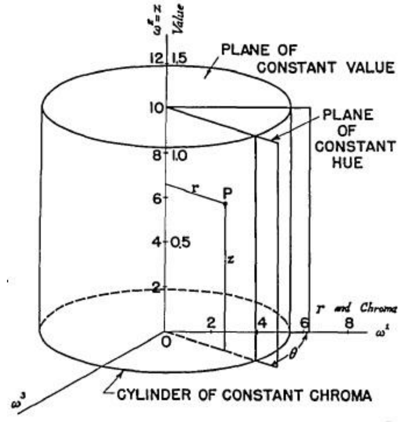
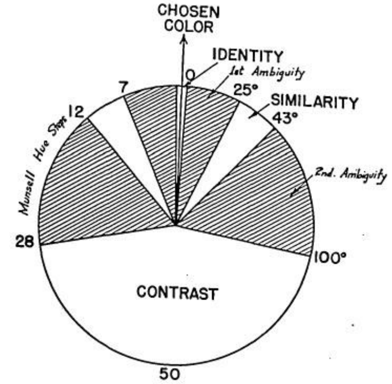
	Theory	System	Example	Area
MOON & SPENCER 20th century	Color harmony was created if the color difference between individual colors appeared *unambiguous*.	 (Moon & Spencer, 1944b: 48)	 (Moon & Spencer, 1944b: 50) **Munsell Samples:** Analogy: Y 8/8-YR8/8  Contrast: 5R 7/8-10GY 7/8 	√

Table 1 (cont'd),

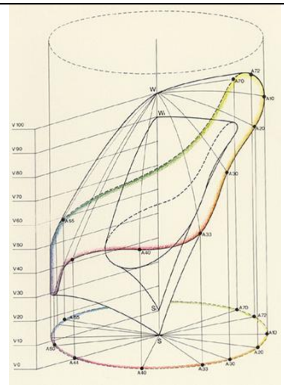
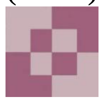
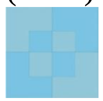
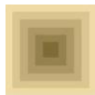
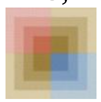
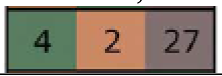
	Theory	System	Example	Area
NEMCSICS 21st century	Color harmonies can be obtained through particularly selected colors within the Coloroid Color System. 1) same A and T color characteristics, and their V color characteristics constitute an arithmetical or geometrical sequence 2) same A and V color characteristics, and their T color characteristics constitute an arithmetical or geometrical sequence 3) Summing the above two special cases the color characteristics are the same, but their T and V color characteristics change jointly on one straight line, where the distances of the points of division constitute an arithmetical or geometrical sequence. 4) The above rules can be equally related to one or more hues as well. Among the many hues the 3-hues or trichrome harmony is of prime importance. 5) Any two hues selected from the above set constitute a dichrome hue harmony even if A basic hue is omitted	 (http://www.colorsystem.com/?page_id=551&lang=en)	1) A35 Coloroid hue, T11.82 (d30V)  2) A55 Coloroid hue, V71.29 (d30T)  3) A12, T28-26-23-20-18-15, V91-83-76-68-60-53  4) A12, T10, V80-67-53-40 A52, T35, V80-67-53-40 A25, T9, V80-67-53-40  5) A12, T20, V60-70-80 A10, T50, V80 A10, T70, V90 	√

Table 1 (cont'd),

	Theory	**System**	**Example**	**Area**
OU & Colleagues (21st century)	A color-difference-based model for color harmony was developed.	$CH_{ABC} = \frac{\text{characteristics}}{3} + \frac{\text{interactions}}{3}$ **CH_{ABC}**= Overall color harmony value **Characteristics:** Average characteristics of each individual color (A, B, C) **Interactions:** Average interactions for color pairs (AB, BC, AC)	Among the selected colors in Ou, et.al. (2011): Most harmonious: (20 light grayish cyan: L83.1, a-4.7, b-4.9; 25 grayish blue: L77.5, a-2.0, b-7.4; 35 achromatic white: L85.3, a0, b0)  Least harmonious: (4 vivid green: L51.1, a-50, b31.3; 2 vivid orange: L59.7, a33.6, b60.9; 27 dark greyish red: L52.8, a10.1, b5.4) 	√

Newton, when he explored the color spectrum, created a color circle consisting of seven colors and color harmony was associated with the orderly steps between these hues (see Figure 5 and 6). With this arrangement of colors, Newton brought order into the chaos of color and his color circle became a useful tool for artists and also it formed a basis to various color systems of 18th and 19th centuries (Gage, 1995). The study by Newton developed an objective and quantitative basis for light and color studies (Gage, 1995).

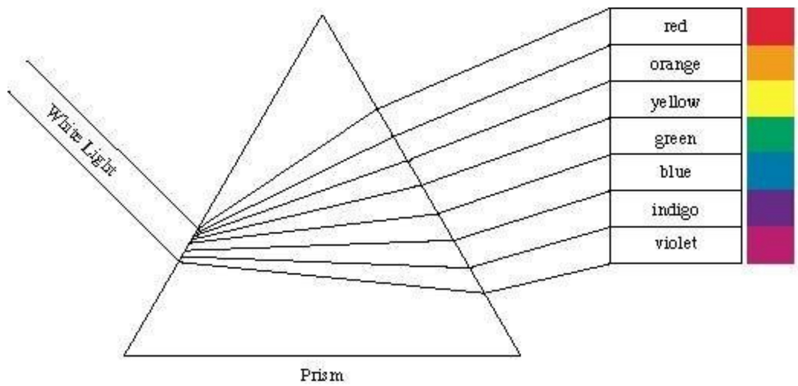


Figure 5. Newton color spectrum.
(http://www.ehow.com/about_5101113_newtons-theory-color.html)

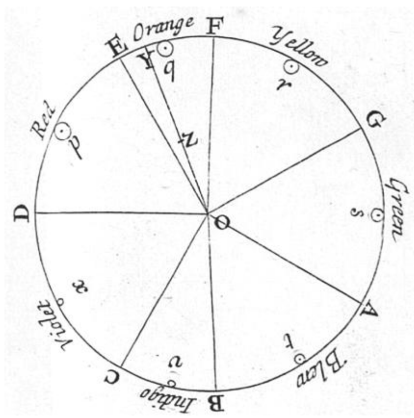


Figure 6. Newton color circle.
(https://commons.wikimedia.org/wiki/File:Newton's_color_circle.png)

According to Newton, color was a physical problem seen as the light fell on objects and then reflected and entered our eyes. On the other hand, Goethe (1970) realized that color vision was influenced by perception and that how colors were seen was dependent on the object, the light and the viewer's perception. Thus, he brought a deeper understanding to color harmony theory and his studies on color harmony attracted the interest of many researchers.

Goethe worked on after-images, complementary colors and colored shadows. He created his color wheel based on his observations on opposed colors and placed the hues symmetrically with three hues on one side of the circle and the other three on the other side (see Figure 7). According to him, color harmony would be obtained if the colors were selected from both sides of the circle.

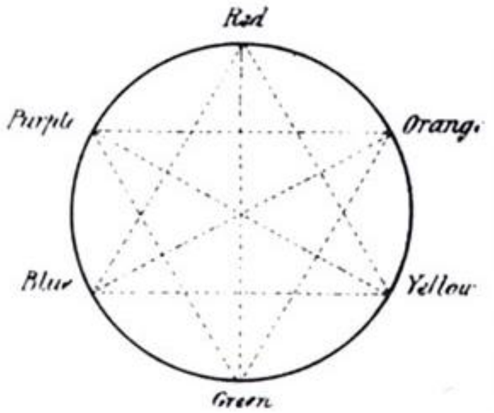
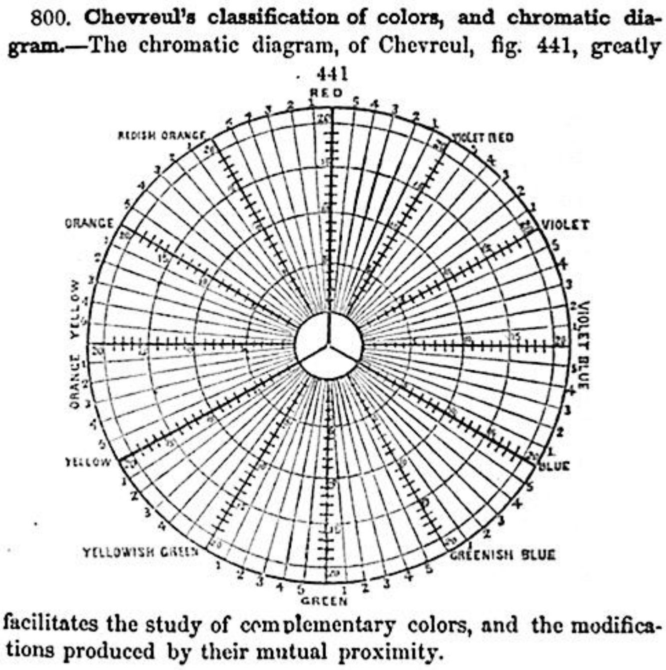


Figure 7. Goethe color circle (Goethe, 1970: 184)

As Gage (1995) stated, many color harmony theories following the studies of Newton and Goethe can be traced back to the theories of these two influential researchers. Chevreul's color harmony theory was similar to Goethe's regarding the harmony of opposing colors. According to Chevreul (1987), color harmony was created in two ways: with the harmony of contrast colors and the harmony of analogous colors. He created a chromatic diagram with the three primary colors of red, yellow, and blue, and the three secondary colors of violet, green, and orange and with eleven steps between each hue, making 72 hues in total (see Figure 8). Chevreul also created a hemispheric color order system which included the tones of these 72 hues but he had considerable problems in placing the colors systematically in the hemisphere by putting them in a way so as to be perceptually uniform (Kuehni and Schwarz, 2007). Thus, he did not published a complete proposal of this color system (Kuehni and Schwarz, 2007).



800. **Chevreul's classification of colors, and chromatic diagram.**—The chromatic diagram, of Chevreul, fig. 441, greatly facilitates the study of complementary colors, and the modifications produced by their mutual proximity.

Figure 8. Chevreul chromatic diagram. (http://en.wikipedia.org/wiki/File:Chevreul%27s_RYB_chromatic_diagram.png)

Many artists and scientists dealing with color theory developed various color circles. Considering these color wheels developed by different colorists, there have been various harmony relationships described such as analogous, complementary, split-complementary, triads and tetrads. However, these relationships of color regarding hues do not embody different tints, shades and tones (see Appendix F for definitions of tint, shade and tone). Hence, some colorists created their color systems including hues and their tints, shades and tones and based these systems on their color harmony theories.

Albert Munsell (1858-1918) was one of the colorists who developed a color system and his color system is one of the most widely used in the world. According to Munsell (cited in Birren, 1969b), in order to create harmony in compositions, colors must be balanced. This balance may be obtained, for example, by bringing an extremely strong color with a grayer color but the areas of these colors are also important for balance. Thus *area* is another factor in color compositions (Birren, 1969b). What Munsell meant by balance is reason and consistency and harmony is based on a measured and orderly relation of colors (Birren, 1969b).

Similar to the theory of Munsell, according to Ostwald (cited in Birren, 1969a), harmony of colors can be obtained if there is a lawful relationship between colors and he believed that harmony is equal to order. Ostwald (cited in Birren, 1969a) also believed that all the possible orders of the color solid must be studied to find all the possible harmonies and he mentioned two primary orders which were equal value hue circles and the monochromatic triangles. Circles show harmonies of equal value of different hues and triangles show harmonies of different values of the same hue (see Appendix F for the definition of value).

Moreover, according to Itten (cited in Birren, 1970), color harmony is the systematic relationship of colors and can be formed as dyads, triads, tetrads, etc. selected from his 12-hue color circle. Harmonious color combinations obtained from the color wheel can be varied considering the seven contrasts that were detected by Itten investigating the characteristics of color effects (Birren, 1970). For instance, the hues of the main chord can be combined with their shades, producing contrast of saturation, or they can be combined with their tints and shades, producing light-dark contrast. A harmony of contrast of extension can be obtained, if the colors have the same lightness value and the pure colors are added in small areas (Birren, 1970). These variations offer different possibilities for harmonious color combinations.

As most color harmony researchers do, Antal Nemcsics (1927-) is one of the color harmony researchers who developed his own color order system regarding his color harmony theories. Nemcsics (2007, 2008, 2009a, 2009b, 2011, 2012; Nemcsics and Takacs, 2013a, 2013b) with a series of experiments clarified some rules for creating harmonious color combinations by using the Coloroid Color System. According to Nemcsics (2003: 10) the color compositions explained below are harmonic color combinations, the elements of which (A denotes hue, T denotes saturation and V denotes luminosity):

1. have the same A and T color characteristics, and their V color characteristics constitute an arithmetical or geometrical sequence,
2. have the same A and V color characteristics, and their T color characteristics constitute an arithmetical or geometrical sequence,
3. Summing the above two special cases the color characteristics are the same, but their T and V color characteristics change jointly on one straight line, where the distances of the points of division constitute an arithmetical or geometrical sequence. The (T, V) pairs can be placed on more parallel straight lines as well, in each case according to the same arithmetical or geometrical sequence.
4. The above rules can be equally related to one or more hues as well. Among the many hues the 3-hues or trichrome harmony is of prime importance. The SET of possible trichrome basic colors belonging to the A basic hue are: {A±1.0,A±4.6,A±6.6, Complementary hue (K) K±1.0,K±4.6,K±6.6} hues. From this set, the basic hue A and more two hues selected next to it, constitute a trichrome color harmony.
5. Any two hues selected from the above set constitute a dichrome hue harmony even if A basic hue is omitted.

In addition to these theories, there are also theories predicated on indicating the degree of color harmony using mathematical formulas. Moon and Spencer (1944a; 1944b), in order to explain the relationship between color harmony and color intervals, developed a mathematical model. According to Moon and Spencer, if there is an ambiguous interval between colors (differences between colors regarding the attributes of hue, value and chroma) of a combination, the combination is found unpleasing and therefore is found to be disharmonious. The studies of Chuang and Ou (2001), Ou and Luo (2006) and Ou, Chong et al., (2011) also followed the theory of indicating color harmony with a formula. These studies developed universal formulas for predicting color harmony, however they still need to be tested for different conditions and cultures. For instance, Granger (1955b) tested the predictive performance of the formula of Moon and Spencer (1944a, 1944b) and found that it had a poor predictive value. The formulas also have some features missing that should be considered, such as area effect and complex environments.

On the other hand, some researchers doubted the existence of rules for obtaining color harmony based on the belief that color harmony depends on subjective judgments (Birren, 1985; Granville, 1987; Kuehni, 2005; Pope, 1944; Sivik and Hard, 1994). Therefore, the existence of objective rules of color harmony was denied. Kuehni (2005: 164) stated that there were no laws of color harmony as told and that if there were, universal laws would be "stifling, because limiting, for creativity". In addition, Pope (1944: 764) stated that "In the discussion of color harmony in the past there has been too much of a tendency to lay down rules which must be followed. There are no rules; there are only possibilities". Contrarily, Moon and Spencer in their reply to the article of Pope (1944) stated that color harmony was found too complex to allow mathematical treatment by Professor Pope but they were more optimistic and believed that in the fields of poster design, interior decoration, fabric design, and dress this theory of mathematical treatment would be of practical benefit.

It can be inferred from the literature of color harmony research that the doubts of some researchers, who disbelieved in the existence of objective rules for color harmony, were unable to persuade other researchers who believed the opposite. Researchers in the second group have carried on searching for rules of color harmony (Chuang and Ou, 2001; Granger, 1953, 1955c; Nemcsics, 2007, 2008, 2009a, 2009b, 2011, 2012; Nemcsics and Takacs, 2013a, 2013b; Ou and Luo, 2003, 2006; Ou, Chong et al., 2011; Ou, Luo et al., 2011; Polzella and Montgomery, 1993; Szabo, Bodrogi and Schanda, 2010) and the rules they have created provide avenues for further research.

2.4 Attributes of Color Harmony

Color harmony is a complex phenomenon that may be influenced by many factors. Burchett (2002) categorized the factors influencing color harmony as order, tone, configuration, interaction, similarity, association, attitude, and area. These categories were obtained by doing content analysis of 12 books on color (Interaction of Color, by Josef Albers; Art and Visual Perception, by Rudolf Arnheim; Principles of Harmony and Contrast of Color, by M. E. Chevreul; Theory of Colours, by Johann Wolfgang von Goethe; Physiological Optics, by Hermann Ludwig Ferdinand von Helmholtz; Art of Color, by Johannes Itten; Language of Drawing and Painting, by Arthur Pope; Color in Business, Science and Industry, by Deane B. Judd; and Gunter Wyszecki; Concerning the Spiritual in Art, by Wassily Kandinsky; World of Color, by David Katz; Color Notation, by Albert H. Munsell; and Measurement of Color, by William David Wright). The amount and types of color harmony meanings were identified and the terms for the categories were synthesized from the selected books. In order to clarify the categories additional related terms were indicated.

Order is color interval and refers to the color combinations selected according to an orderly plan from a color system such as triad, tetrad or complementary. When colors of a combination are selected considering a system with certain interval between them, it is described as harmonious. When there is an unambiguous interval between the colors, the combination is described as disharmonious. Related terms of this attribute gathered from the 12 books are: “absolute harmony, circular principle, chord, color solid, color space, elliptical principle, equal spacing, equidistant, interval, locus, organization, paths, plan, regular path, ring star concept, scales, schemes, score, sequences, single surface principle (planes), straight-line principle, system, unambiguous, uniformly scaled, and unity” (Burchett, 2002: 29).

Tone is a term used as a synonymous with color including the color dimensions: hue, saturation and value. As Burchett (2002) states, it is the fundamental attribute of color harmony influencing determination of preference. As was mentioned in Chapter 2.3 and Chapter 2.5.2, hue, saturation and value dimensions of color are the main components effecting color harmony. Terms used in the literature related to this attribute are: “brightness, brilliance, broken, chroma, cleanness, depth, hue, insistence, intensity, pronouncedness, purity, saturation, shade, strength, temper, timbre, tint, and value” (Burchett, 2002: 30).

Configuration refers to the overall design of the colors influencing the interrelationship of colors. Responses to colors may differ depending on the influence of shape or the proximity of colors (Burchett, 2002). For instance, a green carpet will appear brighter adjacent to a red wall and duller adjacent to a blue wall (Pile, 1997). Terms related to this attribute are: “arrangement, background, color distance, composition, design, direction, form, juxtaposition, orientation, placement, proximity, recurrence (extension of number), shape, and space” (Burchett, 2002: 29).

As a physiological phenomenon, interaction includes the effects related to the adaptation of the eyes such as afterimage and simultaneous contrast. For instance, when two colored surfaces in juxtaposition are viewed simultaneously they exhibit modifications to the eye (Chevreul, 1987). These modifications on the appearance of colors may influence color harmony. Terms related to this attribute of color harmony are: “adaptation dynamics, appearance modification, false color, hue shift, illusion, influence, intersection, leveling, outer equalization, sharpening, simultaneous contrast, successive contrast, and visual displacement” (Burchett, 2002: 29).

Similarity describes the combinations of colors that have something in common and are perceived as more or less alike. This shared characteristic perceived by the viewer may be caused by predominant hue, value or chroma. It can also be achieved by adding to each color of the combination an amount of the other colors (Burchett, 2002). Terms related to this attribute are: “affinity, analogous, approximate harmony, attraction, color connection, color sets, commonality, consistency, consonance, constellations, family, harmony of attraction, monochromatic, mutual, predominance (of hue, etc.), relationship, sameness, similarity of the dominant, similarity of the subordinate, structural contradiction, structural inversion, subordinate elements, and themes" (Burchett, 2002: 29).

Association is the attribute that links color harmony with the affective responses based on traditional color association and symbolism. Pile (1997) stated that colors can transmit emotional and cognitive messages in two ways. These are conviction, in which reactions to color are inborn, intuitive and universal to everyone, and learned associations, which depends on realities that are known to everyone and on meanings that are learned within a particular time and place (Pile, 1997). Terms related to association are: "appropriates, color retention, familiarity, local color, memory color, natural color, preference, preferred direction, purpose, realistic, recognizable, symbolism, and taste" (Burchett, 2002: 29).

Attitude is related to individuals' feelings and refers to the innate personality of a color or a color combination that evokes a feeling of an individual. Terms related to this attribute are: "atmosphere, climate, effect, essence, expression, felt unity, inner need, intuition, mood, soul vibration, temperature (warm, cool), and weight (light, heavy)" (Burchett, 2002: 29). For instance, warm colors (red, orange and yellow hues and their tints and shades) are generally seen as comfortable, cozy and pleasant and cool colors (green, blue and violet hues and their tint and shades) produce calm and relaxing feelings (Pile, 1997). Whereas neutral colors such as white, black, gray and chromatic colors desaturated with high content of neutrals are thought as boring but also practical for creating utilitarian atmospheres with a minimum of emotional content (Pile, 1997).

As one of the attributes of color harmony and the focus of this study, area refers to the scale of the color areas and color harmony depends on the amounts or proportions of color used (Burchett, 2002; Hard and Sivik, 2001). Burchett (2002) also stated that the visual effectiveness of color combinations is directly related to color area. In other words, the proportionate area that any color should occupy in a given color scheme is a matter of its suitability and color harmony is also defined as the 'suitability' of juxtaposed colors. Terms related to this attribute of color harmony are: "angular size, caricature, color measure, displacement, enlargement, extension, magnification, miniature, proportion, quantitative, ratio, reduction, relative size, and scale" (Burchett, 2002: 29).

There have been a few theories about the influence of area on color harmony, namely those developed by Munsell and by Moon and Spencer (Granger, 1953). According to Granger (1953) and Morriss and colleagues (Linnett et al., 1991; Morriss, Dunlap and Hammond, 1982; Morriss and Dunlap, 1987; Morriss and Dunlap, 1988), who examined these two theories, none of the theories was found to be acceptable in providing an accurate prediction. Munsell (cited in Granger, 1953) proposed a rule for areas that the stronger the color the smaller must be its area; while the larger the area, the grayer the chroma (ex. R 7/6, 7 indicates value and 6 indicates chroma - nine parts of this red combined with R 3/3, first 3 indicates value and second 3 indicates chroma- forty-two parts of this red). The rule proposed by Munsell for areas can be shown with the equation below (where A represents area, V value and C chroma):

$$\frac{A_1}{A_2} = \frac{V_2 C_2}{V_1 C_1}.$$

Moon and Spencer (1944c) also claimed that relative area was a function of both value and chroma. According to Moon and Spencer (1944c), the effect of area in color harmony is based on three basic principles:

- They considered that a pleasing balance among n color patches was obtained when the scalar moments regarding the adaptation point (neutral gray) were equal for all patches.
- Other pleasing balances could be obtained when the scalar moments of the color patches were simple multiples of each other.
- The psychological effect of a group of color patches depends on the balance point.

The scalar moment of a color patch is the multiplication of the area of the patch and the distance between the adaptation point and the color point in the w space (a metric space developed by the authors). The adaptation point is “the point in w space corresponding to the state of adaptation of the eye” (Moon and Spencer, 1944c: 93). In this case the adaptation point is neutral gray in the w space. The balance point is the point corresponding to the color obtained by the disk mixture of the component colors of a combination.

Concerning the first principle, if the colors (P and Q) and the adaptation point (A-neutral gray) were on a horizontal line (see Figure 9), a pleasing balance was obtained by:

$S_1r_1=S_2r_2$ (in which S indicates the area of colors)

However, the colors might not be on a horizontal line and they might be on a different plane. In this situation, a pleasing balance was obtained by (for colors P' and Q') (see Figure 9):

$$S_1[(r_1)^2+(z_1-z_A)^2]^{½}=S_2[(r_2)^2+(z_2-z_A)^2]^{½}$$

According to the second principle, a coefficient was added to the equation in order to obtain other pleasing balances:

$$nS_1[(r_1)^2+(z_1-z_A)^2]^{½}=S_2[(r_2)^2+(z_2-z_A)^2]^{½} \text{ (where n is an integer)}$$

For any number m color patches, pleasing effects could be obtained by:

$$n_1S_1[(r_1)^2+(z_1-z_A)^2]^{½}=n_2S_2[(r_2)^2+(z_2-z_A)^2]^{½}=\ldots=n_mS_m[(r_m)^2+(z_m-z_A)^2]^{½}$$

In these equations S indicates area of the color, r and z indicates the coordinates of a color in the w space. The z axis in the w space represents the achromatic colors (see Figure 9).

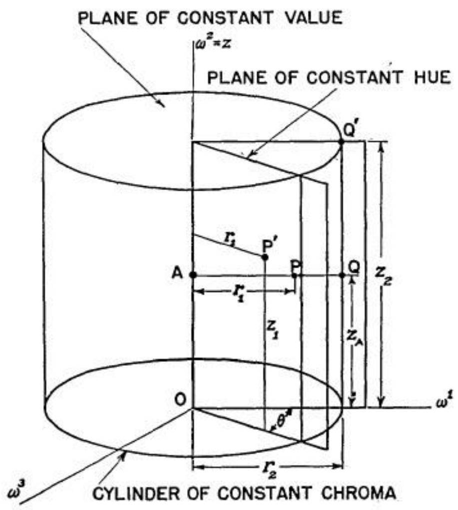


Figure 9. Coordinate systems in metric space (Moon and Spencer, 1944c: 95).

Moon and Spencer (1944c) showed that the equations they proposed could be expressed with Munsell notations, where r in metric space equals to Munsell chroma, θ equals to hue, and z equals to value. The scalar moment of any color from the adaptation point (Munsell N5) is:

$$S[(\text{chroma})^2+64(\text{value}-5)^2]^{½}$$

Concerning the third principle, if the two colors to be used in a design are placed on a Maxwell disk and the proportion of the areas of these colors are kept identical with the design, the disk mixture shows the balance point of these colors. Assuming that the trichromatic coordinates of two colors are (X_1, Y_1, Z_1) and (X_2, Y_2, Z_2) and their areas are S_1 and S_2, the coordinates of the balance point are:

$$X=[(X_1S_1)+(X_2S_2)]/(S_1+S_2),$$

$$Y=[(Y_1S_1)+(Y_2S_2)]/(S_1+S_2),$$

$$Z=[(Z_1S_1)+(Z_2S_2)]/(S_1+S_2),$$

Accordingly, the position of the balance point in the chromaticity diagram is calculated by:

$$x=X/(X+Y+Z)$$

$$y=Y/(X+Y+Z)$$

This balance point, which is influenced by the areas of colors in a combination, has an influence on the psychological effect of a group of colors. For instance, as Moon and Spencer (1944c) stated, if a designer wishes to obtain a cool and restful effect, he/she will select colors that have a balance point in green or if he/she wishes to obtain a warm and stimulating effect, he/she will select colors that have a balance point in red or orange.

Itten also suggested a ratio for harmonious color combinations in one of the seven contrasts he mentioned which is the contrast of extension. According to Itten (cited in Birren, 1970), the power of a pure color is determined by two factors: light value and extent. He based his theory of color extension (area) on light values of hues proposed by Goethe which are yellow-9, orange-8, red-6, violet-3, blue-4, green-6 (Birren, 1970). These values were used to obtain ratios between different hues to obtain harmony such as proportions for the complementary pairs were given as yellow:violet= 3:1, orange:blue= 2:1, and red:green=1:1. However, they indicated the inherent lightness of pure colors and they were valid only when all the hues appeared in their maximum purity (Birren, 1970).

Later, a study was undertaken by Wang, Ou and Luo (2007) investigating any influence of area on harmony for three-color combinations and accordingly to develop a new quantitative model (see Figure 10). As this new model would be based on a two-color harmony model previously developed by the authors, the previous model was first tested using the newer study's experimental data. This model indicated a somewhat good predictive performance, with a correlation coefficient of 0.81, suggesting that there was no significant difference in color harmony between different area proportions. However, in order to justify this claim, the authors searched for a pattern in the effect of area proportion considering the experimental data. These patterns showed that when a color in a combination became larger in size, its contribution to the color harmony value increased and as a result area proportions can be used as weightings in the prediction of harmony. Therefore, a new predictive model was developed adding the areas of the constituent colors to the previous three-color harmony model and this model showed good predictive performance with a correlation coefficient of 0.88.

$$\mathrm{CH}_{(a\,:\,b\,:\,c)} = -0.96 + \frac{1}{a+b+c}\ \left[(\mathrm{a}+\mathrm{b})\ \mathrm{CH}_{ab} + (\mathrm{b}+\mathrm{c})\ \mathrm{CH}_{bc} + (c+a)\ \mathrm{CH}_{ca}\right],$$

In which a, b, c represent areas of the colors, CH_{ab}, CH_{bc}, CH_{ca} represent harmony values of sub-combinations. These harmony values are calculated by:

$$\mathrm{CH}_{ij} = \frac{1}{2} H_C + H_L,$$

where

$$H_C = 0.04 + 0.53 \tanh(0.8 - 0.045 \Delta C)$$

$$\Delta C = [(\Delta H^*_{ab})^2 + (\Delta C^*_{ab}/0.5)^2]^{\frac{1}{2}}$$

$$H_L = H_{Lsum} + H_{\Delta L}$$

$$H_{Lsum} = 0.28 + 0.54 \tanh(-3.88 + 0.029 L_{sum}) \quad \text{in which } L_{sum} = L^*_1 + L^*_2$$

$$H_{\Delta L} = 0.14 + 0.15 \tanh(-2 + 0.2 \Delta L) \quad \text{in which } \Delta L = |L^*_1 - L^*_2|$$

In which L^*, C^*_{ab}, h_{ab} represent CIELAB values for lightness, chroma and hue angle.

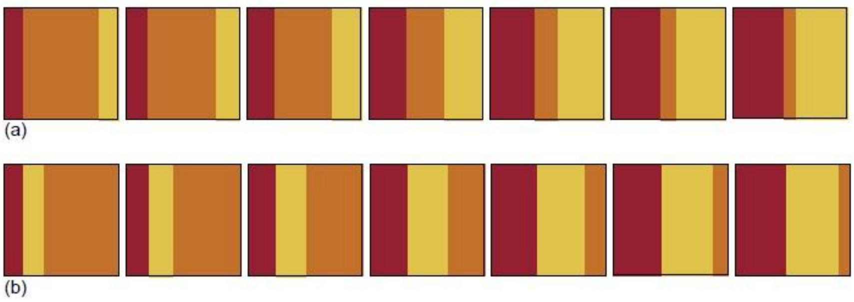


Figure 10. Experimental stimuli for (a) area proportions (1:4:1), (1:3:1), (1:2:1), (2:1:2), (3:1:3) and (4:1:4); (b) area proportions (1:1:4), (1:1:3), (1:1:2), (1:1:1), (2:2:1), (3:3:1) and (4:4:1) (Wang, Ou and Luo, 2007: 2).

A recent study was done by Nemcsics and Takacs (2013b) investigating the optimum ratio between the area coverage of colors for maximum harmony content of color pairs. The stimulus that was used in the experiments is shown in Figure 11. The findings of this study showed that area has an influence on the harmony content of color pairs but it is significant for highly saturated colors and negligible for low saturated colors. The effects of area on the harmony content of color pairs needs further investigation for colors with medium saturation (Nemcsics and Takacs, 2013b). The findings of this study also showed that maximum harmony content was found for the colors with equal ratios in most of the color pairs. However, some color pairs (i.e., A23-A30, A14-A53) displayed minimum harmony content for the equal ratios of saturated colors.

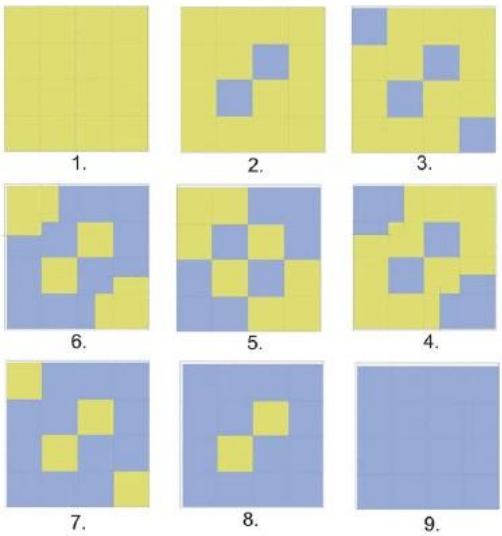


Figure 11. Experimental stimuli for area proportions in percentage 1-(100:0), 2-(87.5:12.5), 3-(75:25), 4-(62.5:37.5), 5-(50:50), 6-(37.5:67.5), 7-(25:75), 8-(12.5:87.5), 9-(0:100) (Nemcsics and Takacs, 2013b: 4).

Color harmony depends on these factors and similar to the definition of the term, the importance and relationship of these factors also differs according to different authorities. Burchett (2002) investigated interrelations of these factors regarding twelve color books that he examined and the correlations he found are shown in Figure 12. Coefficients found to be significant at the <.05 level are indicated as broken lines; those at the higher <.01 level of significance are indicated as solid lines. The factor interaction was shown differently from the others since it was found that most of the other attributes, except tone and order, were depended on interaction and it was an intervening variable.

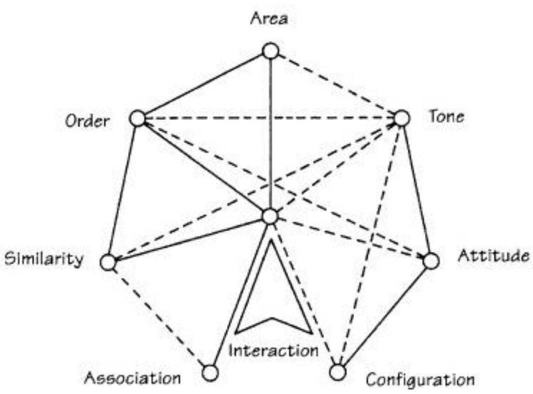


Figure 12. Matrix of Spearman coefficient correlations for eight color harmony attributes (Burchett, 2002: 30).

Shen, Chen and Hsu (1996) divide these factors related to color harmony into two main categories as: speculative and operative. Speculative components of color harmony include absolute/relative harmony, color mood, harmony attraction, similarity/familiarity, fashion trends, and color semantics referring to impressions. Operative components include area, order, hue, power spectrum, and entropy.

Experiments conducted by Gurura, MacDonald and Dalke (2004) showed that background color also has an influence on harmony judgments. Background color changes the appearance of colors used on foreground for what is called a simultaneous contrast effect. Accordingly, lightness, hue and chroma differences between background and foreground color influences the harmony ratings of color pairs. The overall degree of color pairs is determined due to the background color.

In addition, O'Connor (2010) believes that color harmony depends on the characteristics of the observer (age, gender, cultural experiences, personality) and also on the influence of perceptual (intervening perceptual effects), contextual (includes setting and ambient lighting), and temporal factors (such as social or design trends that change over time). Considering the effect of lighting on the harmony content of colors, Szabo, Bodrogi and Schanda (2009) found that the harmony of colors differed under different light sources.

As is clear, there are many factors that influence color harmony. From these factors the ones regarding the characteristics of the observer and social trends might be considered to be the factors that prevent assuming the notion of color harmony as a universal phenomenon. However, some studies indicate that these factors have stronger impacts on color preference than color harmony and color harmony may be a less subjective scale than color preference (Ou, et.al, 2011). Findings of this study also seem to agree well with some of existing color harmony studies (Ou and Luo, 2006; Szabo, Bodrogi and Schanda, 2010), which search for a universal formula for predicting color harmony.

2.5 Color Harmony Research Using Experimental Evaluation Methods

Researchers (Chuang and Ou, 2001; Granger, 1953; Moon and Spencer, 1944c; Nemcsics, 2007, 2008, 2009a, 2009b, 2011, 2012; Nemcsics and Takacs, 2013a, 2013b; Ou, Chong et al., 2011; Ou and Luo, 2003, 2006; Ou, Luo et al., 2011; Polzella and Montgomery, 1993; Szabo, Bodrogi and Schanda, 2010), investigating color harmony, most commonly preferred to do experiments in order to have suitable control on the stimulus. The aim of these experiments was to develop rules for obtaining harmonious color combinations and to create color harmony models for universal usage.

In these studies, it was important to get responses from a large number of subjects for valid results. Subjects with different nationalities could have caused differences in color harmony evaluations due to their cultural background. In most of the experimental studies, Taiwanese and Chinese people were chosen to evaluate the harmony content of colors (Chuang and Ou, 2001; Ou and Luo, 2003, 2006; Ou, Luo et al., 2011). There are also studies in which Hungarian people evaluate the harmony content of colors (Nemcsics, 2007, 2008, 2009a, 2009b, 2011). According to the results of these studies color harmony models were created for universal usage. However, these models have not been tested whether they can be applied universally to different cultures. There have not been any studies on color harmony conducted in Turkey.

Munsell and CIELAB color spaces were mostly used in color harmony studies. Studies aiming to acquire color harmony rules used Munsell color space (Granger, 1953; Moon and Spencer, 1944c; Polzella and Montgomery, 1993) and studies aiming to develop a quantitative color harmony model used CIELAB color space (Chuang and Ou, 2001; Ou and Luo, 2006; Ou, Chong et al., 2011; Ou, Luo et al., 2011). Additionally, Nemcsics (2007, 2008, 2009a, 2009b, 2011, 2012; Nemcsics and Takacs 2013a, 2013b) used Coloroid color space and Szabo, Bodrogi and Schanda (2010) used CIECAM02 color space.

The findings of color harmony studies do not necessarily conflict but they differ in various ways. Some of the studies found that complementary colors and colors having small lightness intervals were harmonious (Granger, 1955a) and some of them found that color pairs with similar hues and colors having median difference or higher lightness summation were harmonious (Chuang and Ou, 2001; Ou and Luo, 2003, 2006). Granger (1955a) and Ou and Luo (2006) also stated that color pairs having lower chroma interval were found to be harmonious, however, Pieters (1979) found that color pairs with higher chroma summation were more harmonious.

Moreover, many researchers found that single color preferences have a significant influence on color harmony evaluation (Chuang and Luo, 2001; Granger, 1955a; Nemcsics, 2009b; Ou and Luo, 2006). For example, Chuang and Luo (2001) found that the degree of color harmony of color combinations including one preferred color is very significantly higher than the combinations including no preferred colors. Additionally, Nemcsics (2009b) found that if the colors of the combinations are preferred, harmony of the overall composition is higher.

There are various problems in the research of color harmony that prevent many researchers work on the subject. One of these problems is the infinite numbers of color combinations that cause difficulty in selecting representative color combinations for a limited research. Researchers, who investigate color harmony and aim to define universal principles for it, remain incapable of doing it because of the small sample size of color combinations. Regarding the complexity of the phenomenon, the use of simplest patterns in color harmony research is another limitation. Most color patches shown side by side do not reflect the practical applications. For instance, in interior spaces, colors usually have more complex relations than they have in the combinations of color patches.

2.5.1 Measuring Color Harmony

In order to measure color harmony, most researchers use color patches or chips as stimuli to be evaluated and basic patterns are obtained by putting the color patches side by side on a gray background (Chuang and Ou, 2001; Ou and Luo, 2006; Ou, Chong et al., 2011; Ou, Luo et al., 2011; Szabo, Bodrogi and Schanda, 2010). Basic color patterns placed on a gray background for two-color combinations and three color combinations can be seen on Figures 13 and 14 respectively.

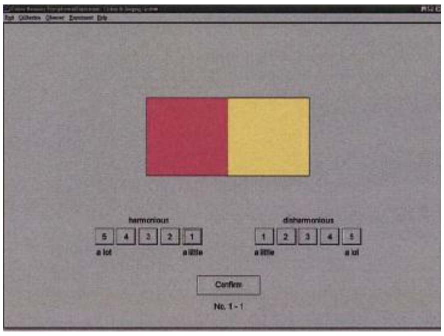


Figure 13. Basic color pattern for two-color combinations (Ou and Luo, 2006: 195).

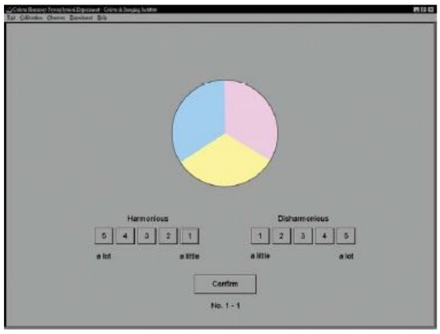


Figure 14. Basic color pattern for three-color combinations (Ou et al., 2011: 3).

Nemcsics (2007, 2008, 2009a, 2009b, 2011) used more complex patterns than the other studies on color harmony (see Figure 15). In the study of Ou, Chong et al. (2011), in addition to a basic color pattern which can be seen in Figure 14, they also used a fairly complex image which is an image of an interior space (see Figure 16).

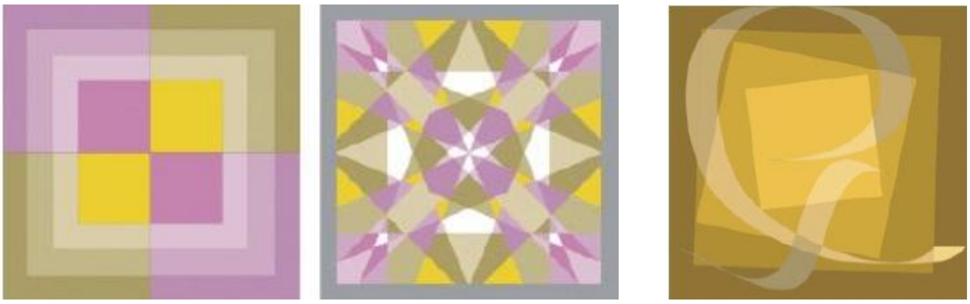


Figure 15. More complex patterns used in the experiments (Nemcsics, 2009a: 37; Nemcsics, 2009b: 213).

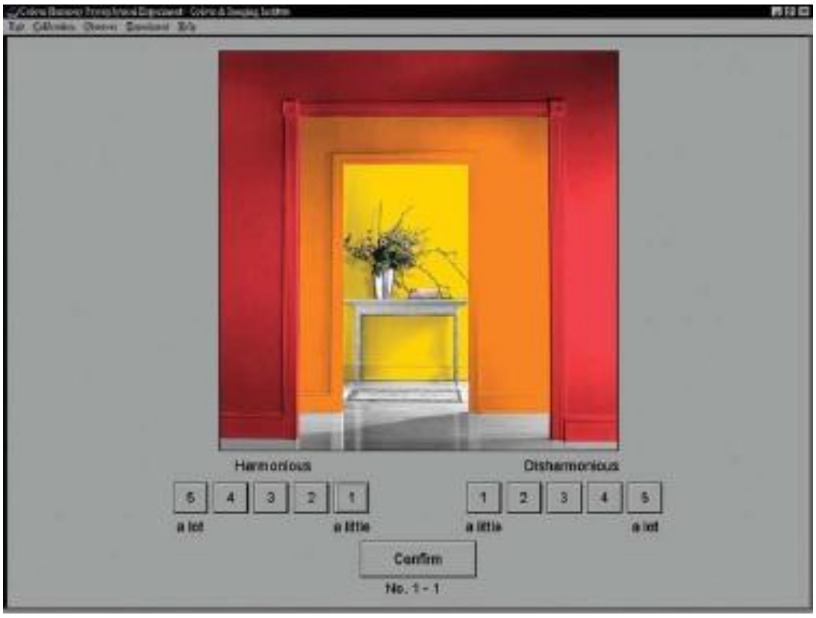


Figure 16. A complex image used in the experiments (Ou et al., 2011: 4).

For evaluating the color harmony content of different color combinations applied on these patterns and images, there are three types of evaluation methods, namely the rank order method (Nemcsics, 2007), the paired comparison method (Nemcsics, 2008, 2009a, 2009b, 2011) and the rating scales method (Chuang and Ou, 2001; Ou and Luo, 2003, 2006; Ou, Chong et al., 2011; Ou, Luo et al., 2011; Polzella and Montgomery, 1993; Szabo, Bodrogi and Schanda, 2010; Wang, Ou and Luo, 2007). The most frequently adopted evaluation method in the color harmony studies is the rating scales method with which the subjects evaluate the color combinations on a harmonious X disharmonious scale. In the paired comparison method, subjects select the more harmonious one of the shown two compositions, until they have judged each possible composition pair. And finally in the rank order method, subjects evaluate a number of test samples beginning by the most harmonic to the least harmonic.

As the studies of experimental color harmony research indicate, there are various methods for measuring color harmony. The findings of these studies and other theories on color harmony based on the three color appearance attributes (hue, lightness and saturation) are summarized in the following two chapters (color harmony of two-color combinations and three-color combinations) with a brief information on color harmony based on only hue.

2.5.2 Color Harmony based on the Three Color Appearance Attributes (HSB)

Hue has been the principal factor that color harmony studies have focused on. The harmony of hues is in relation with hue wheels that try to show harmonious relationships (see Figure 17). There are four widespread schemes of hue harmony (Westland et al., 2007):

a. Monochromatic color harmony

b. Complementary color harmony

c. Analogous color harmony

d. Split-complementary harmony.

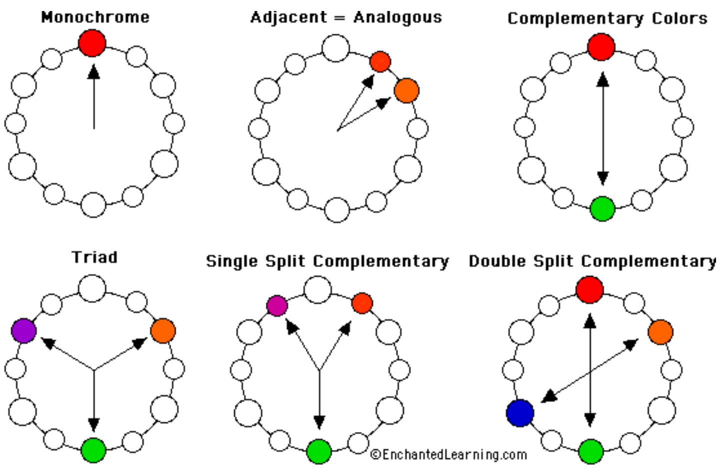


Figure 17. Color harmonies based on hue. (http://www.enchantedlearning.com/art/Colormixing.shtml)

The principle of complementary color harmony was described in 1793 by Benjamin Thompson Count Rumford (Kuehni, 2005). Rumford (cited in Kuehni, 2005) stated, considering only lights but not colorants, colored lights are harmonious if they make white when they are mixed. This principle was also postulated by Goethe and as Kuehni (2005) stated according to Goethe combinations of adjacent colors are not harmonious. According to Goethe (1970), harmonious combinations can be obtained if the colors are selected from opposite sides of his color wheel.

Moreover, Chevreul (cited in Kuehni, 2005) investigated the harmony of contrast (not limited to contrast hues, include also lightness and saturation contrast within the same hue) and analogous colors (adjacent colors of the same hue, saturation or lightness). Munsell (cited in Birren, 1969b) also stated that harmony can be obtained by complementary colors of the same value and same chroma. Additionally, Nemcsics (1980) stated that harmonious combinations can be obtained from the colors having a contrast relation in at least one of the attributes of Coloroid system.

Considering monochromatic color harmony, Ostwald (cited in Birren, 1969a) believed that harmony can be created by colors having the same hue. Munsell (cited in Birren, 1969b) stated, in addition to same hue, harmonious combinations can be obtained by colors having same chroma. Additionally, Nemcsics (1980) stated that harmonious combinations can be obtained from colors with the same hue, same saturation but different lightness values in Coloroid system.

There are other examples of hue harmony including triadic, tetradic and hexadic color harmony. Yellow/red/blue is the most powerful of the triads and orange/violet/green is another distinctive triad (Birren, 1970). Tetrads can be obtained by drawing a square, a rectangle or trapezoid on the color wheel (Birren, 1970). These geometrical figures such as triangles, square and rectangle used for obtaining harmonious colors may be drawn from any given point on the twelve-part color circle (Birren, 1970).

There are also modified triads for making harmonious combinations which are nearly analogous (Leland, 1998). There are twelve modified triads obtained from a twelve-part color wheel (Leland, 1998). Red, orange and yellow combination is one of the modified triad color schemes (Leland, 2008). Purple, blue and green combination is another modified triad color scheme.

Ou and Luo (2006) stated that hue has a significant influence on two-color harmony in terms of hue difference, for instance, as the hue difference between the constituent colors of a color pair decreases, the color pair appears harmonious. The findings of their experimental study showed that color pairs containing blue as a constituent color have the highest color harmony values and the ones that contains red have the lowest for seven hues red, orange, yellow, green, cyan, blue and purple.

Considering these theories on color harmony based on hue, color combinations of two, three and more colors can be obtained. However, there are also other dimensions of color affecting the harmony content of the color combinations. In the following two chapters, theories considering three dimensions of color (hue, chroma and value) for two and three color combinations will be analyzed.

2.5.2.1 Color Harmony of Two-Color Combinations

As was stated above, all the dimensions of colors have an effect on harmony content of the color combinations and there are various experimental studies searching for these effects. For instance, Allen and Guilford (1936) carefully selected 45 color combinations considering hue, tint and chroma differences and 10 subjects judged the affective values of the combinations using a rating scale. The term affective value was used in this study as the pleasantness of a color or color combinations. The results indicated that:

- The law of affective combinations was fully verified; the affective value of a combination is highly dependent upon the affective values of the components.
- There is some evidence that either very small or very large differences in hue give more pleasing results than do medium differences. This tendency is much stronger for the women than for men.
- The affective value of a combination is positively correlated with the amount of contrast in tint, regardless of whether the difference in hue is great, medium, or small. This correlation is much stronger for the men than for the women.
- There is a slight preference for combinations with small differences in chroma rather than large differences. This is a negligible factor in the case of the men (Allen and Guilford, 1936: 648).

As Nemcsics (2008) found out in the experiments, the harmony content of monochrome color pairs depends on brightness and saturation intervals between these colors. Color pairs with the same hue and saturation have the highest harmony content when the brightness interval is d30V (the difference of brightness values obtained by subtracting brightness values of the colors) between these colors in Coloroid system. Harmony content depending on saturation interval influenced by the hue and saturation of the colors in the color pair. Maximum harmony content appears in color pairs where the colors have identical brightness and d30T saturation intervals (difference of saturation values obtained by subtracting saturation values of the colors) having a Coloroid hue A21, A35, A44, A51.5, A64, A74. In order to obtain maximum harmony content, Coloroid saturation interval between the colors have a value more than d30T in yellow-greens, yellows, magentas, and blues and less than d30T in oranges, reds, violets and greens. Color pairs with d30T saturation intervals are perceived to be the most harmonic if they have V60 brightness in greens, yellows, oranges and reds. Color pairs with d30T saturation intervals are also perceived to be the most harmonic if they have V50 brightness in magentas and violets and any brightness levels in Coloroid hues A35 and A63. In order to obtain maximum harmony content, color pairs of magentas, violets, and blues that are brighter than V50 need smaller saturation levels and pairs that are darker than V50 need bigger saturation intervals.

As a result of testing existing color harmony principles (complementary hue, equal hue, equal lightness, equal chroma and equal tone, Ou and Luo (2006) found that equal hue and equal lightness were the only principles for predicting color harmony of two-color combinations. As these two principles also have low values, they also cannot predict harmony accurately. Ou and Luo (2006) identified three factors of color harmony as chromatic difference (a mixture of chroma and hue differences), lightness effect and hue effect. These three factors are assumed to be independent of each other, so therefore in order to form a two-color harmony model they are combined additively as (see Appendix B for detailed information):

$$CH = H_C + H_L + H_H$$

According to this equation, the higher the CH (Color Harmony) value the more harmonious the color pair would appear. The proposed model was tested with another study's data set and the results showed that the predictive performance of the model was high although the experimental settings and observers' cultural backgrounds were different for the test data and the model data. This indicates that there is a general pattern of color harmony for two-color combinations.

In the study of Szabo, Bodrogi and Schanda (2010), the color harmony of two-color combinations was divided into two as monochromatic two-color combinations and dichromatic two-color combinations. In monochromatic two-color combinations, hue is not a relevant factor affecting color harmony but some hues showed higher color harmony means more than in others (see Figure 18 (a)). This phenomenon was defined as hue preference by the authors. Other findings of the study showed that combinations of colors with equal lightness or with extreme lightness difference have the lowest color harmony scores (see Figure 18 (b)), combinations of colors with minimum chroma difference have the highest color harmony score and the score decreases linearly as the chroma difference increases (see Figure 18 (c)), combinations of colors with a low lightness sum have the lowest color harmony score and colors with high lightness sum have the highest score (see Figure 18 (d)). Four equations were obtained fitting each figure and they were combined to obtain a model for predicting color harmony of monochromatic two-color combinations (see Appendix B).

In dichromatic two-color combinations, hue was also a relevant factor affecting color harmony (see Figure 19 (a)). In these combinations, similar results were found as the monochromatic two-color combinations. Based upon the Figure 18 (a-d) and Figure 19 (a-b), a formula was constructed by the authors (see Appendix B).

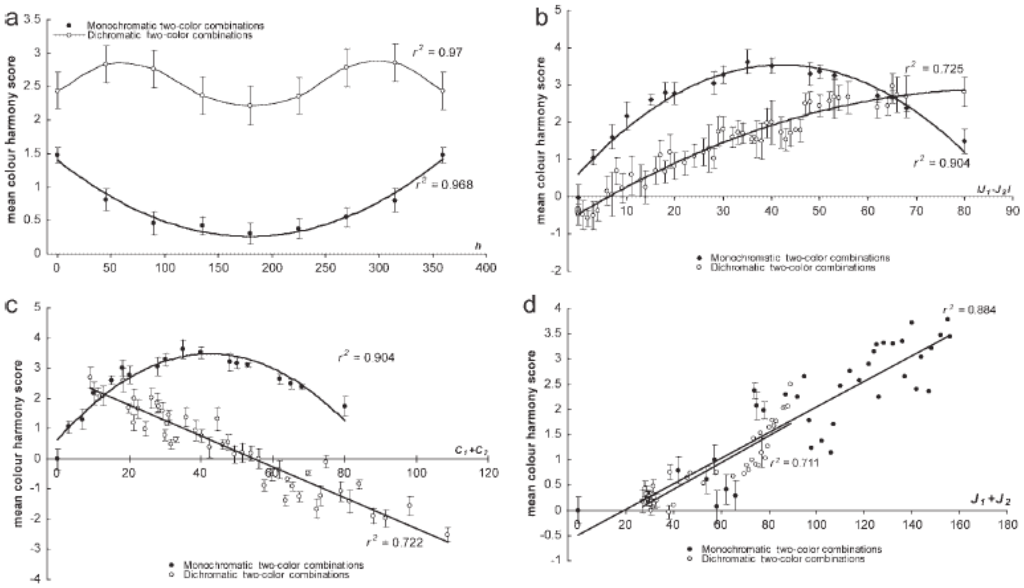


Figure 18. Predicting perceived color harmony for two-color combinations as a function of (a) CIECAM02 hue, (b) absolute lightness, (c) absolute chroma difference and (d) lightness sum (Szabo, Bodrogi and Schanda, 2010: 39).

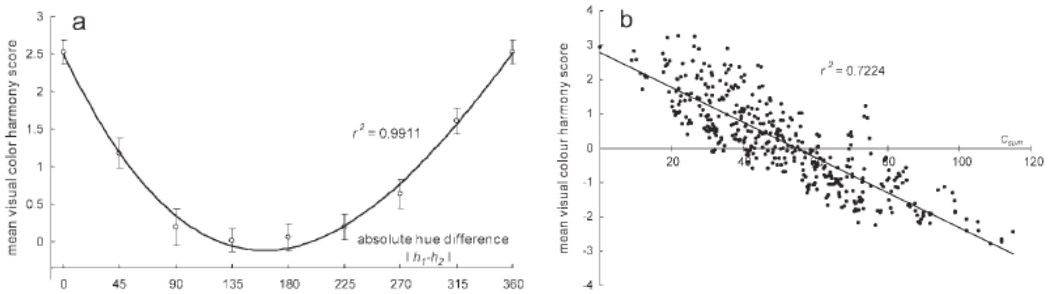


Figure 19. Predicting perceived color harmony for dichromatic two-color combinations as a function of (a) hue preference, (b) sum of chroma (Szabo, Bodrogi and Schanda, 2010: 40).

Experimental studies on color harmony assume that the harmony evaluation is consistent, predictable and color appearance values can be used for predicting color harmony. As was indicated above, there are mathematical formulas obtained from experimental research on color harmony for two-color combinations. The formulas include the three dimensions of color which are hue, chroma and lightness. Values of these dimensions of colors are used for predicting harmony content of color pairs. Further research was conducted for obtaining laws of harmony for three-color combinations.

2.5.2.2 Color Harmony of Three-Color Combinations

Ou, Chong et al. (2011) searched for whether their previously developed two-color harmony model mentioned above could be extended to multicolor combinations which they thought to be more common for artists and designers to deal with multicolor combinations rather than color pairs. Their additivity theory was to use the average of harmony values of each two-color combinations of a three-color combination for predicting overall harmony since it was hypothesized that a three-color combination would be a combination of three color pairs as shown in the equation below:

$$\mathrm{CH_{ABC}} = \frac{\text{characteristics}}{3} + \frac{\text{interactions}}{3} = \frac{k_\mathrm{A} + k_\mathrm{B} + k_\mathrm{C}}{3} + \frac{t_\mathrm{AB} + t_\mathrm{BC} + t_\mathrm{CA}}{3}$$
$$= \frac{[(k_\mathrm{A} + k_\mathrm{B})/2 + t_\mathrm{AB}] + [(k_\mathrm{B} + k_\mathrm{C})/2 + t_\mathrm{BC}] + [(k_\mathrm{C} + k_\mathrm{A})/2 + t_\mathrm{CA}]}{3} = \frac{CH_\mathrm{AB} + CH_\mathrm{BC} + CH_\mathrm{CA}}{3}$$

Here, $\mathrm{CH_{ABC}}$ is the overall harmony value for a three-color (A,B,C) combination obtained from the average of harmony values of color pairs AB, BC and CA; k_A, k_B and k_C are characteristics of each color in the combination; t_AB, t_BC and t_CA are interactions for color pairs AB, BC and CA; CH_AB, CH_BC and CH_CA are harmony values for color pairs AB, BC and CA. Harmony values of the color pairs can be calculated by the two-color harmony model of the authors mentioned above.

This formula was appropriate for three adjacent colors such as three colors on a wheel. However, the authors were interested in the application of this formula to nonadjacent colors. It was assumed that this formula could not predict harmony value for nonadjacent colors which means that when there were nonadjacent colors in a three-color combination the harmony value could not be predicted. Therefore, to make it clear whether the theory also applied to nonadjacent colors, the authors proposed another formula including nonadjacent colors (see Appendix B). A formula was also proposed for color-combinations of more than three colors (see Appendix B).

As Ou, Chong et al. (2011) stated their additive approach performed better than Szabo, Bodrogi and Schanda (2010)'s nonadditive model in which another formula was proposed for color harmony of three-color combinations. Depending on their mathematical model for two-color combinations, the authors first tested this model by resolving three-color combinations into three two-color combinations but it indicated a low predictive performance. Thus, a new model was formulated for three-color combinations as monochromatic and trichromatic color combinations (see Appendix B).

These studies proposing models for predicting harmony values of three-color combinations all indicated that they performed well. However, they were tested and found that one performed better than the other for predicting the harmony of three-color combinations. Ou, Chong et al. (2011) stated that this difference between the models did not mean that one is more reliable than the other in harmony prediction and needed more empirical evidence. In addition, these formulas did not consider area effect that was elaborated in another study by Wang, Ou and Luo (2007) (see Chapter 2.4). Thus, only the proposed formula by Wang, Ou and Luo (2007) was tested in this thesis and discussed in Chapter 5.

2.6 Color Harmony and Preference

The term color harmony is always confused with the term color preference and used interchangeably. The studies of Granger (1953; 1955a, 1955b, 1955c) are examples of this usage. Even in a series of studies on color harmony published sequentially in the same year, referring to harmony judgments, titles of the two articles depicted 'harmony' (Granger, 1955a, 1955b) whereas the last one depicted 'preference' (Granger, 1955c).

Color preference shows whether a color or a combination of colors is preferred by the viewers of it. As can be understood, color preference can be for single colors or combinations of color. However, color harmony is the orderly arrangement of color combinations that cause a pleasant effect on people.

The confusion between these two terms may be caused by their strong relation with each other. Harmony and preference of colors are considered to be strongly related. Judd and Wyszecki (1975: 390) defined color harmony as “when two or more colors seen in neighboring areas produce a pleasing effect, they are said to produce a color harmony.” They proposed that color harmony was a “matter of likes and dislikes” and believed that there was a link between color preference and color harmony.

In the study of Nemcsics (2009b) it was found that the more the colors in the combinations are preferred the more they are found harmonious. However it is also possible to dislike certain colors and still use them in harmonious ways (Holtzschue, 2006). Some studies indicated there are some cases that harmony and preference may differ. For instance, Ou et al. (2004b) found as factor analysis results of an experiment, in which 190 color pairs were assessed on 11 emotion-scales including harmonious-disharmonious and like-dislike as indirect color emotions, that both male and female participants had harmonious-disharmonious and warm-cool in one component. However, like-dislike was categorized into another component for female, although it was categorized into the same component with harmonious-disharmonious for male. Additionally, when Chinese and British observers were compared, it was also found that like-dislike and harmonious-disharmonious were categorized in one component for both groups. Different than the female and male groups, these groups had warm-cool in another component that did not include harmonious-disharmonious.

The findings of Ou, et. al. (2004b) showed that there is a strong relationship between preference and harmony but sometimes they might not be in relation with each other and not measure the same factor. In another study of Ou, et. al. (2004c), a strong correlation was found between like-dislike and harmonious disharmonious but with further analysis it was also found that color combinations that were preferred were not always evaluated as harmonious and that color combinations that were evaluated as harmonious were not always preferred. The percentages of the case when a color pair was evaluated as liked but disharmonious and the case when a pair was evaluated as harmonious but disliked were 4% and 18% respectively (see Figure 20). Harmonious color pairs consisted of 40+18=58% of the entire color pairs and this was higher than the number of liked pairs, 44%. This relationship between color preference and color harmony implied that if an observer likes a two-color combination, there is a 9% chance (4/44=9%) that he/she finds it disharmonious. Conversely, if an observer finds a two-color combination harmonious, there is a 31% chance (18/58=31%) that he/she dislikes it (Ou, et. al., 2004c).

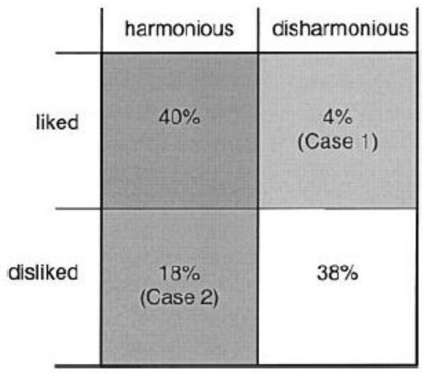


Figure 20. The relationship between color preference and color harmony (Ou et al., 2004c: 388).

In order to clarify the confusion between these terms, Schloss and Palmer (2011) proposed three ways of evaluating perceptual responses to color combinations as:

1) Aesthetic preference for a given combination,
2) Perception of harmony for that combination,
3) Preference for its figural color when viewed against a colored background.

Schloss and Palmer (2011) defined pair preference (preference for a given color combination) as the ‘liking’ of a viewer regarding a given pair of colors as a whole, pair harmony (perception of harmony for a combination) as the strength of perception of the colors in a combination as going or belonging together regardless of liking them and lastly they define figural preference as the liking of figural color itself when viewed against its background color.

According to the results of the experiments that Schloss and Palmer (2011) conducted, the distinction between these three evaluations showed that combination preference and harmony both increase as hue similarity increases but the former relies more on the component color preference and lightness contrast. Combinations consisting of highly contrastive hues are generally evaluated to be neither preferable nor harmonious, however the more the color has a hue contrast with the background the more the figural color is preferred.

As the empirical evidence provided by this study indicates, these three types of judgments are notably different since they produce different patterns of results. Related to the findings of the study, Schloss and Palmer (2011) stated that by making clear distinctions between the three types of judgments, some foundational problems of researchers such as how to define and measure preference and harmony properly, will be resolved. They believe that it is time to answer more advanced questions such as why people prefer the color combinations they do, and how context and/or intended message of visual display might influence color preferences.

As was stated above, color harmony and preference are two terms often confused with one another. Although they have a strong relationship, some studies indicated that there are differences between these terms. In addition to these, there is a basic difference between harmony and preference that in order to mention the notion of harmony there should be at least two colors, whereas preference can be mentioned for also single colors. Many studies have been done on preference of both single isolated colors or color combinations (Camgöz, 2000) but harmony is a subject of not isolated colors but color combinations.

CHAPTER 3

COLOR HARMONY IN INTERIOR SPACES

3.1 Interior Space

People spend most of their lives in man-made environments and inevitably have an interaction with the spaces in which they live. A space is perceived, evaluated and emotionally reacted to by its users. Each element in the formation of a space has a visual relationship with each other which has an influence on the whole and how it is perceived and evaluated by individuals. As Ching (1987) stated, spaces are formed by the relationships of elements and individuals perceiving them.

There are various elements (structural elements such as walls, columns, floor and ceiling and other elements such as furniture, texture, pattern, light, color and material) that compose an interior space. The exterior walls of a building constitute borders of a space and are the connections between interior and exterior spaces. A clear distinction can be obtained between a controlled and isolated interior environment and an exterior space by having thick and heavy walls, whereas they may be thin or transparent in order to merge inside and outside (Ching, 1987). Walls can be load-bearing or non-load-bearing. The materials used for the former may be brick, stone or concrete and for the latter may be glass or gypsum board. Walls (both interior and exterior) are the vertical planes and floor and ceiling are the horizontal planes that define the physical limits of an interior space. Their form, configuration and pattern of window and door openings also influence spatial qualities (Ching, 1987).

Windows and doors are the spatial transitions between exterior and interior space (Ching, 1987). Doors give access from one space to another. When they are closed they divide two adjacent spaces and when open they provide visual, spatial and acoustical links between spaces (Ching, 1987). Windows allow light and air to penetrate an interior space. They also provide visual links between the outside and the inside or from one space to another (Ching, 1987). Additionally, columns and beams are linear structural elements of a space that carry loads. A column is a vertical support transmitting forces downward and a beam is a horizontal member transmitting force along itself to the vertical supports (Ching, 1987).

In addition to structural elements such as columns, walls, floor and ceiling that give a space its form and set the boundaries of that space, other elements, which can be called design elements, such as furniture, texture, pattern, light, color and material are also the major elements of an interior space. Furniture consists of chairs, tables, beds, sofas, shelves, etc. and they can be fixed or movable. They can be used as an element to organize a space by defining circulation patterns and the aesthetic identity of a space (Kilmer and Kilmer, 1992).

Texture is the sense that an object awakes such as rough, smooth, hard and soft (Coates, Brooker and Stone, 2011). Scale (the relation of objects to each other and to people) and reflection of light are important considerations of texture (Friedmann, Pile and Wilson, 1982). For instance, smooth materials reflect light like a mirror whereas rough materials distort it. Different materials can be applied to give a texture to a surface in a space.

Pattern is a decorative element of interior design that can be applied to different surfaces such as furniture and walls (Coates, Brooker and Stone, 2011). One of the considerations of pattern is the scale. The size of the pattern and where it is applied (to walls, floor, curtains or furniture) should be considered while applying. Colors of the pattern should be considered with the colors of the overall design elements of a space.

Light (natural or artificial) is also a powerful and important feature of an interior space. Light is basically required to see but it is also a tool for creating different atmospheres for different purposes. It also has a visual effect on form, texture and color (Friedmann, Pile and Wilson, 1982) causing a change in perception. It may be said that there are three major aspects of lighting: function, aesthetics, and health (Friedmann, Pile and Wilson, 1982). Accordingly, the lighting of an interior space should be appropriate for its function and applied aesthetically but it should not cause eye fatigue and discomfort.

It is important to obtain appropriate lighting in an interior space. For instance, related to the climate, large windows can be used to let more natural light in a space or small window openings can be used. Blinds, shutters and curtains are used to control natural light and they also help to define the aesthetic identity and the mood of the space (Coles and House, 2007). Quantity and quality of illumination can be determined according to the function of the space and desired atmosphere to be obtained. For instance in order to achieve privacy, low illuminance is preferred whereas high illuminance is preferred for public use (Nakamura and Karasawa, 1999; Durak et al., 2007). Colored lightings can also be used to achieve different atmospheres (Odabaşıoğlu and Olguntürk, 2015).

Color has also been an important element of interior design and architecture. The use of color has been important because it helps defining form and space together with light. Therefore, interior architects must learn the characteristics of color in a space in order to create a successful interior (Grimley and Love, 2007). However, color has been considered in different ways by different architects. The color range is limited by some of the most important architects who deal with color (Serra et al., 2012). For example, Le Corbusier (1887-1965) (cited in Serra et al., 2012) warns architects about color usage rather encouraging them and he restricted his color usage by choosing tertiary colors that can be called architectural colors.

According to German architect Bruno Taut (1880-1938) (cited in Serra et al., 2012), there are hues suitable for architecture and others for painting and he rejects the secondary colors (orange, violet and green) because he considers them to be too shocking for architecture. In addition, Gerrit Rietveld (1888-1964) uses primary colors (see Figure 21). Although some trends reduce the usage of color in architecture, new color technologies in materials and lighting make architects use a wider range of colors (Serra et al., 2012). Today, even in the offices, various color schemes consisting of different hues are used by interior architects (see Figure 22, 23 and 24).

Figure 21. Rietveld's Schroder House.
(http://www.archdaily.com/99698/)

Figure 22. Google office İstanbul. Designed by: Burcu Şenparlak, Bülent Dündar, Vural Armutçuoğlu (http://www.arkitera.com/galeri/detay/56783/5/Proje/1616)

Figure 23. Skype Office in Stockholm designed by PS Arkitektur. (Photographer: James Strong. Retrieved from (http://kvadrat.dk/segments/project/29/Skype+Stockholm+Office)

Figure 24. Zenith Barter Office designed by Nuri Ciğerci, Esat Polat, Tülay Daşdemir, Yunus Kaya. (http://www.arkitera.com/galeri/detay/93867/49/Proje/2563?page=49)

Moreover, materials have a direct relation with color, light, texture and pattern that should be addressed carefully by interior designers. There are various materials that can be applied to different elements forming an interior space. For instance, paints, wallpapers and paneling are examples of finishing materials for wall surfaces; stone, wood, carpet and epoxy are examples of floor finishing; metal, wood and gypsum panels are examples of materials used for ceiling and textile, wood and plastics are examples of materials used for furniture. Materials have different properties offering a wide range of color, texture and pattern options for interior designers to create different atmospheres in relation with light. All of these contribute to the character of an interior space (Grimley and Love, 2007).

Each element in an interior space affects how that space is perceived. The style, amount and arrangement of furniture, colors of the furniture and colors applied to the walls, the type, color and amount of light used in the space all influence the perception of individuals. It is important to bring these elements together harmoniously to please users of these spaces.

3.2 Color Harmony Research in Interior Spaces

Colors in an interior space are dominant elements of design and it is important to have a harmonious color scheme in an interior space in order to please its users. However, in the studies of color harmony so far, basic patterns have been used for evaluation. Regarding the complexity of the phenomenon, the use of basic patterns in color harmony is a limitation as color patches shown side by side do not fully reflect practical applications, such as in interior spaces where colors have more complex relations than they have in 2D combinations of color patches. However, there are still a limited number of studies investigating color harmony in interior spaces.

The study of Shen, Chen and Hsu (1996), looking color harmony from an engineering perspective, in order to develop a computer-based consultation system, a quantitative evaluation of color harmony for interior images was constructed. This consultation system aimed to evaluate colors both objectively and subjectively from the viewpoints of color-normal and color-blind individuals. The main idea of relating this system on linguistic features is based on one of the attributes of color harmony proposed by Burchett (1991) as association.

According to Shen, Chen and Hsu (1996), most operative features of color harmony have a lack of association and associations can be differentiated by linguistic meanings (adjectives). As adjectives exciting-calm pair was selected and the reason for this selection was stated as that these adjectives were popular descriptions in interior design. A system was proposed that measures harmony grade quantitatively by Color Linguistic Distribution (CLD - a statistical histogram of the color linguistic value corresponding to two opposing color linguistic meanings) similarity on a one-dimensional image scale of exciting-calm (Figure 25).

The color harmony of interior images was evaluated with four methods, namely the human-based evaluation method (questionnaire) and a computer-based evaluation method with the three different color spaces of CIELUV, CIELAB and hue-dominated method. In the first part, participants evaluated the six images shown in Figure 26 according to a question ‘Please vote your preference/disgust if the demonstrated images were your own bedroom’. In the three computer-based evaluations the harmony grades of the images were evaluated by its CLD similarity to public harmony trends, called reference harmony distributions (RHD). The CLD of the original image is defined as the RHD because it is shown to the subjects next to the other images.

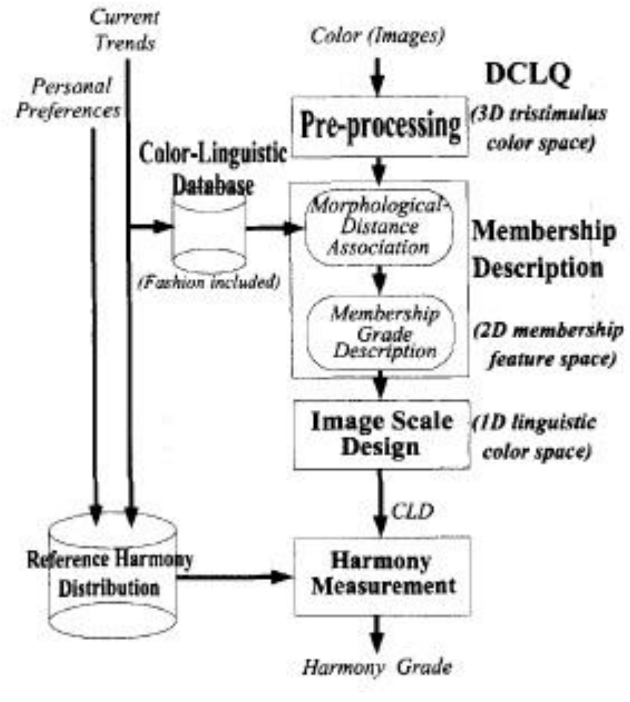
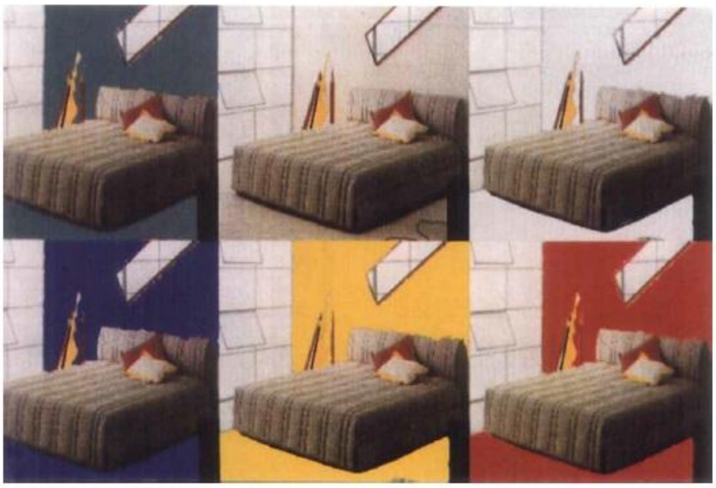


Figure 25. Flowchart of the proposed system, including the three main blocks of DCLQ algorithm, harmony measurement, and reference harmony distribution (RHD) (Shen, Chen and Hsu, 1996: 357).



(A), Gray_Dark_rendered	(B), Original	(C), Gray_Bright_rendered
(D), Blue_rendered	(E), Yellow_rendered	(F), Red_rendered

Figure 26. Six images evaluated by the participants (Shen, Chen and Hsu, 1996: 364).

It was concluded that the harmony of colors can be evaluated by the similarity of linguistic features (in this study exciting-calming membership for example). The results of the harmony and inharmony grades of the four methods are shown respectively below. These indicated the order of the images in Figure 26 from the most harmonious to the least harmonious in harmony grades and from the least harmonious to the most harmonious in inharmony grades for each method.

Harmony Grades (equal to preference votes):

- HG (Questionnaire):

  Original > Gray-Bright-rendered > Blue-rendered > Yellow-rendered > Gray-Dark-rendered > Red-rendered.

- HG (CLD, Lab):

  Original > Gray-Bright-rendered > Blue-rendered > Gray-Dark-rendered > Yellow-rendered > Red-rendered.

- HG (CLD, Luv):

  Original > Gray-Bright-rendered > Blue-rendered > Gray-Dark-rendered > Yellow-rendered > Red-rendered.

- HG (CLD, Hue):

  Original > Red-rendered > Yellow-rendered > Blue-rendered > Gray-Dark-rendered > Gray-Bright-rendered.

Inharmony Grades (equal to disgust votes):

- IHG (Questionnaire):

  Red-rendered > Blue-rendered > Gray-Dark-rendered > Yellow-rendered > Gray-Bright-rendered > Original.

- IHG (CLD, Lab):

  Red-rendered > Yellow-rendered > Blue-rendered > Gray-Dark-rendered > Gray-Bright-rendered > Original.

- IHG (CLD, Luv):

  Red-rendered > Yellow-rendered > Gray-Dark-rendered > Blue-rendered > Gray-Bright-rendered > Original.

- IHG (CLD, Hue):

  Gray-Bright-rendered > Gray-Dark-rendered > Blue-rendered > Yellow-rendered > Red-rendered > Original.

According to these findings, harmony grades obtained from the questionnaire showed that interiors with low saturation and high brightness were found to be more harmonious. Also, findings based on CIELAB and CIELUV color spaces are better than those based on the hue-dominated method in corresponding with the findings obtained from the questionnaire and linguistic similarity. Results also indicated that calculated HG (Harmony Grades) and IHG (Inharmony Grades) of the questionnaire were not in reverse orders. According to the authors, this inconsistency may be because the chosen colors of opposing linguistic meaning (exciting, calm) were not absolutely symmetrical and so the evaluated preference and disgust were not completely complementary. Consequently, the calculated harmony and inharmony order could not inversely agree.

In a further study of these authors (Shen et al., 2000), following the previous approach, a new color selection system was presented considering color harmony for interior design. This new system was obtained by modulating the CLD (color linguistic distribution) and aimed to be a tool used as a color-harmonizing function in a computer-based color consultation system (see Figure 27).

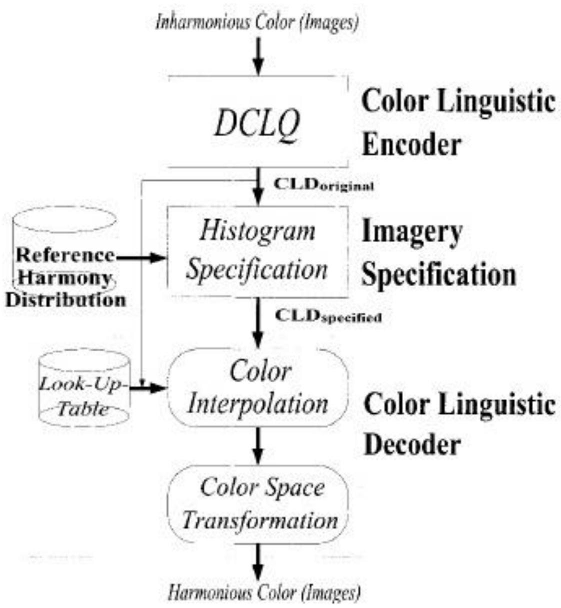


Figure 27. Flowchart of the proposed color selection system (Shen et al., 2000: 23).

According to the flowchart in the previous page, this system, firstly, encodes the CLVs (color linguistic values regarding exciting-calming scale) of the colors in a plate or an image and then based on the imagery specification the encoded CLVs were reconstructed as tristimulus values (L, u, v of CIELUV) by the color linguistic decoder. The resultant images are lower in saturation and higher in brightness than the originals with an impression of calmness since the previous study of the authors indicated that these colors constitute harmonious combinations. The system caused a little change in the colors that are close to this description but it changed exciting colors (high saturation, low brightness) in order to achieve harmony (see Figure 28).

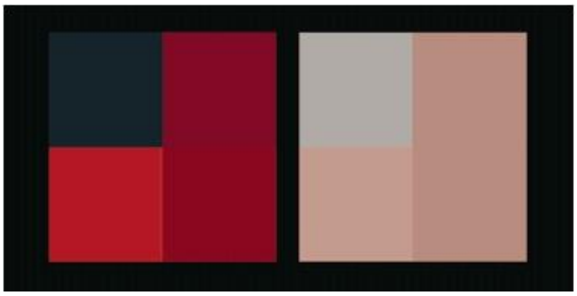
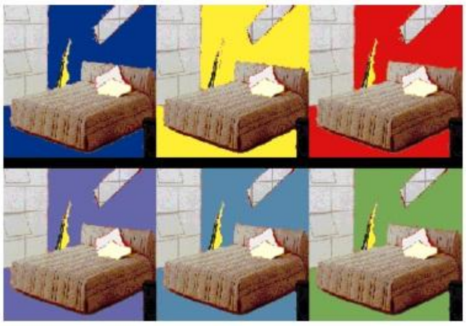


Figure 28. Color selection of plate images: (LEFT) originally inharmonious (exciting) images; (RIGHT) correspondingly harmonious (calm) results (Shen, et.al, 2000: 26).

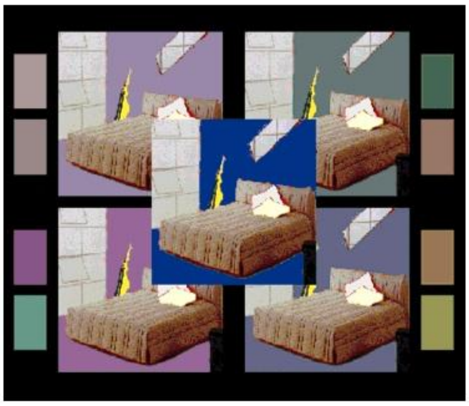
The results indicated that the proposed system improved the harmony grades of inharmonious images up to four times more than the original image. Six interior images that were supposedly inharmonious were used to see the applications of the proposed system (see Figure 29) and the proposed colors of the color-harmonizing tool for the blue-rendered interior image is shown in Figure 30. In interior images the encoded CLDs were modulated by the imager specification referring to four

RHDs (EC=extremely calm; QC=quite calm; SC=slightly calm; practical version=involves the variety of current trends) and therefore four CLDs were reconstructed as corresponding images. Additionally, multiple colors were also proposed by adding a variation to the specified CLV (two small strips next to the images) (see Figure 30).



(A)	(B)	(C)
(D)	(E)	(F)

Figure 29. Six background-rendered images (Shen et al., 2000: 26).



(B), EC		(C), QC
	(A), Blue	
(D), SC		(E), Practical

Figure 30. Color selection of blue-rendered inharmonious image (Shen et al., 2000: 27).

In the study of Ou, Chong et al. (2011), in addition to color patches, complex images were used as a second stage of the experiment and interior images were used as complex images (see Figure 31). It was believed that a complex image was more relevant than a combination of color patches to the work of artists and designers. It was hypothesized that a three-color combination could be seen as a combination of three color pairs and harmony value of each pair could be quantified by a two-color harmony model the authors previously derived. Thus, the authors tested their previously developed two-color harmony model whether it could be applied to three-color combinations by adding each possible dual combinations within the three-color combination. (For example, the color harmony of three-color combination ABC can be calculated by the average of the color harmony of AB, AC and BC). Study results supported their hypothesis.

Figure 31. Interior image used in the study of Ou et al. (2011) (Ou et al., 2011: 358).

The authors also tested the data they obtained from this experiment regarding the conventional color harmony theories of complementary hue, equal hue, equal lightness and equal chroma. It was found that equal hue and equal chroma principles had higher harmony scores than the other two. However, it was also stated that "it is possible to make an interior image appear more harmonious by making the individual colors similar in lightness or having complementary hue angles" (Ou, et.al., 2011: 11).

These three studies do not consider the effect of area in interior spaces. In addition, the colors are applied only on the walls. However, in interior spaces, furniture, walls, floor and ceiling may be differently colored and accordingly the surface areas and relations of the colors may differ. This thesis will investigate the effect of surface areas on color harmony in interior spaces.

CHAPTER 4

THE EXPERIMENT

4.1 Aim of the Study

The main aim of this study is to examine the effect of area on color harmony in interior spaces. Area in color harmony is the relative amount of different color areas represented as a proportion on which color harmony depends. Three primary (red, blue, yellow) and three secondary (green, purple, orange) colors of Itten's color wheel were studied in a simulated office interior with three-harmonious schemes emphasizing different proportional use of each color.

The secondary aim of this study is to investigate how the term color harmony is defined and the link between color harmony and the related terms used to define it. The term color harmony is defined differently by different authorities and in experimental studies researchers prefer to use one of these definitions to inform the evaluators. However, it is also important to note how the evaluators define color harmony and according to what they evaluated a color scheme as harmonious. The related terms that are used to define color harmony can explain why a color scheme is evaluated as harmonious.

4.1.1 Research Questions

The research questions of the study are as follows:

1. Is there a general pattern of color harmony which differs depending on the proportions of colors used in interior spaces?
2. Is there a relationship between color harmony and the related terms used to define it?
3. Is there a relationship in between the related terms used to define color harmony?

4.1.2 Hypotheses

The hypotheses of the study are as follows:

1. Color harmony evaluations differ depending on the proportions of constituent colors' areas in interior spaces.
2. There is a strong and positive relationship between color harmony and the terms used to define it.

3. There is a strong and positive relationship between all the terms used to define color harmony.

4.2 Method of the Study

The method of the study is explained under the following sections: sample group, experiment room and procedure. Detailed information is given about the experiment considering the participants, the experiment and how the experiment was conducted.

4.2.1 Sample Group

The experiment was conducted with the participation of 60 subjects. The majority of the participants were university students (95%) at Marmara University and 5% of the participants were university graduates. Samples were chosen with purposive sampling considering their knowledge of color. Subjects had taken no color courses and had no knowledge of color. The experiment did not concentrate on age and gender effects.

Different subjects participated in the experiment for each four sets. The number of subjects for each set of color combinations and the information of their departments and age range were given in Table 2. The participants who had no eye defects were 63.3% of all, whereas 36.7% of them had eye defects. Participants who had eye defects were asked to wear their corrective equipment such as glasses or contact lenses during the experiments.

Table 2. Information on the subjects.

	Department	Age range	Number
SET 1	73.3% Printing Technology 6.7% Electricity & Energy 20% Teacher Training in Printing	18-24 (M: 20.20 SD:1.656)	15
SET 2	80% Printing Technology 6.7% Electricity & Energy 6.7% Forest Engineering 6.7% Electronic Communications Technology	18-29 (M: 20.13 SD: 2.560)	15
SET 3	60% Printing Technology 6.7% Forest Engineering 33.3% Machinery & Metal Technology	18-27 (M: 20.20 SD: 2.366)	15
SET 4	26.7% Printing Technology 6.7% Forest Engineering 26.7% Machinery & Metal Technology 13.3% Textile Engineering 6.7% Journalism 6.7% Teacher Training in Metal Works 13.3% Aquatic Products	18-44 (M: 22.13 SD: 6.556)	15
		TOTAL	60

4.2.2 Experiment Room

The experiment was conducted in the X-RITE Color Laboratory of the Faculty of Technical Education at Marmara University (see Figure 32). The laboratory had no windows and had viewing conditions appropriate for the standard ISO 3664:2009. This standard specifies viewing conditions for images as prints or images displayed on color monitors. According to these standards, the room had a neutral and matt color. The walls and all the furnishing were gray having a Munsell notation of N8. Additionally, the room had fluorescent lamps that simulate Illuminant D50 for illumination.

Figure 32. X-RITE Color Laboratory of Faculty of Technical Education.

The monitor used in the experiments was an EIZO ColorEdge CG243W with a 24 inch wide format LCD and it had a monitor hood that prevents glare. The resolution of the monitor was 1920X1200 and it had a wide color gamut of 98% of Adobe RGB. A calibration software was provided for the monitor, “ColorNavigator”, for calibrating monitor characteristics and generating color profiles. However, the monitor was calibrated with i1-Pro2 spectrophotometer that measures detailed spectral information from LCD displays. For calibrating the monitor the target values were inserted as monitor native for gamut, 80 cd/m^2 for brightness, D50 for white point and 2.2 for gamma. After calibration the obtained values were 0.15 cd /m^2 for black level, 5016K for white point and 80.2 cd/m^2 for brightness. This data was saved as an ICC color profile to be used in the program that was utilized in the experiments for showing the images randomly.

4.2.3 Procedure

The procedure followed in the study is explained in the following sections as: selecting the function, specifying the colors, creating the interior space, preparing the questionnaire and phases of the experiment.

4.2.3.1 Selecting the Function

The main aim of this study is to explore the effect of area on color harmony in an interior space. Considering the function of the space, private spaces were excluded (e.g. bedroom and living rooms) where personal tastes may be more dominating. Thus a semi-public space was thought to be more suitable for the experiments. Function of the interior space was specified as an office since in office environments furnishings, wall coverings, and floor coverings are kept identical for all users and users are obliged to stay in these spaces.

The recommended depth of an office is between 3.75-7.50m and height of an office 2.50-4.00m (Neufert, 2008). Dimensions of the representational office room used in the experiments were decided to be 4.10x4.40x3.00m which were within the recommended dimensions. The plan of the office used in the visuals is given in Figure 33.

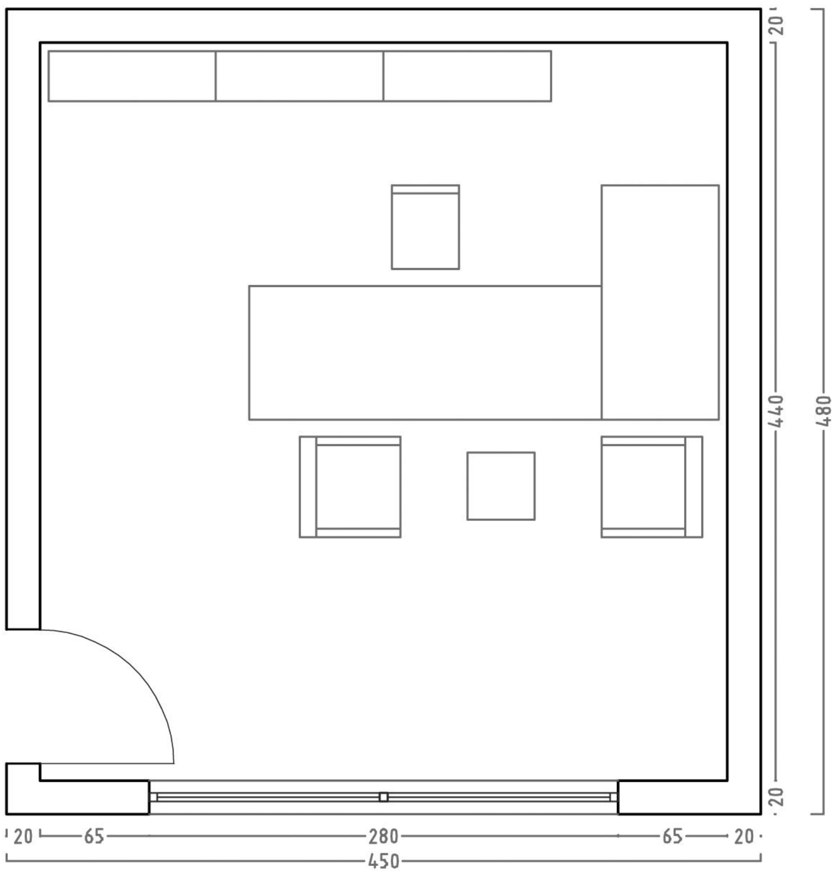


Figure 33. Plan of the office.

4.2.3.2 Specifying the Colors

Colors used in the experiments were selected as the three primary colors (red, blue, yellow) and three secondary colors (green, purple, orange) on Itten's color wheel. 4 sets of three-color combinations were created by using these primary and secondary colors which form equilateral and equiangular triangles on Itten's color wheel (see Figure 34). According to Itten's color harmony theory, colors can be harmonized if their position on Itten's hue circle creates a well-defined polygon such as dyads, triads and tetrads. There are also modified triads which are made up of three colors having one color between each on Itten’s color wheel (Leland, 1998; Leland, 2008). Thus, the selected color schemes were assumed to be harmonious color schemes. Sets of three colors were applied to walls, table-bookshelf-coffee table, and to seating units. Floor and ceiling were gray (See Table 3, see also Appendix C).

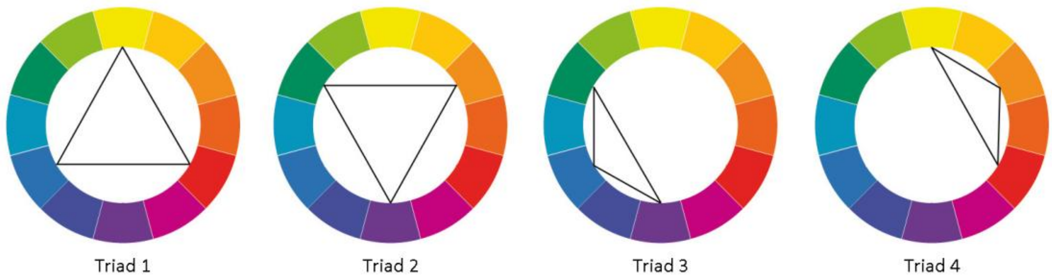


Figure 34. Selected three-color combinations.

Table 3. Three-color combination sets.

	Walls	**Table-Bookshelf-Coffee Table**	**Seating Units**
Set 1 (triadic color scheme 1)	Red (R: 0.76 G: 0.38 B: 0.38)	Blue (R: 0.45 G: 0.45 B: 0.9)	Yellow (R: 0.5 G: 0.5 B: 0.25)
	Red	Yellow	Blue
	Blue	Red	Yellow
	Blue	Yellow	Red
	Yellow	Red	Blue
	Yellow	Blue	Red
Set 2 (triadic color scheme 2)	Green (R: 0.27 G: 0.56 B: 0.27)	Purple (R: 0.72 G: 0.36 B: 0.72)	Orange (R: 0.62 G: 0.46 B: 0.3)
	Green	Orange	Purple
	Purple	Green	Orange
	Purple	Orange	Green
	Orange	Purple	Green
	Orange	Green	Purple
Set 3 (warm color scheme)	Yellow	Red	Orange
	Yellow	Orange	Red
	Red	Yellow	Orange
	Red	Orange	Yellow
	Orange	Red	Yellow
	Orange	Yellow	Red
Set 4 (cool color scheme)	Blue	Green	Purple
	Blue	Purple	Green
	Green	Blue	Purple
	Green	Purple	Blue
	Purple	Blue	Green
	Purple	Green	Blue
Ceiling	Gray (R:0.8 G:0.8 B:0.8)		
Floor	Gray (R:0.2 G:0.2 B:0.2)		

Hue differences were searched in these experiments. Therefore, saturation levels of the selected colors were equal. The reflectance values of walls, ceiling, floor, and furniture of offices are recommended by IESNA as 50-70%, 80% or more, 20-40%, and 25-45% respectively (IESNA Lighting Handbook, 2000). Reflectance values of the ceiling, walls and furniture, and floor were adjusted according to these recommendations as 80%, 50% and 20% respectively. Since the colors that were subject to the harmony evaluations in the experiments were applied to walls and furniture, they had reflectance value of 50%. The reason for applying the color combinations on the walls and furniture is to be able to equalize the reflectance values of all the colors while also considering the recommendations of IESNA.

Luminance is the light reflected from a surface and different hues with constant saturation and brightness levels have different luminance values. This can be observed when a colorful image with constant saturation and brightness level is converted to grayscale. Although the saturation and brightness levels of the colors are fixed, the image in grayscale consists of different levels of grays (see Figure 35). Blue reflects the least amount of light and has the lowest luminance value, therefore in grayscale it is the darkest gray whereas yellow is the opposite (Jonassen, 1982; Simmonds and Reynolds, 1989; Sutton, 2010). According to this, in order to fix the reflectance levels of the colors, the brightness and saturation levels of the colors were fixed in the grayscale.

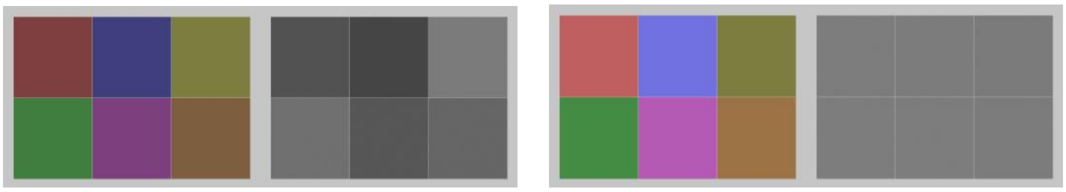


Figure 35. Selected colors with equal brightness and saturation (left), Selected colors with equal saturation and different brightness but fixed in grayscale (right).

4.2.3.3 Creating the Interior Space

Interior spaces for the experiment were created in RADIANCE (See Figure 36). The reason for using RADIANCE is that it is a physically based rendering software allowing accurate estimation of the properties of light to produce photometric models. It is important to obtain colors seen physically accurate since in 3D environments shadows and interreflections have an influence on perception of colors. Ruppertsberg and Bloj (2006) stated that there is not an alternative simulation which is better than RADIANCE to achieve physical realism.

Considering the lighting of the interior space, office lighting should enable working people to perform their tasks effectively and it should provide good visibility for the visual tasks (IESNA, 2000). The selection of a light source for an office depends on color rendering, initial cost, maintenance costs, and energy costs of the light source (IESNA, 2000). However, it is difficult to recommend a certain color temperature (see Appendix F for definition) for office spaces because people's preferences for warm and cool light sources differ from individual to individual (IESNA, 2000). In this study, an important quality considered was the color rendering index (see Appendix F for definition) of the light source. IESNA (2000) recommends choosing lamps of 70 CRI or greater in general, or 85 CRI or above if color critical tasks are being performed in an office. Based on this, OSRAM Mira Led (CRI > 85, CCT 4000) was selected for the study and the photometry file of this luminaire was used in RADIANCE for rendering. Additionally, IESNA (2000) recommends 500 lux for horizontal illuminance and

300 lux for vertical illuminance in a private office. Considering this, the horizontal illuminance level that was maintained at working level was approximately 400 lux (see Figure 36).

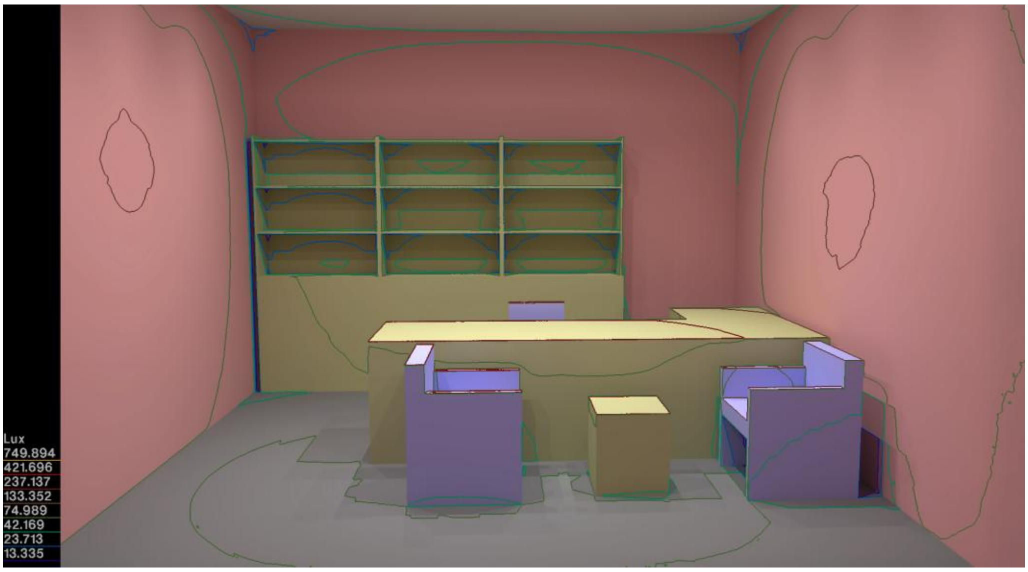


Figure 36. Illuminance levels.

Related to the areas of the perspective of the office, the proportions of the areas of walls, table-bookshelf-coffee table, seating units were as 9: 3: 1 respectively. Accordingly, the proportions of the three-color combinations were 9: 3: 1. The proportions of the colors and their application in the offices for all the sets can be seen in Figure 37, 38, 39 and 40.

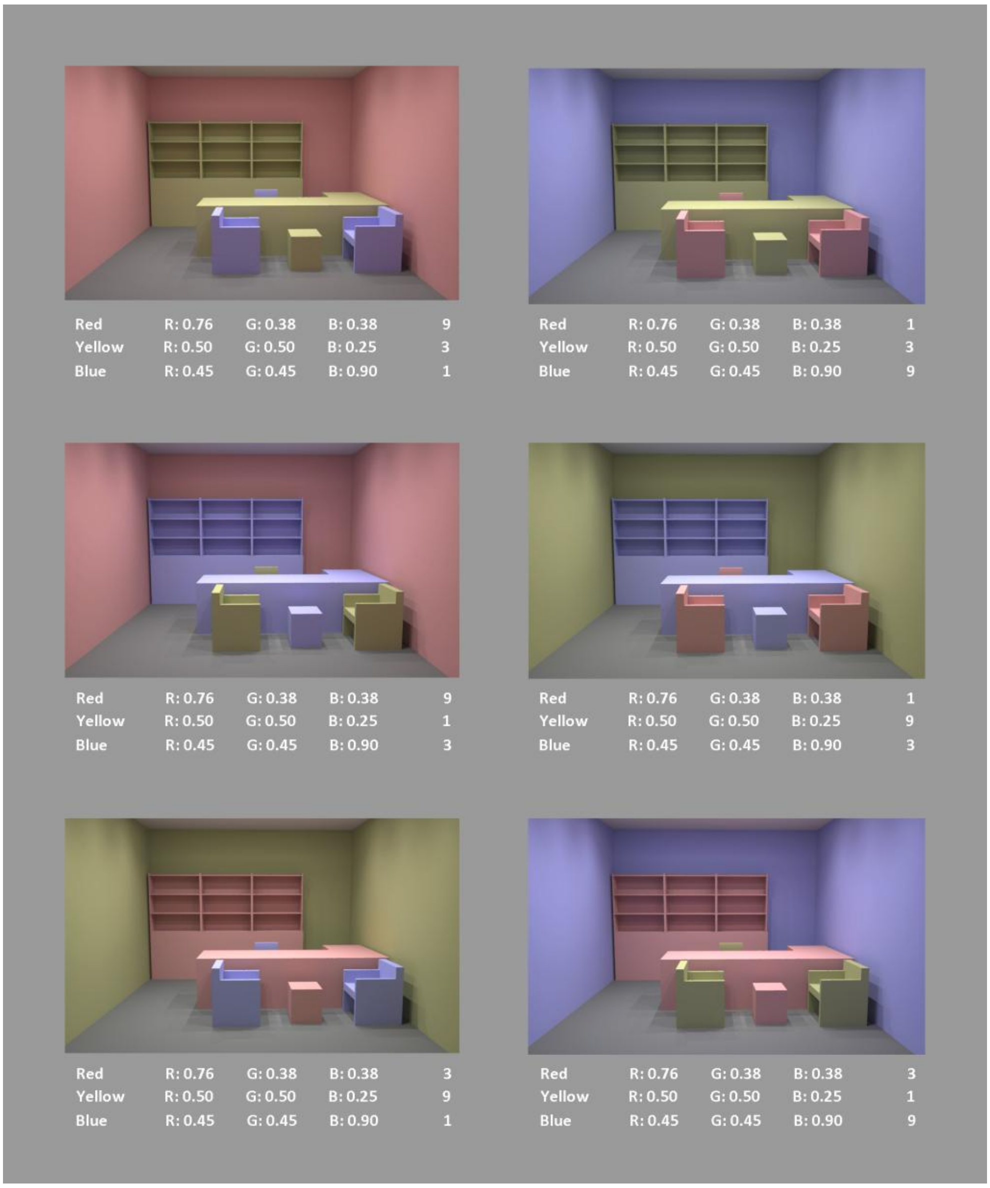


Figure 37. View of the office (Set 1).

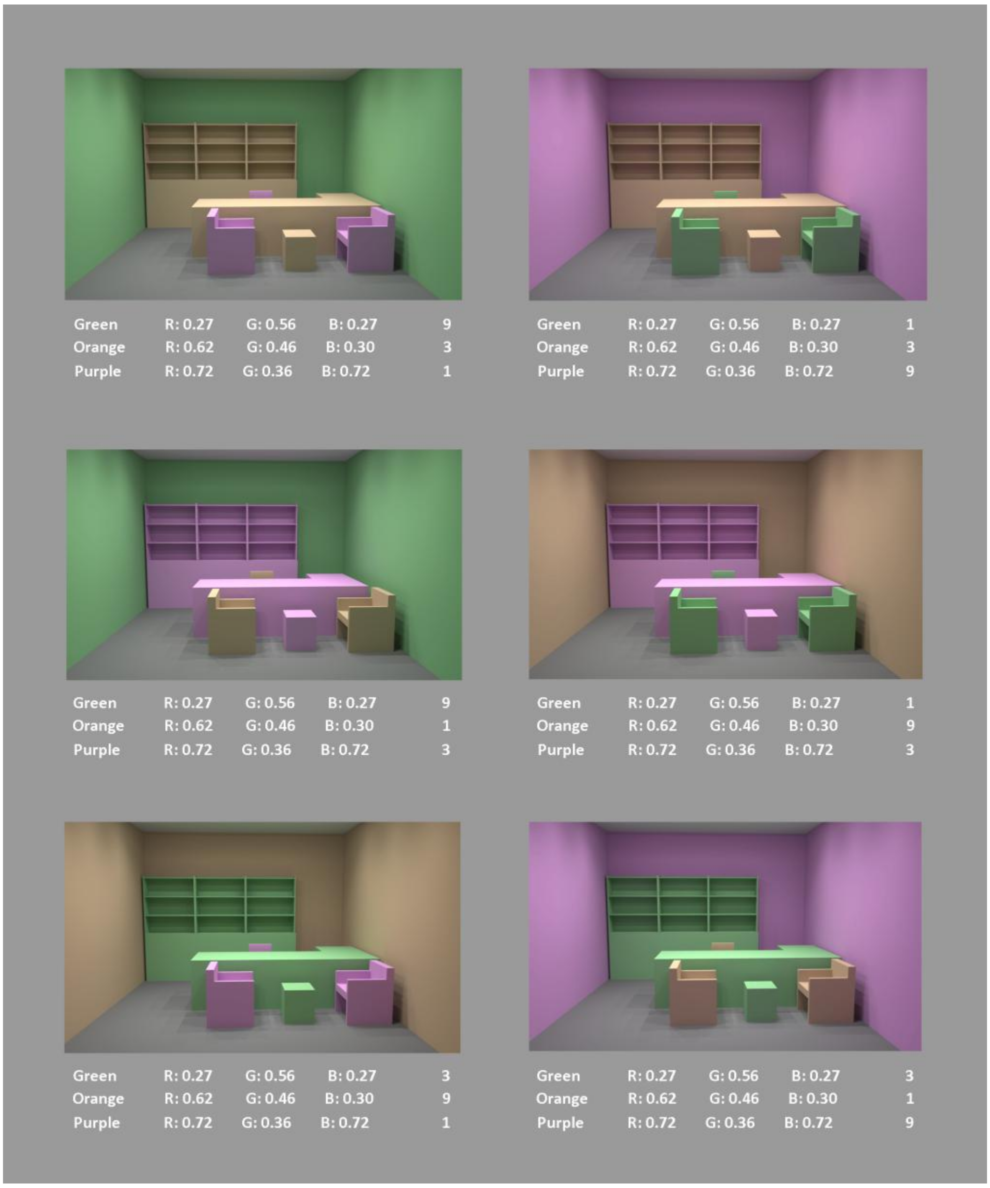


Figure 38. View of the office (Set 2).

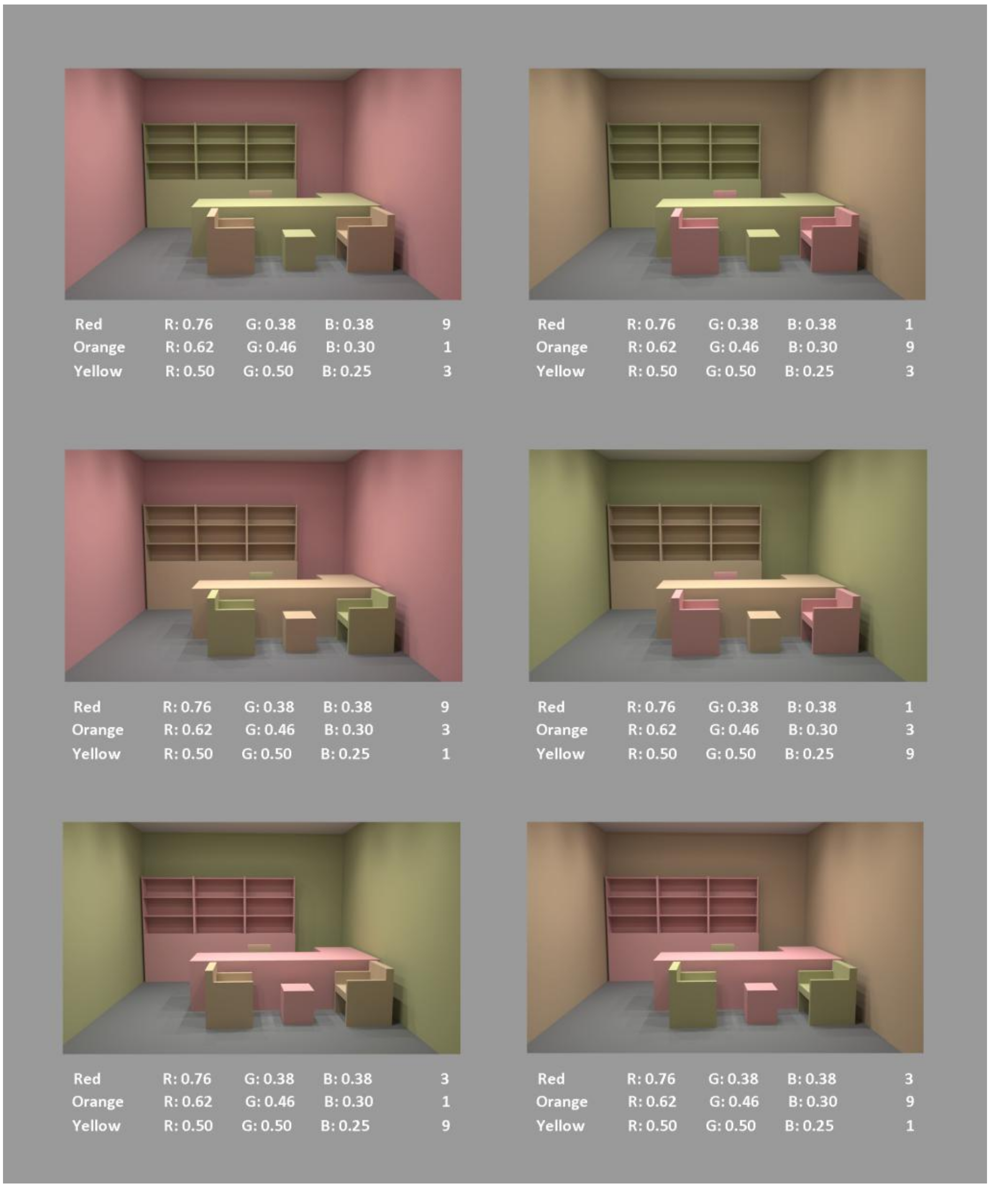


Figure 39. View of the office (Set 3).

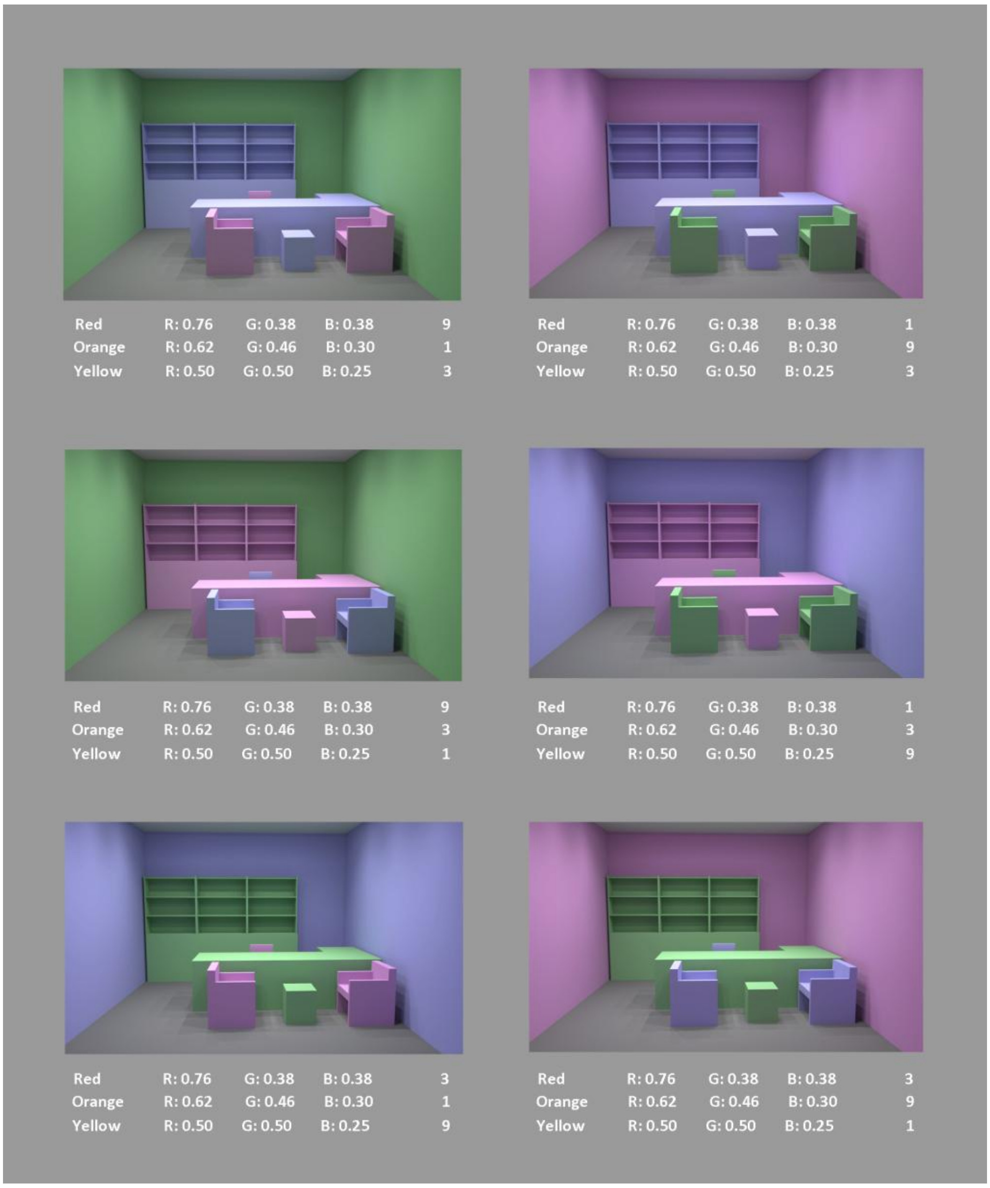


Figure 40. View of the office (Set 4).

Although videos would be better to feel presence in the office environment, images were used in the experiments to be evaluated for their harmony contents. One of the reasons for this was the low presence values of the videos showed in the pilot studies. Two pilot studies, in which videos were used viewing the interior of the office looking from left to right (the first one included videos with a fisheye distortion of view, the second one included videos without distortion), showed that the evaluation of the presence questionnaire for the videos shown to the participants had very low values (see Table 4 and 5). Items of the scales had a range from 0 to 6. The first pilot study conducted with the first year students of Interior Architecture viewing the videos with distortion, had relatively higher values than the second pilot study conducted with the third year students of the same department viewing the videos without distortion. The values of spatial presence, experienced reality and involvement were middle and lower than this approaching to lowest value 0.

Table 4. Presence test results (pilot 1)

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
spatial presence	7	2.60	4.60	3.4857	.73808
experienced reality	7	.00	3.00	2.2500	1.05079
general	7	.00	4.00	2.2857	1.38013
involvement	7	1.00	4.75	2.7500	1.39194
Valid N (listwise)	7				

Table 5. Presence test results (pilot 2)

	N	Minimum	Maximum	Mean	Std. Deviation
general	7	0	3	1.14	1.069
spatial presence	7	1.8	3.6	2.743	.6399
involvement	7	.0	2.0	.900	.7572
experienced reality	7	.2	1.5	.900	.4546
Valid N (listwise)	7				

Since the low presence values may have been related to the viewing conditions looking to the interior of the office from left to right, another video (without distortion) viewing the interior of the office by moving back and forth was prepared and the presence questionnaire was applied to a number of subjects in order to compare it with the previous video. The results of the presence test for the video moving back and forth also showed low means (Table 6). This shows that subjects did not have a sense of being in that space and they saw it as if it was an image. The mean results of the question "I felt like I was just perceiving pictures" for the second pilot study and the evaluations with back and forth video were 3.4 and 1.7 respectively indicating that (especially for the back and forth video) subjects tended to see the videos as images.

Table 6. Presence test results of the video moving back and forth.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
experienced reality	7	.0	3.8	1.507	1.1745
involvement	7	.3	5.0	2.464	1.7762
spatial presence	7	1.4	3.4	2.829	.7251
general	7	0	4	1.71	1.704
Valid N (listwise)	7				

Another reason for using images in the experiments was the observation that the participants needed to compare their evaluations on one color combination with the other leading to the use of paired comparisons in the experiments. Since all the stimuli would be paired, in the paired comparisons showing two videos side by side would not be effective for the subjects to sense presence in the virtual office environments.

4.2.3.4 Preparing the Questionnaire

In the last pilot study, the definition of color harmony was asked to the participants in order to understand how they determine a color combination to be harmonious. Thirty subjects consisting of 22 students from the Marmara University Department of Interior Architecture, 1 interior architect, 1 industrial designer, 2 engineers, 2 teachers and 2 other professions participated in the experiment with a mean age of 26 (age range 19-60, SD=9.8). 22 of the subjects were female and 8 were male. Although the original experiment was conducted with subjects who had not taken any color courses and who did not have any knowledge of color, 24 of the subjects of this pilot study had taken color courses.

The subjects responded to the questions 'What is color harmony according to you? How can a color combination be evaluated as harmonious?' and the content of their answers was analyzed. While analyzing the answers, words were accepted as a unit of analysis. The words that were used by the subjects to describe color harmony were counted. These words, the number of subjects using them and how many times they were repeated are shown in Table 7.

Table 7. The terms related to color harmony.

Word	Number of subjects using the word	%	Repetition of the word	%
Pleasing	16	19.5	16	16
Contrast	10	12.2	11	12
Balance	8	9.8	12	12
Like	7	8.5	10	10
Tints & shades	5	6	6	6
Spaciousness	4	4.9	5	5
Analogous	4	4.9	4	4
Calmness	4	4.9	4	4
Warm colors	4	4.9	4	4
Proportional	4	4.9	4	4
Preference	3	3.7	5	5
Light colors	3	3.7	3	3
Cool colors	3	3.7	3	3
Natural colors	2	2.4	6	6
Association	2	2.4	4	4
Positive effect	1	1.2	1	1
Quantity	1	1.2	1	1
Proximity & Distance	1	1.2	1	1

The terms obtained from the participants were similar to the ones stated in the study of Burchett (2002) in which content analysis of various color books were done regarding color harmony and the terms used for describing it categorized into eight attribute categories and subcategories (related terms of each category). Therefore, the terms obtained in this study were categorized according to these categories (see Table 8). Only the term balance could not be added to these categories since it had a broader meaning. Although balance is in relation with size (area) it also contains other attributes such as the balance of light and dark, warm or cool. It is the equilibrium in areas, energies and light degrees of colors (Sutter, 1858 cited in Christophe, Zanin and Roussaffa, 2011).

Table 8. Categorization of the terms.

Category	Related Terms	Percentage
Area	Proportional Quantity	6.1
Association	Like Preference Natural colors	17
Attitude	Warm-cool Calmness Spaciousness Positive effect Pleasing	39.1
Configuration	Proximity Distance	1.2
Interaction	-------------*	0
Order	-------------*	0
Similarity	Analogous Contrast	17.1
Tone	Light-Dark (Tints & shades)	9.7

(*) = Subjects did not mention any terms related to this category.

According to the percentages of the categories, attitude was the most mentioned attribute of color harmony. Similarity and association followed this category, and tone and balance attributes followed these two. Area was the fourth attribute considering the percentages and configuration had the least percentage in all of the categories.

For the reliability of the terms obtained and their categorization related to their content, another researcher also counted and categorized the terms independently from the researcher. Data obtained from both of the researchers coincided 100%. However, the number of repetition of the words coincided 94%. To eliminate the different opinions on the numbers, the data was revised and a consensus was obtained.

The terms derived from the answers of the subjects were transformed into a questionnaire for the third phase of the experiment by forming them into word pairs (see Table 9). While formulating the questionnaire, 5 of the 18 terms merged and 13 adjective pairs were obtained [1. Like and preference means the same thing. Preference is “liking for one thing rather than another” (Longman dictionary of contemporary English, 1991), 2. Contrast is antonym of similarity (analogous) (Roget's 21st Century Thesaurus, n.d.), 3. Tints & shades indicate light and dark colors, 4. Warm is antonym of cool (Roget's 21st Century Thesaurus, n.d.), 5. Proportion is “the relationship of one thing to another in terms of quantity, size, or number; ratio” (Oxford Dictionary, n.d.) and it includes quantity in its definition.] The definitions of the terms, which were made in reference to dictionaries, are given in the following pages.

Table 9. Word pairs of the third phase of the experiment.

Proportional X Not proportional
Like X Dislike
Positive association X Negative association
Natural X Unnatural
Warm X Cool
Relaxed X Tense
Spacious X Cramped
Positive effect X Negative effect
Pleasant X Unpleasant
Well placed X Not well placed
Analogous X Contrast
Light X Dark
Balanced X Imbalanced

Proportional & Not proportional: As it is stated above, proportion means "the relationship of one thing to another in terms of quantity, size, or number; ratio" (Oxford Dictionary, n.d.).

Like & Dislike: Like means to "enjoy something or think that it is nice or good" (Longman dictionary of contemporary English, n.d.).

Positive/negative association: Association means a "connection made in the mind between different things, ideas, etc." (Longman dictionary of contemporary English, 1991, p.55). For this study, emotional associations were considered.

Natural & Unnatural: Natural means "existing in nature and not caused, made, or controlled by people" (Longman dictionary of contemporary English, n.d.).

Warm & Cool: Warm means "giving a pleasant feeling of cheerfulness or friendliness" (Longman dictionary of contemporary English, 1991, p.1186) and a warm color is one that is based on or contains a color such as red, yellow or orange that suggests warmth (Cambridge Dictionaries Online, n.d.). Cool "describes colors, such as blue or green, that make you feel calm and relaxed" (Cambridge Dictionaries Online, n.d.).

Relaxed & Tense: Relaxed means "feeling calm, comfortable and not worried or annoyed" (Longman dictionary of contemporary English, n.d.). Tense means "feeling worried, uncomfortable, and unable to relax" (Longman dictionary of contemporary English, n.d.).

Spacious & Cramped: Spacious means "large and with a lot of space" (Cambridge Dictionaries Online, n.d.). Cramped means "uncomfortably small or restricted" (Oxford Dictionary, n.d.). This adjective pair is for evaluating whether or not the applied color combinations cause a feeling of spaciousness for the office environment.

Positive/negative effect: This is for evaluating whether or not the applied color combinations influence the subjects positively [“if you are positive about things, you are hopeful and confident, and think about what is good in a situation rather than what is bad” (Longman dictionary of contemporary English, n.d.)] or negatively [“considering only the bad qualities of a situation, person, etc. and not the good ones” (Longman dictionary of contemporary English, n.d.)].

Pleasant & Unpleasant: Pleasant means “enjoyable or attractive and making you feel happy” (Longman dictionary of contemporary English, n.d.).

Well/not well placed: Placement means “the act of finding the right place for something” (Cambridge Dictionaries Online, n.d.). This word pair is for evaluating the configuration of the colors, whether or not they are applied to the right places in the office environment.

Analogous & contrast: Contrast means “a difference between people or things that are compared” (Longman dictionary of contemporary English, 1991, p.223). Analogous means “similar or alike in some ways; able to be compared (with) (Longman dictionary of contemporary English, 1991, p.30).

Light & dark: “A light color is pale and not dark” and a dark color is “quite close to black in color” (Longman dictionary of contemporary English, n.d.).

Balanced & imbalanced: Balance means “a state in which opposite forces or influences exist in equal or the correct amounts, in a way that is good” (Longman dictionary of contemporary English, n.d.).

4.2.3.5 Phases of the Experiment

The experiment was conducted in three phases for all sets of color combinations. The participants entered the laboratory where the experiments were conducted one by one and the lights were on during the experiments. The reason for this was that the laboratory had a lighting condition appropriate for the standard ISO 3664:2009 that specifies viewing conditions for images as prints or images displayed on color monitors. The appropriateness of the ambient lighting level to this standard was checked with Eye-One Match program and it met the recommended levels (see Figure 41).

Figure 41. Eye-One Match program.

In the first phase, subjects were given Ishihara's Tests for Color-Blindness (Ishihara, 1975) before participating in the experiment. Participants, who passed these tests, were asked to give information about their gender, age and profession and were also asked whether they had taken any courses related to color. The researcher took notes of the answers. Subjects were also asked if they had any eye or vision deficiencies and subjects who did were asked to take the experiment with their corrective equipment such as contact lenses or eyeglasses.

In the second phase, there were 4 sets of three-color combinations applied to a created 3D office. Each set of combinations had 6 images since the place of the colors was permutated. Each participant was shown the six possible combinations of the three-color combinations differing in their applied surfaces in the same space with a ratio of 1:3:9 which were paired up with each other for the comparison of their color harmony content. It was critical to eliminate the possible effect of a definite sequence of seeing the images and the left-right position of the images in each pair. In order to control these effects, a computer program was used for mixing the images randomly (see Figure 42). The order of the randomized images and the evaluations were recorded by the program. The background of the surface where the paired images were shown to the participants was gray and a blank gray surface was shown for 2 seconds between each evaluation in order to prevent the afterimage effects. This gray surface was also shown before the first comparison.

Figure 42. Interface of the computer program.

In the third phase, all of the six images used in the second phase were evaluated by the participants considering the related terms of color harmony mentioned in chapter 4.2.3.4. In the literature the definition of color harmony was given to the subjects before they made their evaluations on the harmony content of color combinations. However, in this experiment, different terms used for defining color harmony were used in the third phase for the subjects to evaluate the color combinations considering them. Thus, this data was used for indicating whether or not there was a link between the color combinations evaluated as harmonious in the second phase and their evaluations in the third phase. The data obtained from this phase was also used for comparing the color combinations regarding the terms used for defining color harmony.

Subjects evaluated the six images, one by one, by selecting one of the word pairs told to them for indicating which word is more closely associated with the color combination presented and they did this evaluation for all the 13 word pairs and for all the images in one set. First, the definitions of the words obtained from dictionaries were told to the participants in order to give information about what they assessed (see Appendix E). After this, they answered questions such as 'which word is more closely associated with the color combination presented- like or dislike?'. The questions were asked orally, the subjects indicated their decisions orally and the researcher took notes. The randomly-shown six images were assessed regarding the randomly asked word pairs shown in Table 9 (see Appendix D). It took approximately 20 minutes for each participant to complete all the phases.

4.3 Findings

After all the phases were finished, the collected data was gathered into preference matrices formed by the choices of the subjects. The ranks obtained from the matrices were used for consistency, comparison and correlation analysis.

4.3.1 Consistency Analysis

As mentioned in the Phases of the Experiment section, in the second phase of the experiment harmony evaluations was conducted with the paired comparison method since it was observed that the subjects needed to compare their evaluations for one color combination with the other in the first pilot study in which a 1-7 rating method was used for evaluation. Although paired comparison is a time consuming task, it is the most direct and simple task for the observer and has clear and simple goals (Livens et al., 2003). However, reluctance of the participants or the difficulty of the experimental task may cause inconsistencies in the final ranking. Thus, it is important to check the consistency of the evaluations of the observers, before conducting further analysis.

As Torgerson (1958: 167) stated that in paired comparison method:

> Each stimulus is paired with each stimulus. With n stimuli, there are thus n(n-1)/2 pairs. Each pair is presented to the subject, whose task is to indicate which member of the pair appears greater (heavier, brighter, louder) with respect to the attribute to be scaled. The subject must designate one of the pair as greater. No equality judgments are allowed.

As Dijkstra (2013: 104) stated:

> Although in principle n-1 comparisons would suffice, n(n-1)/2 are required: the comparison of item 1 to 2,3,….,n, of item 2 to 3,4,….,n, up to and including n-1 to n.

According to these, in this experiment there were 15 pairs for harmony evaluations. Considering the consistency of the evaluations, if all the 15 pairs are compared consistently, there must be a linear order of the harmony content of the images. For example,

Office 1 > Office 3 > Office 4 > Office 6 > Office 5 > Office 2

But if they are not compared consistently, linear order cannot be obtained from these evaluations. This shows that the comparisons of that participant are not reliable. For example, if a participant says that office 1 is more harmonious than office 2; office 3 is more harmonious than office 1; but office 2 is more harmonious than office 3. This evaluation is not consistent.

Kendall and Smith (1940) presented a metric for subject consistency occurring as a result of this case. These inconsistencies of the evaluations were called circular triads. According to Kendall and Smith's (1940) formula of coefficient of consistence in paired comparisons:

$$\begin{aligned}\zeta &= 1 - \frac{24d}{n^3 - n}, \quad n \text{ odd} \\ &= 1 - \frac{24d}{n^3 - 4n}, \quad n \text{ even}\end{aligned}$$

where d is the number of circular triads (Iida, 2009):

$$d = \frac{n(n-1)(2n-1)}{12} - \frac{1}{2}\sum_{i=1}^{n} a_i^2 .$$

The consistency coefficients were calculated for each participant in Excel (Table 10). A coefficient of 1 indicates that there is no circular triad and the evaluation of the subject is consistent. As the coefficient value approaches to 0, the consistency of the subject decreases and the coefficient of 0 indicates that there is the maximum number of circular triads in the evaluation.

Table 10. Subject consistency values for the second phase of the experiment.

Subject	SET 1	SET 2	SET 3	SET 4
1	0.625	0.125	1	1
2	1	0.875	0.625	0.375
3	1	0.75	0.75	1
4	1	0.375	0.5	0.75
5	1	1	0.5	0.5
6	0.25	1	0.25	0.875
7	0.75	0.875	0.75	1
8	0.75	0.25	1	0.75
9	0.75	0.125	0.375	1
10	0.5	0.625	0.875	1
11	1	0.25	1	1
12	1	0.875	0.125	0.875
13	1	0.5	0.75	1
14	0.75	0.875	1	0.75
15	0.75	0.25	1	1
Average	0.81	0.58	0.7	0.86

The probability of d=0 for n=6 is 0.022, d=1 for n=6 is 0.051 and d=2 for n=6 is 0.120 (Iida, 2009). Considering 0.1 probability, the accepted number of circular triads is a maximum of 2 and accordingly the acceptable coefficient of consistency is a minimum of 0.75. However, in the study of Eksert (2013) a consistency level of 0.286 was also accepted. Accordingly, in this study, the evaluations of the subjects who have coefficients of consistency over 0.3 were accepted as consistent. According to the consistency coefficients shown in Table 10, 1 subject who had an unacceptable consistency coefficient was excluded from Set 1, 5 subjects were excluded from Set 2 and 2 subjects were excluded from Set 3. None of the subjects were excluded from Set 4 since they all had acceptable consistency coefficients. The number of subjects, whose evaluations were accepted for further analysis, is shown in Table 11.

Table 11. Number of subjects whose evaluations were accepted for further analysis.

	Number of Subjects
SET 1	14
SET 2	10
SET 3	13
SET 4	15

After the exclusion of the inconsistent subjects, further analysis of the data was done in SPSS 20.

4.3.2 Comparison Analysis

Following the consistency analysis, a Friedman test was conducted to understand whether or not there were significant differences in harmony between the color combinations in each set depending on the differences in area coverage. The reason for using a Friedman test is that the same subjects evaluated the six images in each set. According to the Friedman test results, there were no significant differences between the images depending on the differences in the area coverage of the colors in the combination in Set 1 ($X^2_{(5)}$=7.117, p=0.212) and Set 2 ($X^2_{(5)}$=5.249, p=0.386). Whereas there were significant differences between the images in Set 3 ($X^2_{(5)}$=13.291, p=0.021) and Set 4 ($X^2_{(5)}$=11.508, p=0.042). In order to examine where the differences actually occurred in Set 3 and 4, post hoc tests were conducted. SPSS 20 allows post hoc comparisons for a Friedman test by clicking on the output table, thus the results of these pairwise comparisons were reported for Sets 3 and 4. According to the results, in Set 3, there were significant differences between Office 5 and Office 2 ($p=0.018$), Office 5 and Office 3 ($p=.018$), Office 5 and Office 4 ($p=.005$), and Office 1 and Office 4 ($p=.028$) (see Figure 43). In Set 4 there were significant differences between Office 1 and Office 4 ($p=.015$), Office 2 and Office 4 ($p=.008$), and Office 2 and Office 5 ($p=.032$) (see Figure 44).

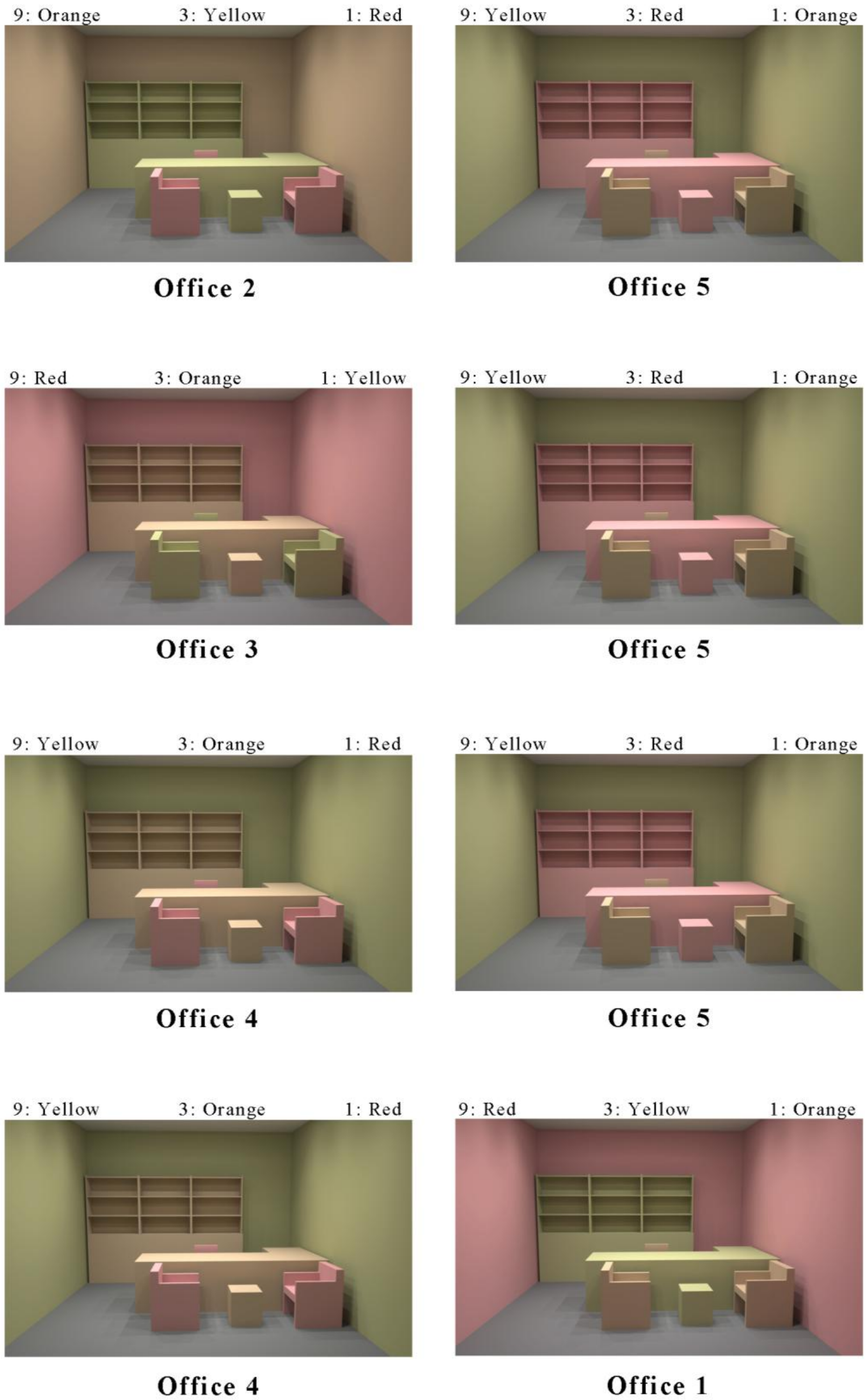


Figure 43. Offices of Set 3 significantly different in color harmony content.

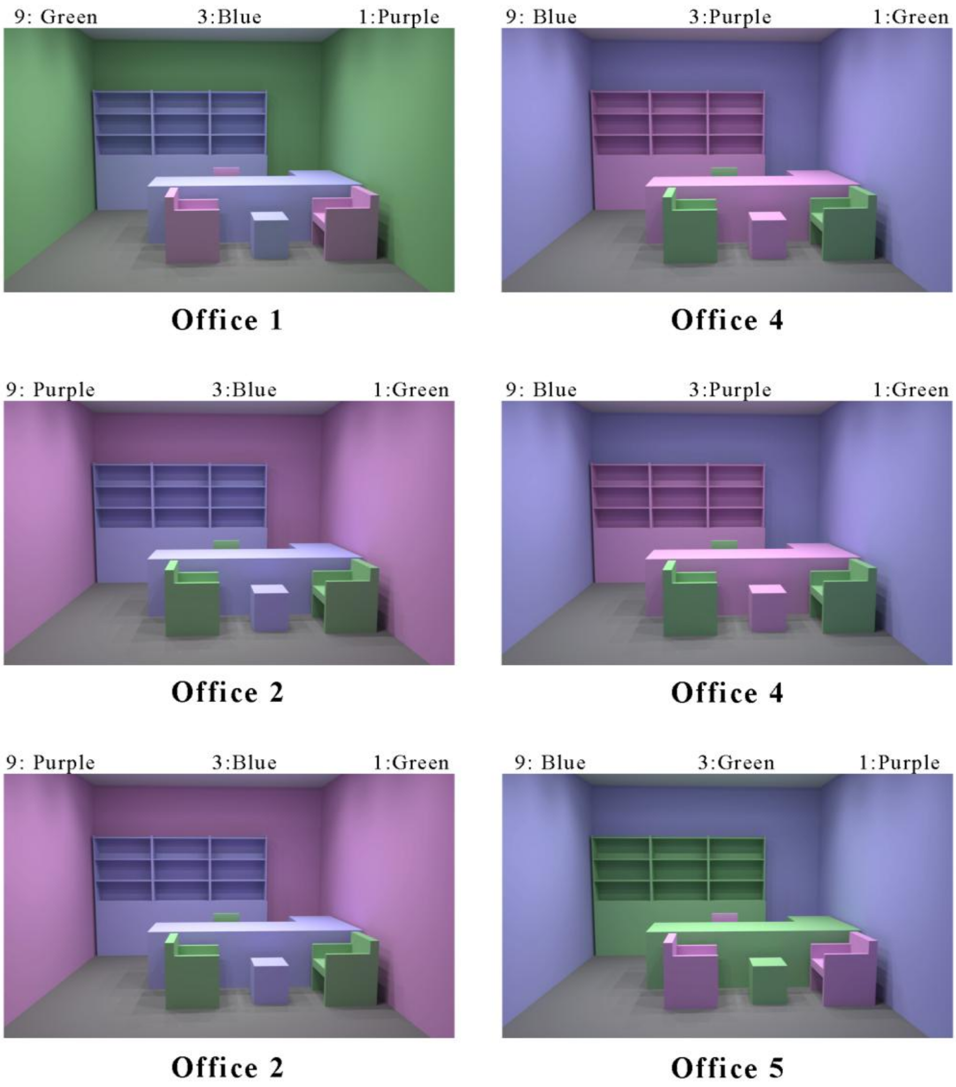


Figure 44. Offices of Set 4 significantly different in color harmony content.

According to the mean ranks of the harmony evaluation of the images (see Table 12) in Set 3, the differences between Office 5 and the Offices 2, 3 and 4 were caused by the fact that Office 5 had the lowest rank and Offices 4, 3 and 2 had the highest ranks respectively (see Figure 45). It may be said that in Set 3 (warm color combination) when orange covered a medium area the color combination was found more harmonious (Office 4 and 3). When yellow covered large area, the combination with a medium coverage of orange (Office 4) was found to be more harmonious than the combination with a medium coverage of red (Office 5). The difference between Office 1 and 4 was caused by the fact that Office 4 had the highest rank and Office 1 had the second lowest rank (see Figure 45). It may be said that the color combination with a small area coverage of red (Office 4) was found to be more harmonious than the combination with a large area coverage of red (Office 1). Additionally, it may also be said that in Set 3, when orange covered a medium area, the combinations were found to be the most harmonious (Office 4 and 3). When it covered large area (Office 2 and 6) the combinations were found to be medium harmonious and when it covered a small area (Office 1 and 5) the combinations were found to be the least harmonious.

Table 12. Mean ranks of the images in each set.

	SET 1	SET 2	SET 3	SET 4
Office 1	3.14	4.05	2.81	4.23
Office 2	3.11	3.75	4.08	4.37
Office 3	3.36	3.40	4.08	3.63
Office 4	4.18	3.60	4.42	2.57
Office 5	4.29	3.80	2.35	2.90
Office 6	2.93	2.40	3.27	3.30

According to the mean ranks of the harmony evaluation of the images (see Table 12) in Set 4, the differences between Office 4 and Offices 1 and 2 were caused by the fact that Office 4 had the lowest rank and Offices 2 and 1 had the highest ranks respectively (see Figure 46). It may be said that in Set 4 (cool color combination), when green covered the least area, the color combination was found to be more harmonious with purple covering a large area (Office 2) than the combination with blue covering a large area (Office 4). The difference between Office 2 and Office 5 was caused by the fact that Office 2 had the highest rank and Office 5 had the second lowest rank (see Figure 46). It may be said that the combination with purple covering a large area and blue covering a medium area (Office 2) was found to be more harmonious than the combinations in which blue covered the large area (Office 5 and 4). Additionally, it may be said that in Set 4, when blue covered a medium area (Office 2 and 1), the combinations were found to be the most harmonious. When it covered a small area (Office 3 and 6) the combinations were found to be medium harmonious and when it covered a large area (Office 5 and 4) the combinations were found to be the least harmonious.

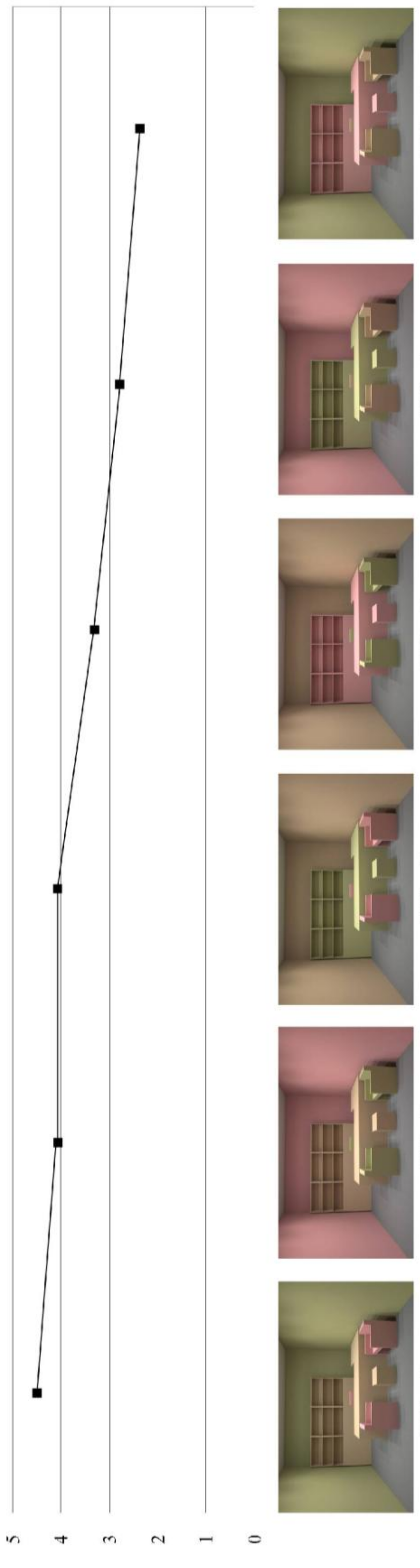


Figure 45. Mean ranks of the images regarding color harmony in Set 3.

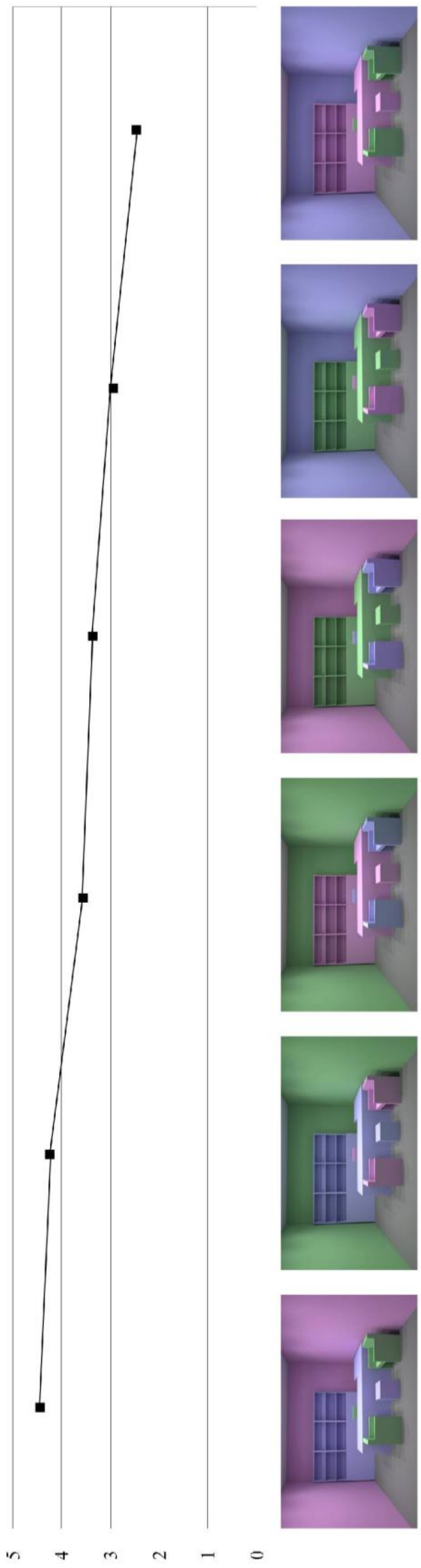


Figure 46. Mean ranks of the images regarding color harmony in Set 4.

4.3.3 Correlation Analysis

The items of the questionnaire used in the second phase of the experiment were expected to measure the same property, namely harmony. Thus, the reliability of the data obtained in the second phase of the experiment was tested using Cronbach's alpha. The reliability of the coefficient of the 13 items was 0.87. Since the acceptable reliability coefficient is above 0.70 (Hidayetoğlu, Yıldırım and Akalın, 2012) the scale was accepted as reliable and was used for further analysis.

First, correlations of the harmony values of the images obtained in the first phase and the values of the related terms of the color harmony obtained in the second phase (summed for each image in all the sets) were analyzed to understand the relationship with harmony and the terms used to define it. A positive correlation between harmony assessments and the terms means that if a combination had a high harmony value it also had a high value from the terms and if it had a low harmony value it also had a low value from the terms. On the other hand, a negative correlation means that if a combination had a high harmony value it had a low value from the terms and if it had a low harmony value it had a high value from the terms. Additionally, the strength of the correlations were indicated as strong, moderate and weak. A correlation coefficient of ±.00 indicated no correlation, ±.20 weak, ±.50 moderate, ±.80 strong and ±1.00 indicated perfect correlation (O'Rourke, Hatcher and Stepanski, 2005). The significance value indicates whether or not the obtained correlation coefficient is valid.

The findings showed that there were positive correlations between harmony and its related terms for fourteen of the twenty-four images with a coefficient above 0.2, which is acceptable (see Table 13). However, five of them were statistically significant. This means that increases or decreases in harmony did not significantly relate to increases or decreases in the terms and might have occurred by chance except in five of the color combinations. The results indicated that, in Set 1, the harmony content of Office 5 had a strong correlation with the terms and Offices 1, 2 and 3 had moderate correlations. In Set 4, Office 3 had a moderate correlation with the terms. Additionally, considering the mean harmony ranks of the images, correlations below 0.2 were obtained for the second harmonious image among six images in Set 1; the first, second and sixth harmonious images in Set 2, the second and sixth harmonious images in Set 3, and the first, fourth and sixth harmonious images in Set 4.

Table 13. Correlations between harmony and its related terms.

		Office 1	Office 2	Office 3	Office 4	Office 5	Office 6
SET 1	Spearman Correlation	.550*	.564*	.588*	.011	.720*	.384
	Sig. (2-tailed)	.042	.036	.027	.969	.004	.176
SET 2	Spearman Correlation	.175	.258	.300	.465	.056	.020
	Sig. (2-tailed)	.629	.471	.400	.175	.878	.957
SET 3	Spearman Correlation	.351	.195	-.084	.440	.012	.313
	Sig. (2-tailed)	.240	.524	.786	.133	.970	.298
SET 4	Spearman Correlation	.286	.189	.539*	.087	.396	-.025
	Sig. (2-tailed)	.301	.499	.038	.758	.144	.929
* =	significant		strong		moderate		weak

In order to further analyze the relationship between words and the images, correlations between the harmony content of each image and 13 word pairs were analyzed separately for all the sets. The findings indicated that, in Set 1, harmony was correlated with all the 13 terms with a coefficient above 0.2 for Office 1 and Office 5. These correlations were all positive for Office 5, whereas one of the terms (similarity) was negatively correlated for Office 1 (see Table 14). On the other hand, harmony was correlated with only spaciousness for Office 4 (see Table 14). For Office 2, no correlation was found between harmony and lightness and also the correlations between harmony and proportion, balance, similarity and naturalness were below 0.2 (see Table 14). Additionally, the term spaciousness had a positive correlation with an acceptable coefficient for all the images in Set 1 (see Table 14).

From Table 14, it can be seen that only 40% of the acceptable correlations were statistically significant and 40% of these significant correlations were under Office 5. Although there were no significant differences between the harmony content of the images in Set 1, mean ranks indicated that Office 5 was also found the most harmonious among all the images (see Table 12). However, although Office 4 was not significantly correlated with any of the terms (see Table 14), it was the second harmonious (see Table 12).

Table 14. Correlations of harmony of the scenes and the terms related to color harmony (Set 1).

SET 1			Office 1	Office 2	Office 3	Office 4	Office 5	Office 6
Terms related to object	**Proportion**	Spearman Correlation	.371	-.036	.774**	-.055	.630*	-.208
		Sig.(2-tailed)	.191	.901	.001	.851	.016	.474
	Balance	Spearman Correlation	.459	.072	.590*	-.146	.445	.553*
		Sig.(2-tailed)	.098	.806	.026	.618	.111	.040
	Placement	Spearman Correlation	.386	.109	.514	.022	.592*	.284
		Sig.(2-tailed)	.173	.709	.060	.940	.026	.325
	Similarity	Spearman Correlation	-.211	.066	.222	.133	.530	-.044
		Sig.(2-tailed)	.469	.823	.445	.649	.051	.881
	Lightness	Spearman Correlation	.260	.000	-.074	.022	.602*	.493
		Sig.(2-tailed)	.369	1.000	.802	.940	.023	.073
Terms related to person	**Liking**	Spearman Correlation	.483	.754**	.456	.055	.517*	.161
		Sig.(2-tailed)	.080	.002	.101	.841	.058	.583
	Association	Spearman Correlation	.576*	.471	.553*	.055	.630*	.288
		Sig.(2-tailed)	.031	.089	.040	.851	.016	.319
	Naturalness	Spearman Correlation	.241	.077	.305	-.101	.554*	.060
		Sig.(2-tailed)	.406	.793	.290	.731	.040	.838
	Warmth	Spearman Correlation	.288	.803**	.627*	-.183	.517	.275
		Sig.(2-tailed)	.319	.001	.016	.532	.058	.341
	Relaxation	Spearman Correlation	.257	.620*	.456	-.095	.407	.199
		Sig.(2-tailed)	.375	.018	.101	.746	.149	.495
	Spaciousness	Spearman Correlation	.257	.620*	.240	.240	.607*	.458
		Sig.(2-tailed)	.375	.018	.409	.409	.021	.099
	Effect	Spearman Correlation	.576*	.620*	.516	.146	.744**	.382
		Sig.(2-tailed)	.031	.018	.059	.618	.002	.178
	Pleasantness	Spearman Correlation	.576*	.614*	.369	.146	.776**	.462
		Sig.(2-tailed)	.031	.019	.194	.618	.001	.096
		*= significant		strong		moderate		weak

According to Table 15, in Set 2, correlations were found between harmony and nine of the terms for the Offices 2 and 3, eight of the terms for Office 6, seven of the terms for the Offices 1 and 5 and six of the terms for Office 4 with a correlation coefficient above 0.2. However, none of the scenes was correlated with the terms significantly, except for the positive correlation of Office 4 with the terms lightness and warmth. The correlation between Office 4 and the terms 'liking' and naturalness could not be computed by SPSS because the values for that variable are the same across all the subjects. All the subjects found the color combination of Office 4 unnatural and did not like it. Although there were no significant differences between the harmony content of the images in Set 2, mean ranks indicated that Office 4 was found the fourth harmonious among the six images (see Table 12).

Table 15. Correlations of harmony of the scenes and the terms related to color harmony (Set 2).

SET 2			Office 1	Office 2	Office 3	Office 4	Office 5	Office 6
Terms related to object	**Proportion**	Spearman Correlation	-.133	.036	.256	-.498	-.073	-.038
		Sig.(2-tailed)	.713	.920	.476	.143	.842	.917
	Balance	Spearman Correlation	-.109	.371	-.073	-.050	-.320	-.038
		Sig.(2-tailed)	.765	.291	.841	.891	.367	.917
	Placement	Spearman Correlation	.578	.371	-.273	.122	.109	-.382
		Sig.(2-tailed)	.080	.291	.445	.737	.765	.276
	Similarity	Spearman Correlation	.071	.074	.256	.398	.133	.561
		Sig.(2-tailed)	.845	.838	.476	.254	.713	.092
	Lightness	Spearman Correlation	.039	-.037	.269	.651*	.498	-.038
		Sig.(2-tailed)	.915	.919	.453	.042	.143	.917
Terms related to person	**Liking**	Spearman Correlation	.218	.223	.430		-.290	.286
		Sig.(2-tailed)	.545	.536	.215		.416	.424
	Association	Spearman Correlation	.296	.483	-.090	-.050	-.290	.286
		Sig.(2-tailed)	.406	.157	.806	.891	.416	.424
	Naturalness	Spearman Correlation	-.036	-.146	.078		.000	-.062
		Sig.(2-tailed)	.921	.688	.830		1.000	.864
	Warmth	Spearman Correlation	.249	.297	.329	.697*	-.267	-.187
		Sig.(2-tailed)	.488	.404	.353	.025	.456	.605
	Relaxation	Spearman Correlation	.296	.291	.039	.130	-.073	.496
		Sig.(2-tailed)	.406	.414	.915	.720	.842	.145
	Spaciousness	Spearman Correlation	.578	.291	.269	.398	.218	.286
		Sig.(2-tailed)	.080	.414	.453	.254	.545	.424
	Effect	Spearman Correlation	.071	.291	.329	.438	-.036	.286
		Sig.(2-tailed)	.845	.414	.353	.205	.922	.424
	Pleasantness	Spearman Correlation	.218	.483	.269	.122	.254	.286
		Sig.(2-tailed)	.545	.157	.453	.737	.479	.424
		*= significant		strong		moderate		weak

Similar to Set 1, the term spaciousness had a positive correlation with an acceptable coefficient for all the images in also Set 2 (see Table 15). In this set, the term liking can also be accepted as having correlation with harmony for all the images. But these correlations were negative for Office 4 and 5. These offices that had orange covering the largest area were not liked but found harmonious by the subjects.

According to Table 16, in Set 3, correlations were found between harmony and ten of the terms for the Offices 4 and 6, six of the terms for the Offices 3 and 5, five of the terms for Office 2 and four of the terms for Office 1 with a correlation coefficient above 0.2. However, statistically significant correlations were between Office 6 and the terms proportion, association, relaxation, pleasantness, between Office 4 and the terms balance, lightness and liking, and between Office 1 and the terms lightness. All of these significant correlations were positive. None of the other scenes was significantly correlated with the terms. The harmony of Office 4 and Office 6 was correlated with more of the terms than the other offices, and they had also the first and third rank in harmony (see Table 12).

Table 16. Correlations of harmony of the scenes and the terms related to color harmony (Set 3).

SET 3			Office 1	Office 2	Office 3	Office 4	Office 5	Office 6
Terms related to object	**Proportion**	Spearman Correlation	.153	.065	-.262	.485	-.195	.581*
		Sig.(2-tailed)	.618	.834	.387	.093	.523	.037
	Balance	Spearman Correlation	-.112	.151	.143	.581*	-.022	.516
		Sig.(2-tailed)	.716	.623	.641	.037	.944	.071
	Placement	Spearman Correlation	-.112	.398	-.024	-.023	-.533	-.252
		Sig.(2-tailed)	.716	.178	.938	.940	.061	.406
	Similarity	Spearman Correlation	.449	.273	-.339	.485	.234	.452
		Sig.(2-tailed)	.124	.366	.257	.093	.442	.121
	Lightness	Spearman Correlation	.582*	.136	-.061	.561*	.266	.091
		Sig.(2-tailed)	.037	.657	.843	.046	.379	.768
Terms related to person	**Liking**	Spearman Correlation	.197	-.105	-.024	.556*	.155	.464
		Sig.(2-tailed)	.520	.732	.938	.049	.612	.110
	Association	Spearman Correlation	.044	-.174	.030	.342	.043	.621*
		Sig.(2-tailed)	.887	.569	.921	.253	.888	.023
	Naturalness	Spearman Correlation	.118	.318	.183	-.171	-.070	.063
		Sig.(2-tailed)	.701	.290	.550	.577	.820	.838
	Warmth	Spearman Correlation	.044	.043	.214	.214	.094	.194
		Sig.(2-tailed)	.887	.889	.482	.483	.761	.526
	Relaxation	Spearman Correlation	.350	-.224	.244	.241	.433	.621*
		Sig.(2-tailed)	.242	.462	.422	.428	.139	.023
	Spaciousness	Spearman Correlation	.330	-.168	.000	.064	.043	.464
		Sig.(2-tailed)	.270	.583	1.000	.835	.888	.110
	Effect	Spearman Correlation	.197	-.108	-.262	.342	.266	.338
		Sig.(2-tailed)	.520	.726	.387	.253	.379	.244
	Pleasantness	Spearman Correlation	.197	-.224	-.078	.455	.266	.621*
		Sig.(2-tailed)	.520	.462	.799	.118	.379	.023

*= significant strong moderate weak

In this set (Set 3), different from the previous two, the term relaxation and similarity had a correlation with an acceptable coefficient for all the images (see Table 16). These correlations were negative for Office 3 in similarity and for Office 2 in relaxation. This means that color combination in Office 3 that had red covering largest and yellow the smallest area, was found contrast but harmonious and Office 2 that orange covering the largest and red covering the least area was found tense but harmonious.

According to Table 17, in Set 4, correlations were found between harmony and ten of the terms for Office 5, nine of the terms for Office 3, six of the terms for Offices 1 and 4, five of the terms for Office 2 and three of the terms for Office 6 with a correlation coefficient above 0.2. Office 4 was correlated with none of the terms significantly and also had the lowest harmony content (see Table 12). Office 2 was significantly and negatively correlated with lightness but had the highest harmony content (see Table 12), indicating that the color combination in Office 2 was found dark but harmonious.

Table 17. Correlations of harmony of the scenes and the terms related to color harmony (Set 4).

SET 4			Office 1	Office 2	Office 3	Office 4	Office 5	Office 6
Terms related to object	**Proportion**	Spearman Correlation Sig.(2-tailed)	.534* .040	-.016 .954	.185 .510	.114 .685	.168 .550	-.066 .816
	Balance	Spearman Correlation Sig.(2-tailed)	.304 .271	.327 .234	.067 .812	.209 .456	.713** .003	.051 .856
	Placement	Spearman Correlation Sig.(2-tailed)	-.125 .657	.424 .115	.158 .573	.114 .685	.319 .247	-.182 .516
	Similarity	Spearman Correlation Sig.(2-tailed)	.419 .120	.104 .713	.274 .322	-.235 .398	.372 .172	-.065 .819
	Lightness	Spearman Correlation Sig.(2-tailed)	.168 .550	-.535* .040	.646* .009	.255 .359	-.539* .038	.339 .216
Terms related to person	**Liking**	Spearman Correlation Sig.(2-tailed)	.145 .605	.240 .389	.491 .063	.289 .296	.507 .054	-.120 .671
	Association	Spearman Correlation Sig.(2-tailed)	.145 .605	.133 .636	.380 .162	.000 1.000	.581* .023	.051 .856
	Naturalness	Spearman Correlation Sig.(2-tailed)	.190 .497	-.065 .817	.084 .766	.420 .119	.079 .779	.000 1.000
	Warmth	Spearman Correlation Sig.(2-tailed)	.065 .819	.104 .713	-.274 .322	-.259 .351	.095 .736	.355 .194
	Relaxation	Spearman Correlation Sig.(2-tailed)	.319 .247	.196 .483	.476 .073	.128 .648	.317 .250	-.120 .671
	Spaciousness	Spearman Correlation Sig.(2-tailed)	.254 .362	.092 .744	.269 .331	-.048 .865	.206 .461	-.291 .293
	Effect	Spearman Correlation Sig.(2-tailed)	.339 .216	.350 .201	.468 .078	-.048 .865	.317 .250	-.120 .671
	Pleasantness	Spearman Correlation Sig.(2-tailed)	.145 .605	.133 .636	.618* .014	.136 .629	.581* .023	.000 1.000

*= significant; red = strong; yellow = moderate; blue = weak

It was also hypothesized that there would be a strong link found between the terms defining color harmony. The correlations of the 13 word pairs were shown in Table 18. According to this, there was a significant and positive correlation between all the terms except similarity and warmth, and lightness and placement. The terms that had a strong correlation were pleasantness & association, effect, liking and association & effect. The terms that had a moderate correlation were like, relaxation, spaciousness, effect & association; spaciousness, effect, pleasantness & relaxation; effect, pleasantness & spaciousness; effect & pleasantness. Correlations between other terms ranged from weak to very weak. The correlation coefficient of the terms proportion, balance & lightness, placement

& similarity were below 0.2 and therefore they could be considered to have no correlation. As can be seen from Table 18, the significant, strong and moderate correlations were not within the terms related to the object but within the terms related to the person.

Table 18. Correlations of the 13 word pairs.

			Terms related to object					Terms related to person							
			prop	**balan**	**place**	**sim**	**light**	**like**	**assoc**	**natu**	**war**	**relax**	**spac**	**effect**	**pleas**
Terms related to object	**prop**	Spearman	1	.473**	.388**	,301**	,140*	,342**	,334**	,268**	,229**	,324**	,255**	,356**	,288**
		Sig.		.000	.000	,000	,013	,000	,000	,000	,000	,000	,000	,000	,000
	balan	Spearman	,473**	1	.389**	,258**	,176**	,470**	,470**	,366**	,255**	,408**	,324**	,417**	,463**
		Sig.	,000		.000	,000	,002	,000	,000	,000	,000	,000	,000	,000	,000
	place	Spearman	,388**	,389**	1	,180**	,048	,316**	,296**	,241**	,231**	,267**	,205**	,301**	,300**
		Sig.	,000	,000		,001	,400	,000	,000	,000	,000	,000	,000	,000	,000
	sim	Spearman	,301**	,258**	.180**	1	,234**	,282**	,198**	,210**	,090	,234**	,217**	,276**	,269**
		Sig.	,000	,000	.001		,000	,000	,000	,000	,111	,000	,000	,000	,000
	light	Spearman	,140*	,176**	.048	,234**	1	,336**	,345**	,281**	,255**	,404**	,484**	,445**	,389**
		Sig.	,013	,002	.400	,000		,000	,000	,000	,000	,000	,000	,000	,000
Terms related to person	**Like**	Spearman	,342**	,470**	.316**	,282**	,336**	1	,675**	,358**	,300**	,658**	,588**	,690**	,707**
		Sig.	,000	,000	.000	,000	,000		,000	,000	,000	,000	,000	,000	,000
	assoc	Spearman	,334**	,470**	.296**	,198**	,345**	,675**	1	,404**	,379**	,679**	,673**	,705**	,750**
		Sig.	,000	,000	.000	,000	,000	,000		,000	,000	,000	,000	,000	,000
	natur	Spearman	,268**	,366**	.241**	,210**	,281**	,358**	,404**	1	,254**	,358**	,414**	,385**	,358**
		Sig.	,000	,000	.000	,000	,000	,000	,000		,000	,000	,000	,000	,000
	warm	Spearman	,229**	,255**	.231**	,090	,255**	,300**	,379**	,254**	1	,319**	,272**	,417**	,321**
		Sig.	,000	,000	.000	,111	,000	,000	,000	,000		,000	,000	,000	,000
	relax	Spearman	,324**	,408**	.267**	,234**	,404**	,658**	,679**	,358**	,319**	1	,676**	,689**	,633**
		Sig.	,000	,000	.000	,000	,000	,000	,000	,000	,000		,000	,000	,000
	spac	Spearman	,255**	,324**	.205**	,217**	,484**	,588**	,673**	,414**	,272**	,676**	1	,674**	,603**
		Sig.	,000	,000	.000	,000	,000	,000	,000	,000	,000	,000		,000	,000
	effect	Spearman	,356**	,417**	.301**	,276**	,445**	,690**	,705**	,385**	,417**	,689**	,674**	1	,724**
		Sig.	,000	,000	.000	,000	,000	,000	,000	,000	,000	,000	,000		,000
	pleas	Spearman	,288**	,463**	.300**	,269**	,389**	,707**	,750**	,358**	,321**	,633**	,603**	,724**	1
		Sig.	,000	,000	.000	,000	,000	,000	,000	,000	,000	,000	,000	,000	

CHAPTER 5

DISCUSSION

The main aim of this study is to investigate the area effect on color harmony in interior spaces. Additionally, the terms related to harmony and their relationships were also under investigation. Four color combinations were tested for their harmony content regarding the areas covered by the colors in the selected triads. The relationship between harmony and the terms used to define it and the relationship between these terms was also examined using the same four color combinations. The findings of the study are discussed below in connection with the hypotheses.

Hypothesis 1: Color harmony evaluations differ depending on the proportions of constituent colors' areas in interior spaces.

Various studies regarding color harmony proved that it is universal and there are objective laws for obtaining color combinations which are found harmonious universally (Birren, 1969a, 1969b; Chevreul, 1987; Chuang and Ou, 2001;

Goethe, 1970; Granger, 1953; Itten, 1973; Moon and Spencer, 1944a, 1944b, 1944c; Nemcsics, 2007, 2008, 2009a, 2009b, 2011, 2012; Nemcsics and Takacs, 2013a, 2013b; Ou, Chong et al., 2011; Ou and Luo, 2003, 2006; Ou, Luo et al., 2011; Polzella and Montgomery, 1993; Szabo, Bodrogi and Schanda, 2010; Wang, Ou and Luo, 2007). The findings of this study also indicate that there is a general pattern of color harmony (which differs depending on the proportions of areas of colors) in interior spaces for some of the color combinations. This finding may also be interpreted as color harmony not being a purely subjective judgment, changing from one person to another, but rather a universally accepted concept.

According to the findings of this study, there was a significant difference between the combinations in Set 3 and Set 4 depending on the areas of the colors, whereas there was not a significant difference between the images in Set 1 and Set 2. The color combination of each set was obtained from a triangle on Itten's color wheel which was accepted as harmonious. Set 1 was a triad of primary colors (red-blue-yellow), Set 2 was triad of secondary colors (purple-green-orange), Set 3 was a triad of warm colors (red-yellow-orange) and Set 4 was a triad of cool colors (blue-purple-green). Although the selected color combinations were accepted as harmonious, the findings showed that area influenced harmony in warm and cool color combinations. Accordingly, various other color combinations, which are accepted as harmonious, should be tested in a further study for testing the weight of area in changing the harmony of them and also for testing whether the findings lead to a different definition of color harmony.

The findings of this thesis indicated that, in Set 3 (warm color combination), orange was the leading color that influenced the harmony evaluations of the subjects. The order of the harmony content of the combinations changed depending on the area covered by orange. The combinations with orange covering a medium area was more harmonious than the combinations with orange covering a large area and the combinations with orange covering a small area were less harmonious than these. The reason for orange being the leading color might be that it is a mixture of red and yellow. Thus, it might work as a mediator in color harmony evaluation of warm color combination. In some studies, orange was also mentioned as the warmest color among the three (Colombo, Del Bimbo and Pala, 1998; Sivik and Taft, 1991 cited in Hardin, 2005). According to this, the findings might be interpreted that color harmony of warm color combination depends on the area of the color perceived as the warmest.

Moreover, the findings indicated that, in Set 4 (cool color combination), blue was the leading color that influenced the harmony evaluations of the subjects. The order of the harmony content of the combinations changed depending on the area covered by blue. The combinations with blue covering a medium area was more harmonious than the combinations with blue covering a small area and the combinations with blue covering a large area were less harmonious than these. Different from the warm color combination, in cool color combination, the leading color blue was not the mixture of the other two but it was mixed with other colors (yellow or red) to obtain them in subtractive mixing. It is the base of green and purple. Thus, it might work as a mediator in color harmony evaluation of cool color combination. In literature, blue was also mentioned as the coldest color among the three (Kimura, 1950 cited in Oyama and Nanri, 1960; Newhall, 1941 cited in Oyama and Nanri, 1960; Oyama and Yamamura, 1960 cited in Oyama and Nanri, 1960; Sivik and Taft, 1991 cited in Hardin, 2005). According to this, the findings might be interpreted that color harmony of cool color combination depends on the area of the color perceived as the coldest.

As stated in Chapter 2.4, there have been a few theories about the influence of area on color harmony. Some of these theories asserted area as a function of value and chroma (Birren, 1969b; Moon and Spencer, 1944c) and some of them proposed a ratio for only pure hues depending on their inherent lightness (Birren, 1970). In order to compare the findings of this study with the equations proposed by Munsell (Birren, 1969b) and Moon and Spencer (1944c) (see Chapter 2.4), RGB values of the selected colors were converted to Munsell Notations. There have been many studies on the topic of conversion between Munsell space and other spaces (Mahyar, Cheung and Westland, 2010) however there is not a certain conversion model. RGB values were converted to Munsell Notations by using Wallkill Color Munsell Conversion Program Version 4.01 and obtained values were used in both of the equations stated above. Calculations showed similar results for both of the equations and indicated an approximate proportion of Red:3 Blue:2 Yellow:6 for Set 1, Green:3 Purple:2 Orange:6 for Set 2, Red:1 Yellow:2 Orange:2 for Set 3 and Blue:2 Green:3 Purple:2 for Set 4.

Although the ratios used in this thesis were different from the ones stated above, there are some similarities and contradictions considering the findings. According to the equations that Munsell and Moon and Spencer proposed, in Set 3 (warm color combination), if red covers less of an area than orange and yellow, the combination is harmonious. Similar to this, findings of this thesis indicated that the two combinations with red covering the least area were found to be the first and third most harmonious among the six images. On the other hand, the combination with red covering the largest area was also found to be the second most harmonious in this thesis indicating that red is not required to cover less area than orange and yellow in a combination for harmony in an interior space.

Moreover, according to the equations that Munsell and Moon and Spencer proposed, in Set 4 (cool color combination), if green covers more area than blue and purple, the combination is harmonious. However, the findings of this thesis indicated that combination with green covering the least and purple covering the largest area was found to be the most harmonious. Supporting the equations, findings also indicated that combinations with green covering the largest area were found to be the second and third most harmonious among the six images.

Moreover, in order to compare the findings of this thesis with another theory regarding area effect on color harmony, the three-color combinations used in this thesis were tested using the three-color harmony model (considering area proportions) developed by Wang, Ou and Luo (2007). Since the model required

CIE Lab values for lightness, chroma and hue, first, CIE Lab measurements were obtained from the RGB images in Photoshop CS5. According to the model, the obtained values for the images were very close or the same and they had negative values (see Table 19) indicating low harmony values with no distinctive difference between the images. However, if these values were put in an order, the obtained order for each was as follows:

SET 1 Office 6 = Office 3 = Office 1 = Office 2 = Office 4 = Office 5

SET 2 Office 1 = Office 2 = Office 3 = Office 4 = Office 5 = Office 6

SET 3 Office 2 > Office 6 > Office 4 > Office 5 > Office 1 = Office 3

SET 4 Office 4 = Office 2 > Office 5 = Office 6 > Office 1 = Office 3

Table 19. Color harmony values of the images according to the model developed by Wang, Ou and Luo (2007).

	SET 1	SET 2	SET 3	SET 4
Office 1	-1,62	-1,62	-1,54	-1,59
Office 2	-1,62	-1,62	-1,48	-1,52
Office 3	-1,62	-1,62	-1,54	-1,59
Office 4	-1,62	-1,62	-1,50	-1,52
Office 5	-1,62	-1,62	-1,52	-1,54
Office 6	-1.62	-1,62	-1,49	-1,54

According to the order represented above, the images had the same harmony values in Set 1 and Set 2 showing no differences between them. Thus, in primary and secondary triad colors, the area of colors did not affect the harmony content. The findings of this thesis also supported this. However, although there were differences between the images in Set 3 and Set 4, the order of the harmony content of the images were different from the findings of this thesis.

According to the three-color harmony model, in Set 3, the color of the walls led the harmony content of the combination. Color combinations with orange covering a large area were more harmonious than with yellow covering a large area and these were more harmonious than the combinations with red covering a large area. This is in contradiction with the findings of this thesis, since findings of this thesis indicated no explicit effect of wall color on harmony content. Besides, combination with yellow covering the largest and orange covering the medium area was found to be the most harmonious.

Furthermore, according to the three-color harmony model, green was the leading color that changed the harmony content of the combinations in Set 4. Color combinations with green covering a small area were more harmonious than with green covering a medium area and these were more harmonious than combinations with green covering a large area. This is also in contradiction with this thesis, since findings of this thesis indicated that blue was the leading color that changed the harmony content in Set 4.

Considering the comparisons stated above, the differences between the findings of this thesis and the theories developed by Munsell and by Moon and Spencer indicated that these theories are questionable in providing an accurate prediction. This supports the findings of the studies (Granger, 1953; Linnett et al., 1991; Morriss, Dunlap and Hammond, 1982; Morriss and Dunlap, 1987; Morriss and Dunlap, 1988) which examined these two theories and found that none of the theories were acceptable in providing an accurate prediction. Additionally, although three-color harmony model proposed by Wang, Ou and Luo (2007) showed good predictive performance, the differences between the findings of this thesis and the model indicated that it should be tested further with more color combinations.

Hypothesis 2: There is a strong and positive relationship between color harmony and the terms used to define it.

Although it was expected that there would be a strong link between color harmony and the related terms defining it based on each image, the findings of this study indicated no strong correlation between harmony and the terms, except one of the images shown among all the sets. However, moderate, weak and very weak correlations were found. Among all the correlations, only five correlations were found to be statistically significant. The harmony content of none of the images in Set 2 and Set 3 had a significant correlation with the terms. A detailed examination of the correlation of harmony with each word also indicated that in Set 2 and Set 3 a small number of the images had significant correlation with the words. However, there was a significant correlation between the harmony content of the four images (Office 5, Office 3, Office 2 and Office 1) in Set 1 and one image (Office 3) in Set 4. The strongest correlation between harmony content and the terms was in Office 5. Office 5 was positively and significantly correlated with 9 (proportion, placement, lightness, liking, association, warmth, spaciousness, effect, pleasantness) of the 13 terms and it had the highest rank of harmony in Set 1.

The findings of this study indicated that moderate and weak correlations were found between harmony and its related terms. There were also very weak correlations which were accepted as having no correlation. The reason for this might be the variation of the subjects' evaluations causing a decrease in the correlation coefficients. Considering the findings, it is difficult to say that one term was more correlated with harmony than the other terms for all the sets. This finding was in contradiction with the findings of Ou et al. (2004c) who found that harmony was closely correlated with 'liking' (like-dislike) and relaxation (relaxed-tense). However, it also supported the finding of Ou et al. (2004c) who found that harmony had a weak correlation with warmth (warm-cool). All of these indicated that the relationship between harmony and the terms related to it needs further investigation in order to be comprehensively explained. There might be some other terms for defining color harmony, which might not be detected with this thesis but might emerge with further investigations.

Hypothesis 3: There is a strong and positive relationship between all the terms used to define color harmony.

Since the obtained terms were assumed to measure the same thing, i.e. 'harmony', it was expected to find a strong link between the terms used to define color harmony. As stated in the findings section, a significant, strong and moderate correlation (20% of all the correlations) was found between some of the terms fulfilling partially the expectations. However, many of the terms had weak and very weak correlations (80% of all the correlations).

According to the findings, participants liked the color combinations which had positive effects on them and which they found relaxed, spacious and pleasant associating with positive emotions. Although naturalness, warmth, similarity and lightness were mentioned in relation with ‘liking’ in the pilot study, in which the definition of color harmony was asked, these terms had weak correlation with the term ‘liking’ in this study. Variations in the evaluations might be one reason for this. Some of the participants might like the color combinations with warm, similar and light colors or with cool, similar and dark colors. The examples may be varied.

The correlations between all the 13 terms indicated that the significant, strong and moderate correlations were not within the terms related to object but within the terms related to person. This might mean that subjects were more consistent while making evaluations related to themselves than related to the object because it might be difficult to evaluate the properties of an object. The low correlation (coefficient below 0.2) of lightness with proportion, balance and placement also indicates the difficulty for the subjects to evaluate color combinations according to these terms.

CHAPTER 6

CONCLUSION

Color is one of the elements of design and has considerable importance in interior spaces. Color affects people psychologically and physiologically. It is important to consider these influences of color while designing an interior space to create user-friendly spaces. It is also important to satisfy the aesthetic needs of people. Applying harmonious colors to interior spaces is one of the ways of fulfilling this need. Interior designers should select harmonious colors carefully to please a wider range of users. Therefore, establishing principles in color harmony should help designers by creating a useful and accurate tool for selecting the most pleasing color combinations for the users. In order to find out these principles, many studies have been undertaken and there is an excessive number of color harmony theories and models. However these studies do not combine both the concepts of area and color harmony in the scope of interior spaces.

The main aim of this study was to investigate the effect of area on color harmony in interior spaces. It also aimed to search for the relationship between color harmony and terms related to it. Furthermore, the relationship between the terms related to color harmony was also analyzed. It is important to investigate the effect of area on color harmony in interior spaces since in interior spaces, colors generally may not be applied in equal proportions. Therefore, in this study, different color schemes of three-colors were applied to an office space, differing in their areas. Four color schemes were evaluated for their harmony content and it was expected to find differences between the combinations due to differences in area. However, differences were found only for the images in warm and cool color schemes.

Considering the secondary aim of the study, the relationship between color harmony and its related terms was examined. Since the terms were gathered from the definitions of color harmony obtained from a number of subjects, it was expected that these terms and color harmony would have strong correlations and that there would be strong correlations between these terms. However, it was found that there were no strong but rather moderate and weak correlations between the two. Regarding the relationship between the terms related to color harmony, it was found that there were significant and strong correlations between some of the terms (pleasantness-liking, association, effect; effect-association) but not all of them and these strong correlations were between the terms related to person.

The implications of the findings of the study can be concluded as follows:

1. Harmonious three-color combinations obtained from equilateral triangles on Itten's twelve part color wheel are found to be harmonious regardless of area differences.
2. In modified triads (warm and cool color scheme), area differences should be considered while applying these colors to an interior space.
3. Related to the second item, while applying a warm color scheme (red, yellow and orange) to an interior space, orange should cover the medium area for obtaining the most harmonious combination.
4. Related to the second item again, while applying a cool color scheme (blue, purple and green) to an interior space, blue should cover a medium area for obtaining the most harmonious combination.

As in all experimental research this study also has limitations which may lead to future research for exploring more about color harmony in interior spaces. One of the limitations of the study is due to color selection. In this study only 4 three-color combinations (differing in hue) were investigated however in future research the number of combinations can be increased with different hues, chromas or values. As the number of combinations increases a guideline for harmony with a large number of color combinations can be created for interior designers.

Moreover, in this study, area effect on color harmony was investigated in an office which is a semi-public space. In future research the same study can be repeated and tested with different kinds of public spaces such as restaurants, cafes, bars and interiors of schools. Furthermore, in this study gender and age differences in color harmony evaluation were not investigated. Future research might profit from looking into these other avenues of determining the best forms of creating harmony. Additionally, differences between subjects with color knowledge and without color knowledge, with design background and without designed can be investigated.

This study contributes to the literature as a study of area effect on color harmony in interior spaces since area effect on color harmony has not been studied in interiors before. The implications of the findings of this study stated above can be used by architects and interior architects/designers to obtain pleasant and aesthetic spaces for a wider range of users. The findings of the study also can be used by researchers working on color.

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APPENDIX A

COLOR ORDER SYSTEMS

There are a great number of colors- up to 10 million based on hue, saturation and lightness as defined by Judd and Wyszecki (1975) and Fehrman and Fehrman (2000) but there is not a certain number in the literature- that the human eye can perceive and there is a need for a system to categorize all of these colors. In order to arrange colors, color order systems have been developed and they can be divided into three broad groups as: 1. Color order systems based on subtractive mixture, 2. Color order systems based on additive mixture and 3. Color order systems based on perceptual evaluation (Wyszecki, 1986; Johston-Feller, 2001).

A.1 Color Order Systems based on Subtractive Mixing

Colors seen as light reflected from a surface (indirect light) are called subtractive colors (Holtzschue, 2006). The subtractive color model is a method for creating a wider range of colors by mixing dyes, inks and pigments. In this model, when colors are mixed, each subtracts (absorbs) some wavelengths of light and the obtained color is the remaining wavelength visible to the eye. The primaries of this model are red, yellow and blue but these primaries do not give the largest color range (gamut) (Westland et al., 2007). These painters' primaries have been accepted as non-optimal in terms of subtractive gamut and ideal subtractive primaries have been accepted as cyan, magenta and yellow (Westland et al., 2007). Color systems based on subtractive method are the arrangements of colors obtained by dyes, inks, natural colorants and paint pigments. In the following chapters, CMYK (Cyan, Magenta, Yellow, Key-black) and CIELAB (Commission Internationale de I'Eclairage-LAB) color models will be mentioned. These systems have no connection (or only a limited connection in the case of CIELAB) to perceptual scales (Kuehni, 2005). CMYK is a system used in printing and CIELAB is a space and formula proposed by CIE for the coloration industries (Kuehni and Schwarz, 2008).

A.1.1 CMYK Color Model

The CMYK color model is the system used in the printing industry. The primaries in this system are cyan, magenta, yellow and black (see Figure A1). The three primary colors (cyan, magenta, yellow) of this system are the secondary colors of the RGB color system and black is added to these since it cannot be obtained by mixture of these colors. Four printing plates are used for each color and various colors are obtained by printing small dots on the paper using these plates. When the dots are combined on a paper, the human eye sees different colors.

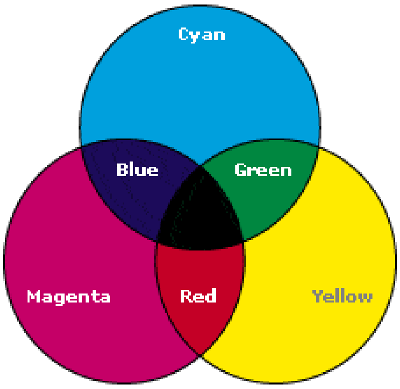

Figure A1. CMYK colors.
(http://www.sketchpad.net/basics4.htm)

A1.2 CIELAB

In 1976, the Commission Internationale de I'Eclairage, (the International Lighting Commission referred as CIE) recommended CIELAB color space, which is a mathematical conversion of the metric color system previously developed by CIE and an approximately uniform color space, for use (Hunterlab, 2008). It is one of the two formulas (the other one is CIELUV, see Appendix A.2.2) proposed by CIE in 1976. CIE decided to recommend two different formulas because it was discovered that lighting engineers and industrial colorists were interested in different spaces and formulas (Kuehni and Schwarz, 2008). The former is interested in the linear transformation of the CIE chromaticity diagram and the latter is interested in predicting perceived average color differences (Kuehni and Schwarz, 2008).

CIELAB is not additive (Johnston-Feller, 2001) and was recommended by CIE for object colors (CIE, 2014; Kuehni and Schwarz, 2008; Green and Macdonald, 2002; Johnston-Feller, 2001). The space is arranged in a non-cubical form and each color is located in this three dimensional color space by three coordinates which are L, a and b. L represents the black (zero) and white (100) axis running from top to bottom (see Figure A2). (a) denotes the red/green value and (b) denotes yellow/blue value and they do not have numerical limits (Hunterlab, 2008).

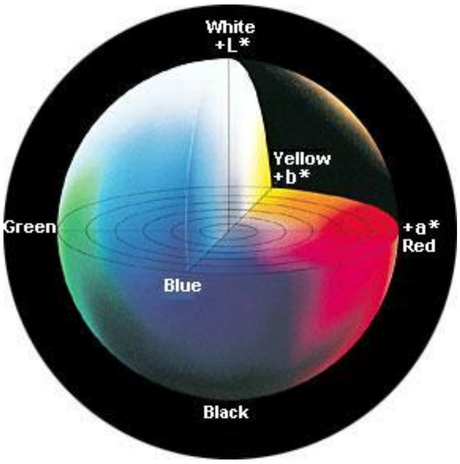

Figure A2. CIELAB color solid. (http://www2.konicaminolta.eu/eu/Measuring/pcc/en/part1/07.html)

A.2 Color Order Systems based on Additive Mixing

Colors seen as direct light are called additive colors (Holtzschue, 2006). The additive color model is a method for creating a wider range of colors by mixing light. This model starts with darkness and when light sources of different wavelengths are added, the obtained color is the mixture of these lights. The primaries of this method are red, green and blue because the greatest gamut can be generated by using these primaries (Westland et al., 2007). Color systems based on the additive method are the arrangements of colors obtained by light. Additive (light) color-order systems are used in relation with computer displays (Kuehni, 2005).

Nassau (1998) divided additive mixing into three types: simultaneous additive mixing, temporal additive mixing and spatial additive mixing. Simultaneous color mixing involves "superimposed light beams", temporal additive mixing is shown by "rapidly spinning a disc on which colored sections have been painted" and spatial additive mixing, used by the pointillism technique of painting, is obtained by placing small spots of colors adjacent to each other so that they merge at a distance (Nassau, 1998: 15).

In the following chapters, RGB, CIELUV and the Ostwald Color System are going to be mentioned. RGB is the color system based on simultaneous additive mixing that uses the primaries of additive mixture. CIELUV color space is also based on the additive mixing method because of the additivity of its u, v chromaticity diagram (Johnston-Feller, 2001). Ostwald (cited in Birren, 1969a) arranged hues on his color wheel by using disk-mixture, thus the relationship between the colors in this system were arranged by using the temporal additive mixing method (also called partitive/optical mixing). Ostwald (cited in Billmeyer and Saltzman, 1966; Kuehni, 2003; Gulrajani, 2010) formed a double-cone color solid based on the additive disk mixture. As a result, it was also accepted as a color system based on additive mixing.

A.2.1 RGB Color Model

The primary colors of light are red, green and blue and the name of the RGB color model comes from the initials of these colors. Mix of red and green produces yellow, red and blue produces magenta, green and blue produces yellow and a mix of all the primaries produces white light (see Figure A3). This color model is used in computer monitors and televisions. Different colors can be obtained using different intensities of the mixed light.

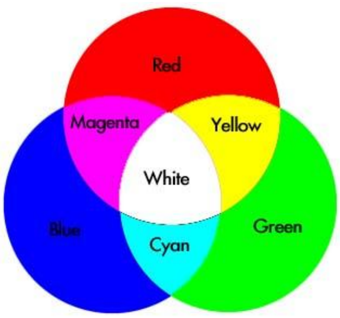

Figure A3. RGB color mixture.
(http://www.d.umn.edu/~mharvey/th1501color.html)

There are three primary and three secondary colors on the RGB color wheel, namely red, green, blue and yellow, cyan, magenta and these hues are indicated with degrees dividing the whole circle into six. The degrees start with red being 0^0, yellow 60^0, green 120^0, cyan 180^0, blue 240^0 and magenta 300^0 (see Figure A4). In the RGB system, color stimuli are arranged in a cubic space where all three dimensions of colors have a value between 0 - 255 (Kuehni and Schwarz, 2008). Mid-gray has RGB values of 128 for each dimension (Kuehni and Schwarz, 2008).

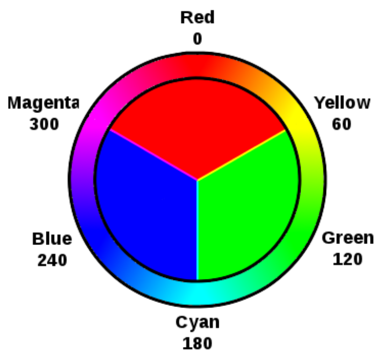

Figure A4. RGB color wheel.
(http://en.wikipedia.org/wiki/File:Simple_RGB_color_wheel.png)

A.2.2 CIELUV

CIELUV color space, similar to CIELAB color space, is a mathematical conversion of the metric color system previously developed by CIE. CIELUV was recommended by CIE in the same year with CIELAB (in 1976) as a uniform color space (Green and Macdonald, 2002). CIELUV has the ability to work with additive color mixtures (Green and Macdonald, 2002; Johnston-Feller, 2001) and was recommended by CIE for lights (CIE, 2014; Kuehni and Schwarz, 2008). Johnston-Feller (2001: 34) stated that "Industries for which additive color mixture of lights is the major concern prefer to use CIELUV". The space is arranged by three coordinates which are L, u and v. L represents the luminance and ranges from 0 to 100. u and v represent the chromaticity of a color (see Figure A5).

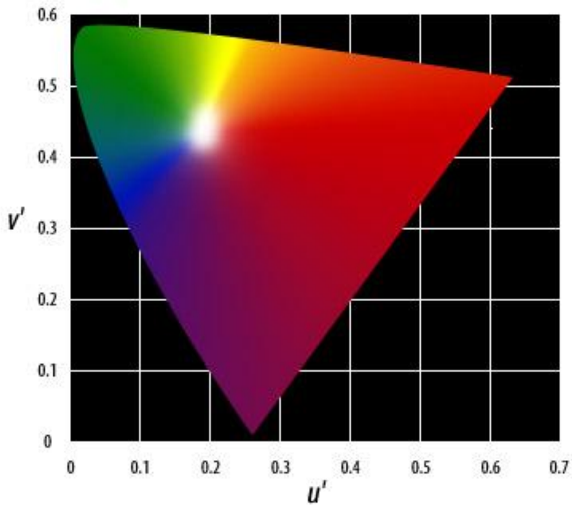

Figure A5. CIELUV u'v' chromaticity diagram.
(http://dba.med.sc.edu/price/irf/Adobe_tg/models/cieluv.html)

A2.3 Ostwald Color System

Wilhelm Ostwald (1853-1932), a Russian-German scientist, created this color system. Similar to the Munsell Color System, in the Ostwald Color System hues are arranged in a circle and the gray scale was used as the central axis. The four primary hues are red, yellow, green and blue and between these primaries four secondary hues of orange, leaf green, turquoise, purple are placed on the wheel.

Between these eight hues, additional hues are inserted which makes 24 hues in total (see Figure A6).

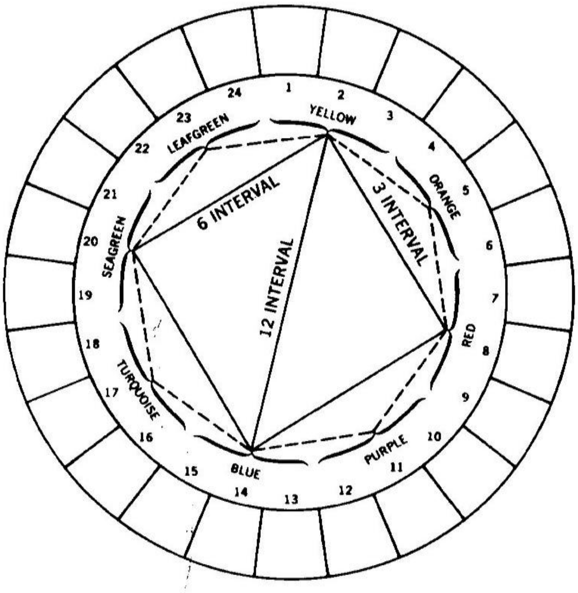

Figure A6. Ostwald color circle (Birren, 1969a: 67).

It differs from Munsell's system in that hues are numbered from 1 to 24 and values are lettered with (a) indicating white and (p) indicating black. A color is identified with a number and two letters indicating the white and black content of that color. Another difference of the Ostwald's System from Munsell's is the shape of the color solid. Unlike the irregular form of the Munsell Color Solid, the Ostwald Color Solid consists of two cones (see Figure A7).

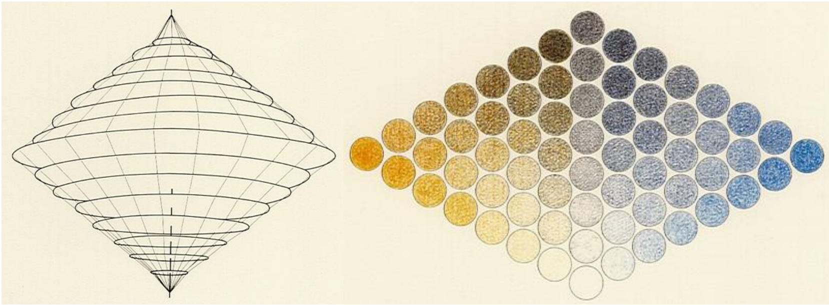

Figure A7. Ostwald Color Solid
(http://www.colorsystem.com/?page_id=551&lang=en)

In the Ostwald Color System, colors are arranged according to four dimensions: hue, equal whiteness, equal blackness and equal chromaticness (Kuehni and Schwarz, 2008). The system was criticized as less practical and the discussions of potential users of the system showed that an arrangement "according to hue, saturation and relative brightness with, unlike the Ostwald system, visually equidistant steps" was needed (Kuehni and Schwarz, 2008: 162).

A.3 Color Order Systems based on Perceptual Evaluation

Perceptual color order systems are based on "judgments of psychologically significant differences between color percepts" (Kuehni and Schwarz, 2008: 92). According to Ewald Hering (1834-1918) (cited in Kuehni and Schwarz, 2008), whose thoughts provided a basis for Natural Color System (NCS), colors should be treated as independent of laws of light or colorant mixture. Psychological color order systems are arranged according to three color dimensions hue, lightness (value) and saturation (chroma) (Kuehni and Schwarz, 2008). However, Hering (cited in Kuehni and Schwarz, 2008) stated that these attributes were in association with physical measurements and proposed a purely psychological system.

In the following chapters Munsell, Natural and Coloroid color systems are going to be mentioned. The Natural Color System (NCS) is a system developed based on the thoughts of Hering stated above. Similar to the Natural Color System, the Ostwald Color System is also based on Hering's color theory. However, Ostwald placed colorimetric opponent hues (obtained by using disk-mixture) opposite each other on the color wheel instead of perceptually opponent hues (Gulrajani, 2010). Therefore, this system was mentioned under the group 'color systems based on additive mixing' (see Appendix A.2.3). In Munsell and Coloroid color systems, colors are arranged according to the three attributes stated above and perceptual scales.

A.3.1 Munsell Color System

Albert Munsell (1858-1918), an American artist and instructor, developed his own color system and it was first published in 1915 (Pile, 1997). In this system, each color is defined by its hue, value and chroma. Hues are indicated by letters and hues are divided into five principal colors as red, yellow, green, blue, and purple. Between these principal colors there are intermediate hues which are indicated with two letters. Along with the two letters these 10 hues are identified with the number 5 preceding the letters. There are also other hues which are defined with other numbers showing the steps between the principal and intermediate colors (see Figure A8).

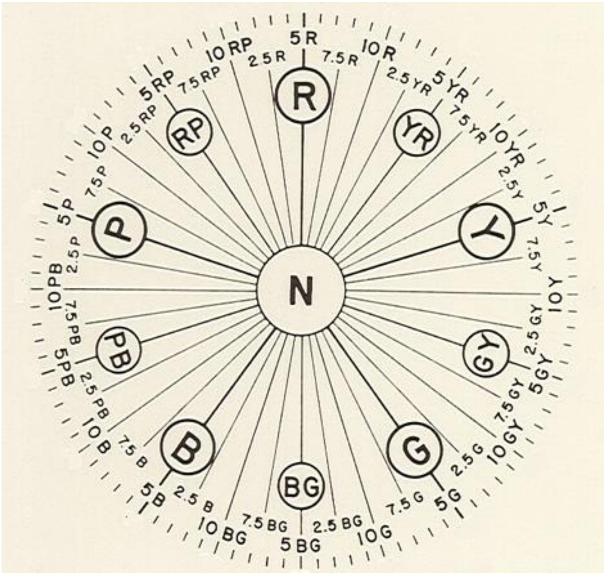

Figure A8. Munsell color wheel showing the steps between the principal and intermediate colors (Birren, 1969b: 72).

The whole color wheel consists of 100 hues. Values are indicated by numbers from 1 to 10, 1 showing the value of black, 10 showing the value of white and the numbers between showing the gray values. The hue circle constitutes the horizontal plane and the scale of values constitutes the vertical axis. The space between the wheel and the vertical central axis is the chroma scale. Chroma of colors are also indicated with numbers, 2 showing the least saturated and 14 showing the most saturated. This systematization generates the Munsell Color Solid (see Figure A9). To summarize, in Munsell notation the first number and letter denotes hue, the second number denotes value and the third number denotes the chroma. According to Kuehni (2005), the popularity of this color system lies on how easy it is to understand, for both the trained and untrained, the three attributes of the system.

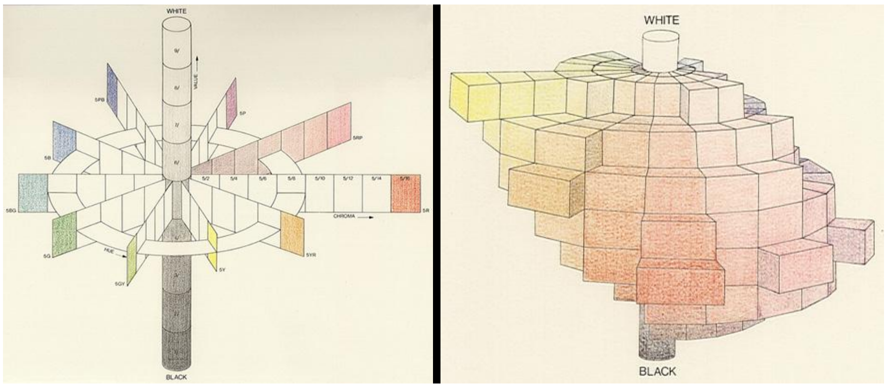

Figure A9. Munsell Color Solid.
(http://www.colorsystem.com/?page_id=551&lang=en)

A.3.2 Natural Color System (NCS)

NCS is a Swedish Color System that is based on the color perception study of Ewald Hering (Pile, 1997). The color diagram of Hering is based, not on the physical mixing of colors, but on perception (Feisner, 2006). According to Hering's study red, yellow, green and blue are primary colors because they cannot be described with any combinations of other colors (Hunt, 1987). For example, the color purple can be described as a bluish red or reddish blue. Therefore, the system consists of four hues red, yellow, green and blue which are placed on a circle with nine steps between each, making 40 hues in total. Each hue has a triangular chart consisting of the pure hue, white and black at the vertices of that triangle (see Figure A10).

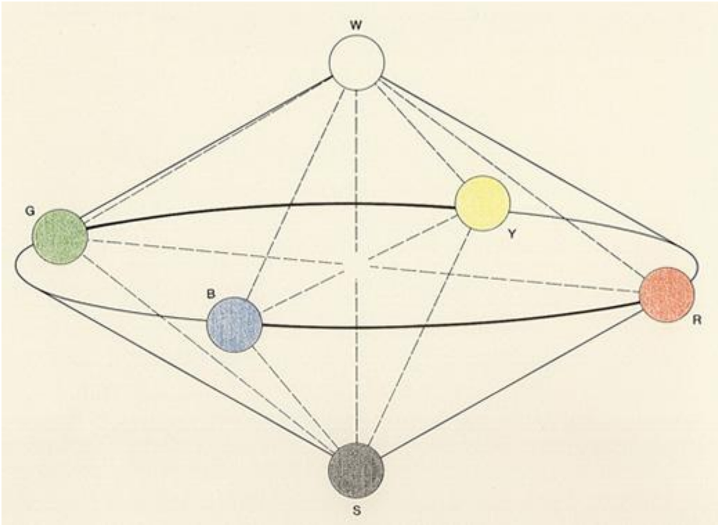

Figure A10. NCS color solid
(http://www.colorsystem.com/?page_id=551&lang=en)

All the hues in this color system are named with the binary combinations of the initials of the four primary hues such as YR (Yellow-Red), RB (Red-Blue), BG (Blue-Green) and GY (Green-Yellow) (see Figure A11). Additionally, as can be seen on the NCS color circle, there is a number placed between these letters indicating the percentage of the primary colors in the mixture for obtaining other colors. For instance, G50Y is a color obtained by the mixture of 50 percent green and 50 percent yellow and G10Y is a color obtained by the mixture of 90 percent green and 10 percent yellow. This indication only shows the hue component of a color. In order to define the level of whiteness and blackness components of a color, other letters and numbers are added. If a 30 percent white (W) and 20 percent black (S) and 50 (C) percent hue is added to the mixture (the total of W, S and C must be 100), the color is indicated as S2050-G10Y.

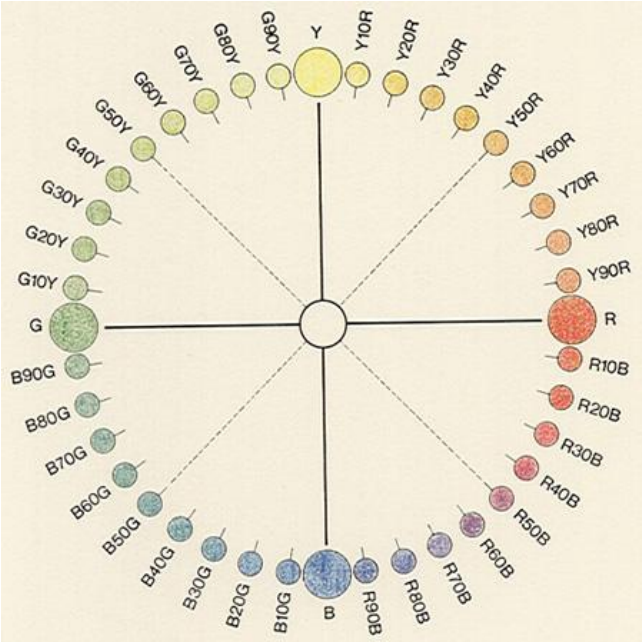

Figure A11. NCS color circle.
(http://www.colorsystem.com/?page_id=551&lang=en)

Each triangle of a certain hue consists of 66 colors, making over 2,000 colors in total for the atlas of the color system (Kuehni, 2005) (see Figure A12). Only 1,741 of these color specifications have been painted as paper samples because of lack of suitable colorants (Kuehni, 2005). The concepts of the NCS color system rely on the observer and are accepted as universally applicable (Kuehni, 2005) because “it is based on the presumed reasonably uniform experiences of observers when looking at color stimuli, independent of their source” (Kuehni, 2008: 144). As Kuehni (2005) stated, this is the reason that the NCS color system is popular with designers or architects and it is used where instrumental measurement is difficult but a color is required to be defined because its use of visual judgments makes colors easy to define. This color system was named as the Natural Color System by Hering, in comparison to the trichromatic theory of Helmholtz that is considered unnatural by Hering (Kuehni and Schwarz, 2008).

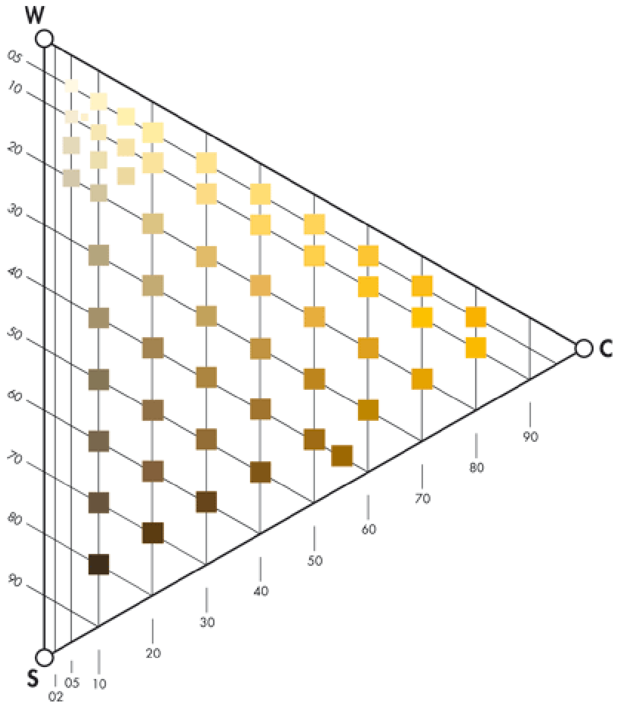

Figure A12. Example of an NCS hue triangle. (http://www.ncscolour.com/en/ncs/how-ncs-works/logic-behind-the-system)

A.3.3 Coloroid Color System

The coloroid color system is a color space developed by Antal Nemcsics (1927-) and it has been registered as the Hungarian Standard (Nemcsics, 2003). This system is based on surface colors (Nemcsics, 2012) and is mainly for architects and it "constitutes a color system of perceptions built on harmonic color differences of perceived surface colors enlightened by daylight and sensed by an observer possessing normal color vision” (Nemcsics, 2003: 1). Three dimensions of color are indicated as a Coloroid hue (A), Coloroid saturation (T) and Coloroid luminosity (V).

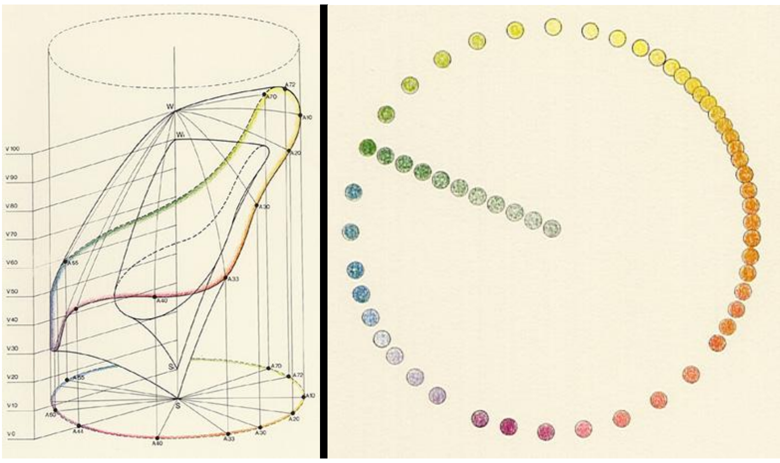

Figure A13. Coloroid color solid and circle.
(http://www.colorsystem.com/?page_id=551&lang=en)

There are 48 colors on the Coloroid color wheel “being located at approximately identical number of harmony intervals to each other” (Nemcsics, 2003: 3) (see Figure A13). For each hue (A10, A11, A12, A13, A14, A15, A16 yellow; A20, A21, A22, A23, A24, A25, A26 orange; A30, A31, A32, A33, A34, A35 red; A40, A41, A42, A43, A44, A45, A46 purple and violet; A50, A51, A52, A53, A54, A55, A56 blue; A60, A61, A62, A63, A64, A65, A66 cold green; A70, A71, A72, A73, A74, A75, A76 warm green) there is a color plane delimited by the achromatic axis of the Coloroid color space. Colors are denoted with the three dimensions A-T-V respectively. For instance, the color of a 13 Coloroid hue, a 22 Coloroid saturation and a 56 Coloroid luminosity is indicated as 13-22-56.

APPENDIX B

EQUATIONS FOR PREDICTING COLOR HARMONY

B.1 Models for Two-Color Combinations

Two-color harmony model proposed by Ou and Luo (2006) is as follows:

$$CH = H_C + H_L + H_H$$

where

$$H_C = 0.04 + 0.53\tanh(0.8 - 0.045\Delta C)$$

$$\Delta C = [(\Delta H^*_{ab})^2 + (\Delta C^*_{ab}/1.46)^2]^{\frac{1}{2}}$$

$$H_L = H_{Lsum} + H_{\Delta L}$$

$$H_{Lsum} = 0.28 + 0.54\tanh(-3.88 + 0.029L_{sum})$$

in which $L_{sum} = L^*_1 + L^*_2$

$$H_{\Delta L} = 0.14 + 0.15\tanh(-2 + 0.2\Delta L)$$

in which $\Delta L = |L^*_1 - L^*_2|$

$$H_H = H_{SY1} + H_{SY2}$$

$$H_{SY} = E_C * (H_S + E_Y)$$

$$E_C = 0.5 + 0.5 \tanh(-2 + 0.5C^*_{ab})$$

$$H_S = -0.08 - 0.14\sin(h_{ab} + 50°) - 0.07\sin(2h_{ab} + 90°)$$

$$E_Y = [(0.22L^* - 12.8)/10]\exp\{(90° - h_{ab})/10 - \exp[(90° - h_{ab})/10]\} .$$

Here,

CH = color harmony value,

H_C = chromatic effect,

H_L = lightness effect,

H_H = hue effect,

ΔH^*_{ab} = CIELAB color difference values in hue,

ΔC^*_{ab} = CIELAB color difference values in chroma,

h_{ab} = CIELAB hue angle for a constituent color in a color pair,

L^*_1 and L^*_2 = lightness values of the constituent colors in a color pair,

E_Y = the trend called "yellow effect" that high-lightness yellows tended to harmonize and low-lightness yellows tended not to harmonize,

E_C = serves as a correction equation illustrating that the hue effect (H_S+E_Y) becomes less significant as the chroma decreases,

H_{SY1} and H_{SY2} = prediction of mean color harmony values for each constituent color of a color pair.

Model developed by Szabo, Bodrogi and Schanda (2010) for monochromatic two-color combinations is shown below.

Best fitting equation for Figure 18 (a):

$$\mathrm{CHF}_{\mathrm{2M,HP}} = 0.361\sin(1,511h) - 2.512$$

For Figure 18 (b):

$$\begin{aligned}\mathrm{CHF}_{\mathrm{2M,Jdiff}} = {} & 2.33 \cdot 10^{-5}|\Delta J|^3 - 0.004|\Delta J|^2 \\ & + 0.211|\Delta J| + 0.246\end{aligned}$$

For Figure 18 (c):

$$\mathrm{CHF}_{\mathrm{2M,Cdiff}} = 3.87 - 0.066|\Delta C|$$

For Figure 18 (d):

$$\mathrm{CHF}_{\mathrm{2M,Jsum}} = 0.0268\ J_{\mathrm{sum}} - 0.656$$

These four equations were combined to obtain:

$$\begin{aligned}\mathrm{CHF}_{\mathrm{2M}} = {} & 0.283 \cdot \big(3.275\ \mathrm{CHF}_{\mathrm{2M,Jdiff}} - 0.643\ \mathrm{CHF}_{\mathrm{2M,Jsum}} \\ & - 2.749\ \mathrm{CHF}_{\mathrm{2M,Cdiff}} - 4.773\ \mathrm{CHF}_{\mathrm{2M,HP}}\big) - 5.305\end{aligned}$$

Here,

CHF = color harmony formulae,

subscript 2M = monochromatic two-color combinations,

$|\Delta J|$ = absolute value of lightness difference between the two colors,

J_{sum} = lightness sum of the samples,

$|\Delta C|$ = absolute value of chroma difference,

subscript HP = hue preference,

h = hue of the composition,

all correlates of color appearance are defined in CIECAM02.

Model developed by Szabo, Bodrogi and Schanda (2010) for dichromatic two-color combinations is as follows:

$$\begin{aligned} \mathrm{CHF}_{2D} = 0.47 \cdot (&0.515\ \mathrm{CHF}_{2D,Jdiff} + 0.391\ \mathrm{CHF}_{2D,Jsum} \\ &+ 0.205\ \mathrm{CHF}_{2D,Cdiff} + 1.736\ \mathrm{CHF}_{2D,Csum} \\ &+ 2.187\ \mathrm{CHF}_{2D,hdiff} + 5.104\ \mathrm{CHF}_{2D,HP}) - 2.283 \end{aligned}$$

Here,

CHF = color harmony formulae,

2D = dichromatic two-color combinations,

J_{diff} = lightness difference,

J_{sum} = lightness sum,

C_{diff} = chroma difference,

C_{sum} = chroma sum,

h_{diff} = hue difference,

HP = hue preference.

B.2 Models for Three-Color Combinations

Model developed by Ou, Chong et al. (2011) for predicting color harmony of three-color combinations including nonadjacent colors is as follows:

$$CH_3 = \frac{CH_{AB} + CH_{BC} + CH'_{CA}}{3}$$

where

CH_3 = overall harmony value for an interior image with three wall colors (A,B,C) in which A and C are nonadjacent,

CH'_{CA} = harmony value for the nonadjacent color pair and can be calculated with the equation below.

Harmony value of AB and BC can be calculated with two-color harmony model.

$$CH'_{CA} = 0.2 + 0.65 \tanh(1.7 - 0.045\Delta C')$$

where

$$\Delta C' = \left[(\Delta H^*_{ab})^2 + (\Delta C^*_{ab}/1.30)^2\right]^{\frac{1}{2}}$$

In order to apply this formula, not only to three-color combinations, but also to combinations of any number of colors, another equation was proposed as follows:

$$CH = \frac{1}{n+m}\left[\sum_{i=1}^{n}(CH_{A,i}) + \sum_{j=1}^{m}(CH_{N,j})\right]$$

where

n = number of adjacent color pairs,

m = number of nonadjacent color pairs,

$CH_{A,i}$ = harmony of the i-th adjacent color pairs and calculated by the two-color harmony model mentioned in the section Color Harmony of Two-Color Combinations,

CH_{Nj} = harmony of the j-th nonadjacent color pairs and calculated by the equation above.

Model developed by Szabo, Bodrogi and Schanda (2010) for predicting color harmony of monochromatic and trichromatic color combinations is shown below.

For monochromatic three-color combinations best fitting equation for Figure B1 (a):

$$\mathrm{CHF}_{3\mathrm{M,HP}} = 10^{-7}h^3 - 9 \cdot 10^{-5}h^2 + 0.0172\ h + 0.4291$$

For Figure B1 (b):

$$\begin{aligned}\mathrm{CHF}_{3\mathrm{M,Jdiff}} = &-5.419 \cdot 10^{-7}\Delta J^4 + 1.173 \cdot 10^{-4}\Delta J^3 \\ &- 8.008 \cdot 10^{3}\Delta J^2 + 1.813 \cdot 10^{-1}\Delta J + 1.1\end{aligned}$$

For Figure B1 (c):

$$\mathrm{CHF}_{3\mathrm{M,Cdiff}} = -0.0342\ \Delta C + 3.8324$$

For Figure B1 (d):

$$\mathrm{CHF}_{3\mathrm{M,Jsum}} = 0.0121\ J_{\mathrm{sum}} + 0.1222$$

These four equations were combined to obtain for monochromatic three-color combinations:

$$\begin{aligned}\mathrm{CHF}_{3\mathrm{M}} = 2.523 \cdot (&-0.0325\ \mathrm{CHF}_{3\mathrm{M,Jdiff}} \\ &+ 2.2659\ \mathrm{CHF}_{3\mathrm{M,Jsum}} + 3.4194\ \mathrm{CHF}_{3\mathrm{M,Cdiff}} \\ &- 1.355\ \mathrm{CHF}_{3\mathrm{M,Csum}} + 0.721\ \mathrm{CHF}_{3\mathrm{M,HP}}) + 1.318\end{aligned}$$

Here,

CHF = color harmony formulae,

3M = monochromatic three-color combination,

Jdiff = lightness difference,

Jsum = lightness sum,

Cdiff = chroma difference,

Csum = chroma sum,

HP = hue preference.

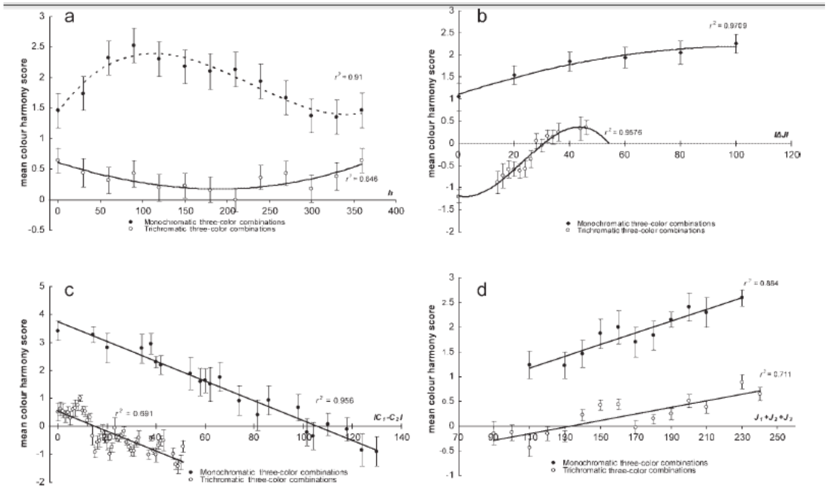

Figure B1. Predicting perceived color harmony for three-color combinations as a function of (a) CIECAM02 hue, (b) absolute lightness difference, (c) absolute chroma difference, (d) lightness sum (Szabo, Bodrogi and Schanda, 2010: 43).

The equation proposed for trichromatic three-color combinations is:

$$\begin{aligned}\mathrm{CHF}_{3T} = 2.187 \cdot (&0.967\ \mathrm{CHF}_{3T,\mathrm{Jdiff}} + 1.9397\ \mathrm{CHF}_{3T,\mathrm{Jsum}} \\ &+ 0.4399\ \mathrm{CHF}_{3T,\mathrm{Cdiff}} - 0.1153\ \mathrm{CHF}_{3T,\mathrm{Chrdiff}} \\ &+ 0.11\ \mathrm{CHF}_{3t,\mathrm{HP}}) + 0.134\end{aligned}$$

where

$$\mathrm{CHF}_{3T,\mathrm{Jdiff}} = -5 \cdot 10^{-5} \Delta J^3 + 0.0042\ \Delta J^2 - 0.0694\ \Delta J - 0.4898$$

$$\mathrm{CHF}_{3T,\mathrm{Jsum}} = 0.0121\ J_{\mathrm{sum}} - 0.1222$$

$$\mathrm{CHF}_{3T,\mathrm{Cdiff}} = 6 \cdot 10^{-4} \Delta C^2 - 0.0647\ \Delta C + 0.7711$$

$$\begin{aligned}\mathrm{CHF}_{3T,\mathrm{HP}} = &((\sin(h_1 - 4.836) \times -0.151 - 7.378) \times 3.796 \\ &+ 3.97) + ((\sin(h_2 - 4.836) \times -0.151 - 7.378) \\ &\times 3.796 + 3.97) + ((\sin(h_3 - 4.836) \times -0.151 - 7.378) \\ &\times 3.796 + 3.97)\end{aligned}$$

$$\mathrm{CHF}_{3\mathrm{T,hdiff}} = -1.923\ \Delta h_1^2 \Delta h_2^2 + 3.781\ \Delta h_1^2 + 3.781\ \Delta h_2^2 + 5.793\ \Delta h_1 \Delta h_2 - 7.605\ \Delta h_1 - 7.605\ \Delta h_2 + 3.6766$$

Here,

CHF = color harmony formulae,

3T = trichromatic three-color combination,

Jdiff = lightness difference,

Cdiff = chroma difference,

HP = hue preference,

hdiff = hue difference.

APPENDIX C

RGB VALUES OF THE COLORS

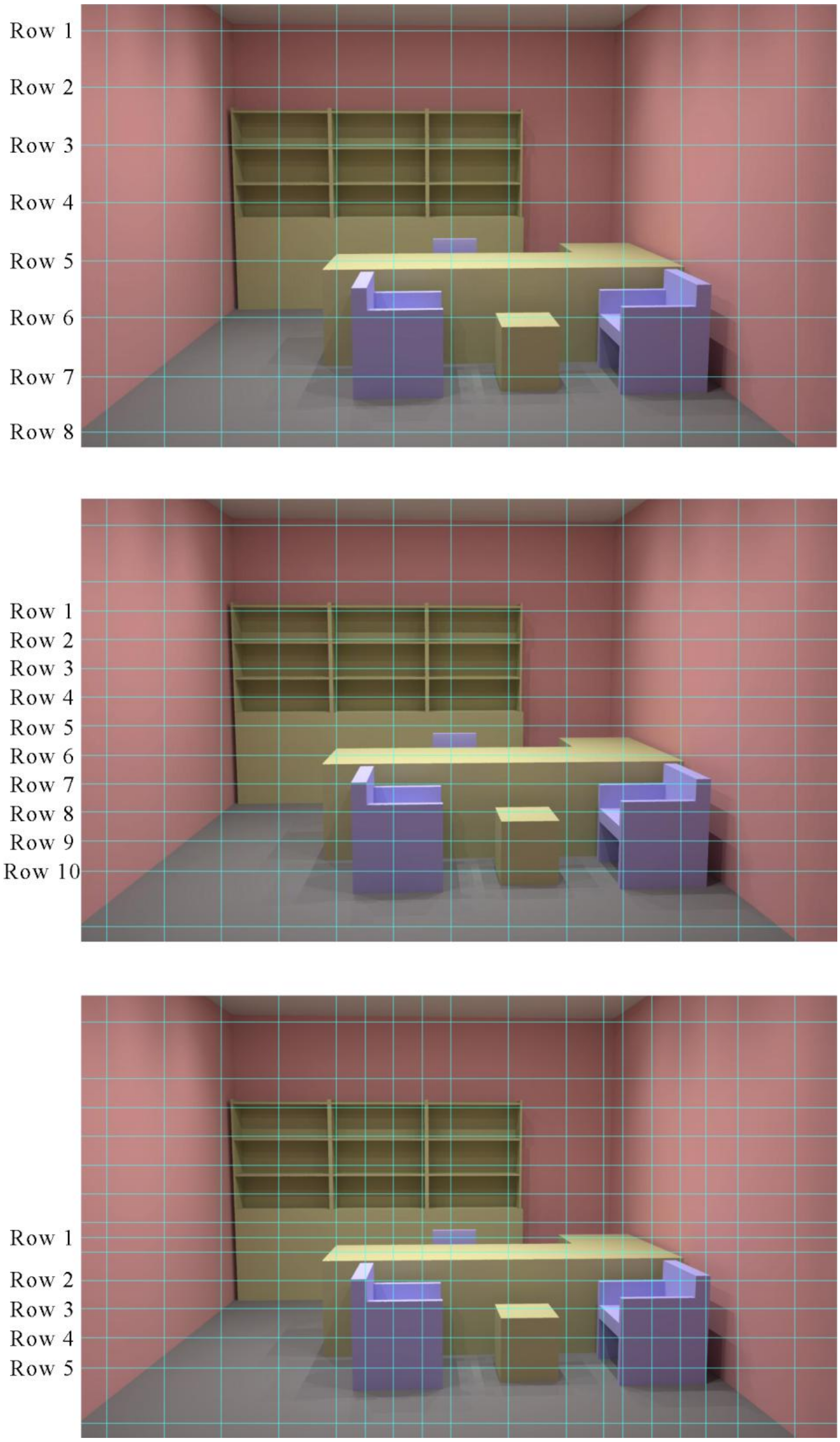

Figure C1. Grids for measuring the RGB values, for the walls (top), for the table-bookshelf-coffeetable (middle), for the seating units (down).

Table C1. RGB values of Set 1 – Office 1.

SET 1 - OFFICE 1											
Walls (Red)				**Table-bookshelf-coffeetable (Yellow)**				**Seating units (Blue)**			
Row 1				**Row 1**				**Row 1**			
Point	**R**	**G**	**B**	**Point**	**R**	**G**	**B**	**Point**	**R**	**G**	**B**
1	175	119	118	**1**	81	67	42	**1**	134	128	174
2	158	106	104	**2**	69	60	34	**Row 2**			
3	169	67	63	**3**	87	74	45	**1**	109	96	132
4	111	67	64	**4**	85	74	43	**2**	200	192	255
5	120	72	69	**5**	78	68	39	**3**	181	174	245
6	122	74	70	**Row 2**				**4**	126	118	200
7	122	74	70	**1**	111	103	71	**5**	144	138	210
8	121	73	69	**2**	87	83	52	**6**	109	86	119
9	113	68	63	**3**	124	118	82	**Row 3**			
10	105	61	58	**4**	120	115	80	**1**	107	93	128
11	153	103	99	**5**	117	113	77	**2**	107	93	130
12	166	113	110	**Row 3**				**3**	108	94	130
13	174	118	117	**1**	99	87	56	**4**	127	122	163
Row 2				**2**	85	77	45	**5**	105	88	122
1	191	133	130	**3**	106	96	62	**6**	105	87	119
2	188	131	128	**4**	104	95	61	**7**	104	84	117
3	128	82	78	**5**	97	89	56	**8**	105	83	115
4	129	81	79	**Row 4**				**Row 4**			
5	140	90	87	**1**	92	78	49	**1**	105	92	177
6	143	93	91	**2**	85	77	45	**2**	106	92	128
7	143	93	89	**3**	95	84	53	**3**	106	92	128
8	142	92	88	**4**	93	82	50	**4**	77	72	104
9	138	87	82	**5**	86	78	47	**5**	103	86	119
10	127	78	74	**Row 5**				**6**	101	84	117
11	184	126	124	**1**	131	119	84	**7**	102	83	115
12	187	129	126	**2**	138	128	91	**8**	101	81	112
13	182	124	122	**3**	140	131	94	**Row 5**			
Row 3				**4**	139	130	93	**1**	102	90	123
1	195	135	135	**5**	136	127	91	**2**	102	90	123
2	195	135	132	**Row 6**				**3**	102	90	124
3	140	95	89	**1**	127	115	83	**4**	100	85	118
4	148	95	92	**2**	227	222	162	**5**	97	81	112
5	138	87	84	**3**	234	228	167	**6**	95	79	109
6	195	136	133	**4**	235	229	167	**7**	94	76	107
7	193	134	132	**5**	232	226	165				
8	180	122	120	**6**	221	212	153				
Row 4				**7**	203	194	140				
1	189	131	128	**Row 7**							
2	188	131	128	**1**	122	112	81				
3	145	99	94	**2**	125	115	86				
4	147	95	92	**3**	121	116	92				
5	143	93	89	**4**	128	119	91				
6	195	136	131	**5**	132	121	87				
7	189	119	118	**6**	125	114	85				
8	176	119	118	**Row 8**							
Row 5				**1**	117	107	82				
1	181	124	124	**2**	105	97	72				
2	178	123	120	**3**	226	221	162				
3	143	99	94	**4**	111	104	77				
4	173	120	115	**Row 9**							
5	180	124	126	**1**	106	96	73				
6	170	115	115	**2**	96	91	67				
Row 6				**3**	111	98	71				
1	172	118	118	**4**	102	98	72				
2	166	116	115	**Row 10**							
3	136	95	91	**1**	109	97	70				
4	164	112	114								
5	163	110	109								
Row 7											
1	164	113	113								
2	136	92	94								
3	157	101	102								
Row 8											
1	150	101	102								
Mean	157	105	103	**Mean**	126	117	82	**Mean**	112	98	138

Table C2. RGB values of Set 1 – Office 2.

SET 1 - OFFICE 2

Walls (Blue)			
Row 1			
Point	**R**	**G**	**B**
1	134	133	192
2	119	118	171
3	71	70	108
4	71	71	111
5	79	79	123
6	77	77	119
7	76	76	117
8	77	76	118
9	71	71	111
10	69	68	108
11	115	115	164
12	128	127	184
13	130	129	187
Row 2			
1	148	149	213
2	146	146	206
3	89	89	132
4	91	91	140
5	101	101	152
6	102	102	152
7	104	103	155
8	101	100	151
9	96	96	145
10	87	87	134
11	141	141	200
12	146	145	207
13	136	137	195
Row 3			
1	150	150	216
2	149	149	210
3	102	103	143
4	103	102	153
5	100	99	151
6	153	151	212
7	149	148	210
8	133	133	192
Row 4			
1	146	146	208
2	145	145	205
3	107	107	150
4	105	105	156
5	103	102	153
6	153	151	207
7	147	146	206
8	133	132	191
Row 5			
1	137	138	197
2	136	135	193
3	108	108	150
4	136	136	187
5	139	138	197
6	128	127	186
Row 6			
1	131	131	190
2	129	128	180
3	105	105	146
4	125	124	180
5	120	120	176
Row 7			
1	128	127	184
2	106	104	152
3	116	116	170
Row 8			
1	112	112	165
Mean	117	116	169

Table-bookshelf-coffeetable (Yellow)			
Row 1			
Point	**R**	**G**	**B**
1	66	66	53
2	61	60	41
3	74	73	56
4	74	74	56
5	67	66	47
Row 2			
1	105	105	78
2	84	84	56
3	120	120	88
4	118	119	86
5	111	112	79
Row 3			
1	89	89	67
2	77	77	52
3	98	98	71
4	96	95	69
5	92	92	66
Row 4			
1	80	80	62
2	77	77	53
3	87	87	64
4	85	85	60
5	79	79	55
Row 5			
1	121	122	97
2	131	132	104
3	134	134	103
4	134	134	102
5	129	129	98
Row 6			
1	119	120	96
2	228	228	169
3	236	236	175
4	236	236	175
5	230	230	171
6	218	218	164
7	196	196	148
Row 7			
1	115	116	91
2	120	117	91
3	125	115	88
4	127	122	93
5	128	126	95
6	120	116	90
Row 8			
1	113	110	87
2	106	103	79
3	228	228	169
4	108	105	81
Row 9			
1	102	99	78
2	96	93	70
3	102	101	83
4	102	100	76
Row 10			
1	100	101	82
Mean	120	119	86

Seating units (Red)			
Row 1			
Point	**R**	**G**	**B**
1	169	121	124
Row 2			
1	125	91	103
2	232	171	174
3	243	177	181
4	236	170	175
5	187	128	130
6	116	84	105
Row 3			
1	123	90	102
2	124	90	103
3	124	90	103
4	158	115	115
5	116	84	98
6	114	83	99
7	113	82	100
8	111	81	100
Row 4			
1	120	88	100
2	122	89	101
3	122	89	101
4	92	65	68
5	113	82	96
6	112	82	97
7	109	79	97
8	106	78	95
Row 5			
1	119	87	99
2	119	87	99
3	119	87	99
4	112	82	94
5	107	78	91
6	105	77	92
7	102	91	103
Mean	132	97	105

Table C3. RGB values of Set 1 – Office 3.

SET 1 - OFFICE 3

Walls (Red)			
Row 1			
Point	**R**	**G**	**B**
1	175	121	126
2	157	108	115
3	101	64	71
4	105	65	71
5	112	71	76
6	111	70	77
7	112	71	79
8	112	71	79
9	102	62	69
10	98	61	67
11	151	103	110
12	165	114	118
13	171	119	122
Row 2			
1	194	135	139
2	187	132	138
3	122	81	89
4	125	81	85
5	139	91	96
6	139	93	99
7	140	94	98
8	137	91	95
9	136	87	94
10	121	77	83
11	183	128	136
12	189	132	135
13	180	124	128
Row 3			
1	194	136	140
2	194	137	142
3	135	93	102
4	145	95	102
5	134	88	93
6	194	137	146
7	193	135	139
8	180	124	128
Row 4			
1	192	133	137
2	187	130	136
3	139	97	104
4	144	96	101
5	138	92	98
6	196	138	150
7	189	132	135
8	174	119	123
Row 5			
1	183	127	128
2	176	123	126
3	140	98	105
4	177	123	134
5	179	125	128
6	166	115	117
Row 6			
1	173	120	121
2	168	118	121
3	135	95	102
4	163	113	113
5	160	110	112
Row 7			
1	165	115	118
2	138	95	95
3	155	107	106
Row 8			
1	151	103	104
Mean	149	106	111

Table-bookshelf-coffeetable (Blue)			
Row 1			
Point	**R**	**G**	**B**
1	72	61	104
2	59	54	96
3	77	66	118
4	76	66	121
5	67	60	110
Row 2			
1	103	97	148
2	83	81	131
3	116	112	169
4	113	109	166
5	106	103	161
Row 3			
1	90	81	131
2	75	71	123
3	97	89	145
4	94	87	144
5	87	83	137
Row 4			
1	82	71	120
2	69	64	115
3	86	77	132
4	83	76	130
5	77	70	124
Row 5			
1	125	114	160
2	131	123	172
3	133	126	179
4	130	125	174
5	126	120	169
Row 6			
1	122	112	156
2	220	216	255
3	223	221	255
4	225	222	255
5	221	217	255
6	210	205	255
7	194	186	255
Row 7			
1	118	109	152
2	119	112	150
3	114	110	145
4	121	114	157
5	123	116	171
6	119	110	154
Row 8			
1	110	103	140
2	101	97	135
3	219	215	255
4	106	99	138
Row 9			
1	101	94	127
2	92	88	124
3	106	95	131
4	98	94	131
Row 10			
1	102	92	128
Mean	118	111	158

Seating units (Yellow)			
Row 1			
Point	**R**	**G**	**B**
1	142	137	105
Row 2			
1	113	102	75
2	126	118	79
3	127	120	77
4	124	118	74
5	152	148	104
6	111	91	67
Row 3			
1	112	100	72
2	111	100	74
3	110	99	73
4	133	129	98
5	109	95	69
6	107	91	66
7	108	90	65
8	108	88	64
Row 4			
1	109	98	72
2	109	98	72
3	109	98	72
4	80	77	55
5	105	91	66
6	105	89	64
7	105	88	64
8	101	84	61
Row 5			
1	106	95	69
2	106	95	69
3	107	96	69
4	103	90	66
5	101	87	62
6	98	84	60
7	96	80	58
Mean	111	99	72

Table C4. RGB values of Set 1 – Office 4.

SET 1 - OFFICE 4

Walls (Yellow)			
Row 1			
Point	**R**	**G**	**B**
1	140	139	102
2	126	125	93
3	76	76	55
4	76	76	53
5	82	82	58
6	85	85	62
7	84	84	61
8	82	81	59
9	73	73	53
10	75	75	53
11	121	120	91
12	132	131	96
13	136	135	99
Row 2			
1	156	156	113
2	152	152	113
3	95	95	70
4	97	96	68
5	105	105	76
6	108	107	78
7	107	106	77
8	106	105	76
9	102	101	73
10	90	90	65
11	150	149	112
12	153	152	110
13	143	142	104
Row 3			
1	159	158	115
2	157	157	116
3	107	107	82
4	109	109	79
5	103	103	75
6	159	159	120
7	157	156	113
8	143	141	103
Row 4			
1	154	154	112
2	152	152	110
3	111	111	84
4	111	112	81
5	109	109	79
6	160	158	122
7	154	153	111
8	138	137	100
Row 5			
1	146	145	105
2	142	141	103
3	114	114	86
4	142	141	107
5	147	144	105
6	131	132	94
Row 6			
1	139	138	101
2	135	134	98
3	111	111	84
4	131	130	91
5	127	127	91
Row 7			
1	132	133	95
2	112	110	77
3	122	122	87
Row 8			
1	120	119	84
Mean	123	122	89

Table-bookshelf-coffeetable (Blue)			
Row 1			
Point	**R**	**G**	**B**
1	64	64	97
2	57	57	100
3	70	70	114
4	68	68	112
5	64	63	111
Row 2			
1	100	100	146
2	79	80	131
3	113	113	168
4	111	111	165
5	104	104	156
Row 3			
1	84	84	127
2	74	74	126
3	93	92	144
4	90	90	141
5	85	85	135
Row 4			
1	75	75	115
2	80	80	132
3	81	82	131
4	79	80	131
5	73	72	122
Row 5			
1	117	117	154
2	125	125	169
3	129	129	174
4	128	127	174
5	123	123	168
Row 6			
1	114	115	151
2	216	216	255
3	223	224	255
4	225	226	255
5	218	218	255
6	206	208	255
7	186	187	252
Row 7			
1	111	112	149
2	115	112	149
3	119	110	149
4	122	117	160
5	122	120	172
6	117	112	153
Row 8			
1	109	105	140
2	102	98	135
3	216	216	255
4	104	101	136
Row 9			
1	99	96	126
2	91	88	124
3	97	98	126
4	97	95	132
Row 10			
1	95	96	124
Mean	114	114	156

Seating units (Red)			
Row 1			
Point	**R**	**G**	**B**
1	169	121	122
Row 2			
1	128	93	86
2	255	186	184
3	227	163	162
4	237	171	170
5	191	129	128
6	118	86	74
Row 3			
1	124	91	84
2	126	91	85
3	124	91	85
4	156	113	118
5	117	86	78
6	116	85	75
7	115	84	73
8	116	85	72
Row 4			
1	123	90	83
2	123	90	83
3	123	90	83
4	95	67	65
5	114	83	76
6	113	82	74
7	112	82	72
8	111	81	70
Row 5			
1	121	88	81
2	119	87	82
3	121	88	83
4	113	82	75
5	110	80	73
6	108	78	69
7	105	77	67
Mean	134	97	91

Table C5. RGB values of Set 1 – Office 5.

SET 1 - OFFICE 5

Walls (Yellow)			
Row 1			
Point	**R**	**G**	**B**
1	142	139	98
2	129	123	85
3	80	74	49
4	81	77	50
5	86	81	54
6	88	82	54
7	85	78	51
8	84	77	51
9	76	70	46
10	76	72	47
11	125	119	83
12	133	130	91
13	138	136	98
Row 2			
1	158	155	111
2	155	151	108
3	100	94	64
4	98	94	64
5	107	103	71
6	109	105	73
7	109	105	73
8	109	105	73
9	106	101	69
10	96	91	62
11	154	147	106
12	155	151	108
13	145	143	103
Row 3			
1	160	157	113
2	161	157	113
3	114	106	74
4	115	109	74
5	108	103	70
6	165	158	114
7	159	155	111
8	144	141	101
Row 4			
1	155	153	109
2	155	151	108
3	119	111	79
4	112	110	76
5	114	109	76
6	168	157	114
7	154	151	110
8	139	138	97
Row 5			
1	146	145	103
2	145	142	102
3	121	113	79
4	151	141	101
5	148	145	106
6	133	132	95
Row 6			
1	139	138	99
2	135	133	95
3	115	110	79
4	130	131	95
5	127	127	91
Row 7			
1	132	131	94
2	115	115	84
3	122	122	87
Row 8			
1	118	119	84
Mean	125	121	86

Table-bookshelf-coffeetable (Red)			
Row 1			
Point	**R**	**G**	**B**
1	91	56	49
2	84	49	45
3	100	60	54
4	102	59	55
5	92	54	50
Row 2			
1	135	91	87
2	122	81	79
3	154	104	101
4	150	101	99
5	147	99	97
Row 3			
1	119	76	70
2	104	62	59
3	130	83	77
4	130	82	77
5	125	77	73
Row 4			
1	105	67	59
2	95	56	52
3	116	71	65
4	114	69	64
5	108	64	60
Row 5			
1	149	108	102
2	160	116	112
3	164	119	114
4	164	118	113
5	160	114	110
Row 6			
1	145	105	100
2	255	202	201
3	255	207	205
4	255	209	206
5	255	203	202
6	255	192	190
7	239	174	170
Row 7			
1	141	102	98
2	143	104	103
3	143	103	111
4	153	109	111
5	162	110	108
6	145	102	103
Row 8			
1	133	98	97
2	128	91	93
3	255	201	200
4	130	93	93
Row 9			
1	122	88	88
2	116	82	82
3	126	91	86
4	125	89	89
Row 10			
1	123	90	84
Mean	147	104	101

Seating units (Blue)			
Row 1			
Point	**R**	**G**	**B**
1	134	129	176
Row 2			
1	99	100	129
2	202	201	255
3	196	196	255
4	185	185	255
5	141	140	206
6	94	94	110
Row 3			
1	97	98	126
2	98	99	127
3	97	98	126
4	166	165	225
5	93	93	115
6	91	91	113
7	89	89	108
8	89	90	105
Row 4			
1	95	96	123
2	96	97	123
3	96	97	124
4	67	67	92
5	90	90	113
6	89	89	110
7	87	87	107
8	87	87	104
Row 5			
1	94	95	122
2	94	95	122
3	94	95	122
4	89	89	113
5	86	86	107
6	84	84	103
7	82	82	100
Mean	107	107	137

Table C6. RGB values of Set 1 – Office 6.

SET 1 - OFFICE 6

Walls (Blue)			
Row 1			
Point	**R**	**G**	**B**
1	135	130	191
2	123	117	173
3	76	70	113
4	76	71	116
5	83	77	127
6	82	75	122
7	82	75	122
8	80	73	120
9	74	67	112
10	72	66	111
11	119	112	169
12	129	124	183
13	132	129	190
Row 2			
1	149	147	213
2	147	143	207
3	95	88	136
4	93	89	140
5	104	99	153
6	105	100	155
7	107	102	156
8	105	100	155
9	101	94	150
10	91	85	137
11	146	139	204
12	146	142	208
13	137	135	198
Row 3			
1	152	149	216
2	151	147	211
3	110	102	150
4	110	103	162
5	103	96	152
6	157	148	215
7	151	147	213
8	137	133	196
Row 4			
1	146	144	209
2	146	143	206
3	113	106	156
4	108	104	161
5	108	102	158
6	159	147	213
7	147	144	207
8	134	130	191
Row 5			
1	139	138	201
2	138	135	197
3	114	107	156
4	144	134	195
5	139	137	198
6	128	126	184
Row 6			
1	133	130	191
2	130	127	184
3	108	103	147
4	124	124	178
5	122	121	179
Row 7			
1	127	125	183
2	105	105	152
3	117	117	173
Row 8			
1	112	112	165
Mean	119	113	171

Table-bookshelf-coffeetable (Red)			
Row 1			
Point	**R**	**G**	**B**
1	91	55	68
2	87	48	56
3	102	60	71
4	100	58	69
5	94	53	62
Row 2			
1	133	89	96
2	118	73	77
3	153	102	107
4	151	101	105
5	143	94	97
Row 3			
1	117	74	85
2	123	76	81
3	130	82	91
4	127	80	89
5	122	75	82
Row 4			
1	105	65	77
2	106	61	67
3	117	71	82
4	115	69	78
5	106	62	70
Row 5			
1	149	107	119
2	160	115	126
3	165	118	127
4	164	117	124
5	159	113	120
Row 6			
1	147	105	117
2	255	199	207
3	255	205	213
4	255	207	212
5	255	202	210
6	255	191	199
7	239	173	183
Row 7			
1	142	102	111
2	156	127	114
3	143	104	112
4	151	107	112
5	158	107	115
6	143	101	108
Row 8			
1	135	98	105
2	128	90	95
3	255	199	206
4	131	93	99
Row 9			
1	122	88	94
2	116	82	85
3	123	90	102
4	122	86	91
Row 10			
1	120	88	100
Mean	142	104	111

Seating units (Yellow)			
Row 1			
Point	**R**	**G**	**B**
1	140	135	103
Row 2			
1	103	103	86
2	119	118	88
3	121	120	84
4	120	119	80
5	149	148	106
6	94	94	86
Row 3			
1	102	101	84
2	102	101	84
3	102	101	84
4	134	128	96
5	95	95	81
6	94	94	82
7	93	93	84
8	92	92	84
Row 4			
1	100	100	82
2	100	99	84
3	101	100	84
4	76	76	57
5	93	93	80
6	91	91	79
7	90	90	80
8	89	89	81
Row 5			
1	97	97	81
2	97	97	82
3	98	98	83
4	91	91	78
5	89	89	78
6	86	86	76
7	84	84	75
Mean	102	101	83

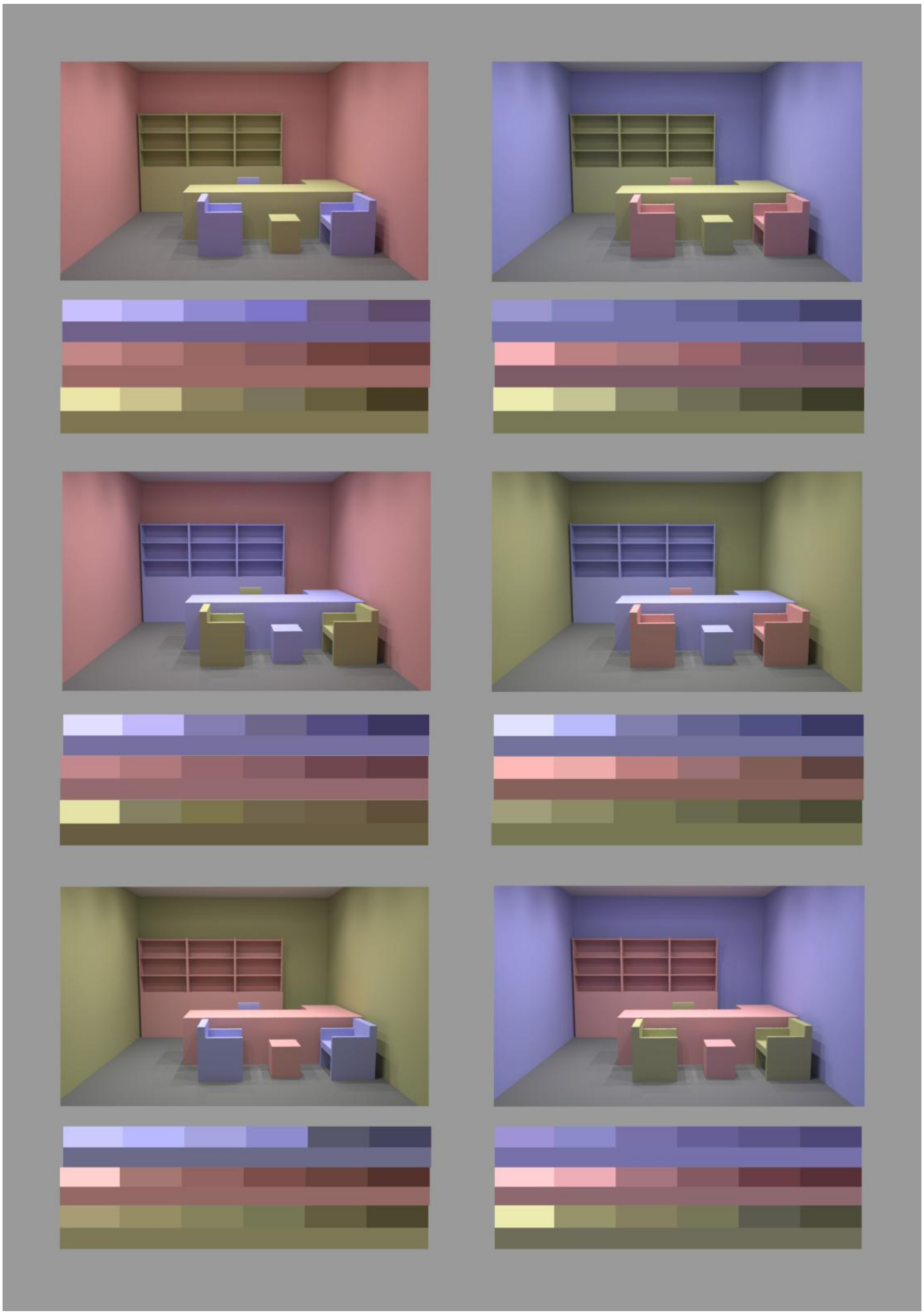

Figure C2. Colors of the 6 images related to the shadows and interreflections (Set 1).

Table C7. RGB values of Set 2 – Office 1.

SET 2 - OFFICE 1

Walls (Green)			
Row 1			
Point	**R**	**G**	**B**
1	106	149	104
2	94	132	91
3	54	80	51
4	55	81	52
5	59	89	55
6	57	86	55
7	57	86	55
8	57	84	53
9	52	78	49
10	52	77	48
11	89	126	85
12	99	140	96
13	102	148	102
Row 2			
1	119	167	117
2	115	161	114
3	69	99	65
4	68	102	67
5	76	112	76
6	79	115	77
7	78	114	76
8	78	114	76
9	73	107	70
10	65	96	62
11	113	159	110
12	116	162	115
13	109	157	109
Row 3			
1	120	179	119
2	120	168	118
3	83	117	80
4	81	118	77
5	77	113	75
6	122	170	118
7	120	168	118
8	108	154	107
Row 4			
1	117	165	115
2	116	162	115
3	85	119	82
4	82	118	80
5	81	117	79
6	124	171	117
7	116	164	116
8	104	150	104
Row 5			
1	110	156	109
2	108	154	108
3	86	120	83
4	111	153	105
5	112	155	109
6	99	145	99
Row 6			
1	103	148	105
2	102	145	102
3	83	117	84
4	98	141	98
5	96	139	96
Row 7			
1	99	142	99
2	82	116	81
3	92	134	94
Row 8			
1	89	120	90
Mean	91	130	89

Table-bookshelf-coffeetable (Orange)			
Row 1			
Point	**R**	**G**	**B**
1	72	66	44
2	68	57	39
3	79	71	48
4	81	69	45
5	76	64	42
Row 2			
1	118	104	78
2	103	86	66
3	133	117	91
4	131	113	89
5	101	86	63
Row 3			
1	96	86	61
2	89	74	53
3	108	94	68
4	107	93	67
5	101	86	63
Row 4			
1	83	77	51
2	82	70	48
3	97	85	59
4	95	81	55
5	85	73	51
Row 5			
1	131	121	94
2	142	131	103
3	147	133	104
4	147	131	105
5	144	128	102
Row 6			
1	129	119	92
2	254	222	181
3	255	232	190
4	255	231	187
5	255	229	186
6	244	216	176
7	218	196	157
Row 7			
1	131	116	95
2	134	113	96
3	140	119	98
4	139	122	94
5	131	115	92
6	115	100	81
Row 8			
1	123	108	89
2	117	102	83
3	252	223	181
4	119	104	85
Row 9			
1	109	98	80
2	103	90	74
3	107	101	79
4	112	99	82
Row 10			
1	107	101	77
Mean	131	116	90

Seating units (Purple)			
Row 1			
Point	**R**	**G**	**B**
1	178	130	170
Row 2			
1	119	93	118
2	163	113	164
3	151	101	154
4	164	109	167
5	185	127	185
6	100	88	102
Row 3			
1	115	91	117
2	115	91	117
3	115	91	117
4	155	115	150
5	105	86	108
6	104	85	105
7	101	84	102
8	97	85	99
Row 4			
1	114	90	116
2	114	90	116
3	114	90	116
4	91	67	91
5	104	85	105
6	102	83	103
7	99	82	98
8	94	80	95
Row 5			
1	111	87	111
2	110	86	110
3	112	88	112
4	105	83	104
5	99	80	99
6	95	78	96
7	90	76	91
Mean	117	91	117

Table C8. RGB values of Set 2 – Office 2.

SET 2 - OFFICE 2

Walls (Purple)			
Row 1			
Point	**R**	**G**	**B**
1	168	118	167
2	150	105	148
3	94	61	90
4	97	62	94
5	105	68	102
6	102	65	98
7	105	68	101
8	103	66	99
9	94	59	91
10	92	59	88
11	145	100	141
12	161	112	159
13	169	117	166
Row 2			
1	188	133	188
2	185	131	183
3	117	77	112
4	116	78	115
5	130	88	128
6	133	88	129
7	133	88	129
8	129	87	127
9	125	83	123
10	116	76	111
11	180	126	176
12	185	131	183
13	176	123	175
Row 3			
1	190	135	192
2	191	134	187
3	131	91	126
4	137	90	132
5	128	86	124
6	194	136	187
7	188	134	186
8	174	121	173
Row 4			
1	184	129	184
2	184	130	182
3	136	94	130
4	138	93	136
5	137	92	133
6	195	136	184
7	184	131	183
8	169	118	168
Row 5			
1	176	123	175
2	171	121	170
3	138	196	132
4	170	118	164
5	174	124	173
6	163	113	162
Row 6			
1	166	116	165
2	161	115	162
3	134	94	131
4	157	111	157
5	156	108	156
Row 7			
1	160	113	159
2	132	94	133
3	151	105	152
Row 8			
1	144	101	146
Mean	149	104	146

Table-bookshelf-coffeetable (Orange)			
Row 1			
Point	**R**	**G**	**B**
1	83	60	54
2	75	54	45
3	89	65	55
4	89	65	55
5	81	62	48
Row 2			
1	122	99	83
2	105	84	67
3	140	115	95
4	134	112	91
5	163	135	114
Row 3			
1	105	81	69
2	89	67	54
3	116	90	75
4	112	89	73
5	106	85	68
Row 4			
1	97	70	61
2	90	68	54
3	105	77	65
4	103	77	64
5	95	73	59
Row 5			
1	144	116	104
2	151	125	108
3	154	129	109
4	153	127	110
5	148	122	107
Row 6			
1	139	113	98
2	255	221	184
3	255	230	190
4	254	228	191
5	255	224	185
6	225	190	162
7	223	187	161
Row 7			
1	134	110	97
2	134	113	96
3	125	113	91
4	138	117	96
5	144	119	99
6	132	111	92
Row 8			
1	123	104	89
2	116	99	81
3	255	219	183
4	119	102	86
Row 9			
1	112	94	82
2	105	89	73
3	119	95	85
4	112	96	80
Row 10			
1	116	93	85
Mean	137	113	95

Seating units (Green)			
Row 1			
Point	**R**	**G**	**B**
1	117	154	110
Row 2			
1	83	107	83
2	110	153	108
3	138	192	142
4	145	195	142
5	110	158	110
6	82	96	83
Row 3			
1	81	104	84
2	81	105	81
3	82	106	84
4	100	136	98
5	79	98	79
6	78	95	77
7	78	92	79
8	78	92	79
Row 4			
1	80	102	81
2	80	104	80
3	80	104	82
4	65	89	65
5	77	96	77
6	76	93	75
7	74	91	75
8	74	88	73
Row 5			
1	78	100	79
2	78	100	79
3	78	102	80
4	75	94	75
5	72	90	74
6	71	88	72
7	71	85	72
Mean	85	110	85

Table C9. RGB values of Set 2 – Office 3.

SET 2 - OFFICE 3			
Walls (Green)			
Row 1			
Point	**R**	**G**	**B**
1	106	149	104
2	95	131	95
3	55	79	55
4	54	80	53
5	60	86	59
6	59	85	58
7	58	84	59
8	58	84	57
9	54	78	54
10	53	75	52
11	90	126	90
12	100	141	101
13	105	148	103
Row 2			
1	119	169	120
2	117	163	117
3	70	99	71
4	68	101	70
5	77	111	78
6	81	115	82
7	80	114	81
8	79	114	81
9	73	106	75
10	66	97	66
11	116	159	116
12	115	162	116
13	110	156	109
Row 3			
1	121	169	121
2	121	168	122
3	83	112	82
4	81	116	83
5	78	112	79
6	123	169	123
7	120	167	121
8	109	155	108
Row 4			
1	117	165	115
2	116	163	117
3	88	119	87
4	85	121	85
5	81	115	82
6	125	166	124
7	117	165	117
8	107	150	104
Row 5			
1	111	157	110
2	110	153	108
3	89	120	88
4	104	145	103
5	110	156	109
6	102	145	102
Row 6			
1	106	149	106
2	103	144	102
3	85	116	84
4	98	141	98
5	97	138	96
Row 7			
1	99	142	99
2	89	125	89
3	94	135	93
Row 8			
1	89	130	90
Mean	92	130	92

Table-bookshelf-coffeetable (Purple)			
Row 1			
Point	**R**	**G**	**B**
1	79	55	79
2	78	49	79
3	89	58	89
4	92	58	91
5	84	53	84
Row 2			
1	127	91	129
2	120	82	121
3	146	103	146
4	144	101	146
5	137	94	137
Row 3			
1	106	75	107
2	98	62	98
3	120	82	121
4	117	79	118
5	113	75	114
Row 4			
1	95	66	94
2	94	58	94
3	106	72	107
4	106	68	107
5	97	61	97
Row 5			
1	140	109	141
2	154	118	156
3	160	119	161
4	159	118	160
5	152	114	153
Row 6			
1	137	106	138
2	255	202	255
3	255	208	255
4	255	207	255
5	255	202	254
6	254	192	255
7	233	175	234
Row 7			
1	134	103	137
2	140	105	137
3	142	103	134
4	149	109	144
5	154	108	154
6	141	104	138
Row 8			
1	130	97	126
2	123	90	121
3	255	200	255
4	127	94	125
Row 9			
1	117	88	116
2	113	82	113
3	116	92	118
4	122	89	120
Row 10			
1	114	90	114
Mean	141	103	141

Seating units (Orange)			
Row 1			
Point	**R**	**G**	**B**
1	172	144	123
Row 2			
1	111	103	80
2	235	207	168
3	204	180	142
4	163	140	108
5	170	145	115
6	93	96	65
Row 3			
1	108	102	78
2	108	102	80
3	108	102	80
4	148	127	106
5	99	98	70
6	97	95	70
7	95	95	69
8	94	94	66
Row 4			
1	106	100	76
2	106	100	76
3	107	101	77
4	92	83	66
5	97	95	70
6	95	93	68
7	92	92	66
8	90	90	64
Row 5			
1	104	98	76
2	103	97	75
3	104	98	76
4	99	94	72
5	91	89	66
6	88	88	64
7	85	84	63
Mean	115	107	82

Table C10. RGB values of Set 2 – Office 4.

SET 2 - OFFICE 4

Walls (Orange)			
Row 1			
Point	**R**	**G**	**B**
1	159	135	111
2	140	118	97
3	86	68	56
4	88	70	58
5	96	77	63
6	98	79	64
7	95	73	60
8	92	73	59
9	86	68	56
10	84	66	54
11	134	111	93
12	148	126	105
13	157	132	110
Row 2			
1	176	150	123
2	171	145	120
3	109	87	73
4	107	88	71
5	120	99	80
6	122	101	82
7	121	100	81
8	121	100	81
9	115	94	77
10	106	84	70
11	168	140	116
12	170	144	119
13	163	139	115
Row 3			
1	177	151	124
2	176	150	123
3	124	100	87
4	125	102	86
5	119	98	81
6	181	151	127
7	176	150	123
8	160	136	110
Row 4			
1	173	147	122
2	170	146	120
3	128	107	90
4	126	103	85
5	124	103	84
6	184	149	129
7	173	147	122
8	155	133	109
Row 5			
1	162	140	116
2	159	134	112
3	128	106	92
4	159	132	111
5	161	140	113
6	150	128	104
Row 6			
1	154	132	108
2	150	128	105
3	122	103	86
4	143	125	101
5	143	123	99
Row 7			
1	146	125	104
2	127	111	88
3	139	119	95
Row 8			
1	133	115	91
Mean	138	115	95

Table-bookshelf-coffeetable (Purple)			
Row 1			
Point	**R**	**G**	**B**
1	90	54	82
2	82	47	79
3	99	58	92
4	97	55	91
5	88	51	84
Row 2			
1	132	87	128
2	113	72	112
3	148	101	145
4	145	98	144
5	143	97	143
Row 3			
1	113	72	106
2	105	65	102
3	125	79	118
4	122	77	118
5	113	71	109
Row 4			
1	103	64	95
2	96	56	91
3	114	68	107
4	111	66	105
5	102	60	98
Row 5			
1	149	105	140
2	158	113	152
3	163	116	158
4	162	115	159
5	157	110	152
Row 6			
1	146	102	137
2	255	198	255
3	255	205	255
4	254	204	255
5	255	200	255
6	255	188	255
7	237	171	233
Row 7			
1	141	100	132
2	140	103	136
3	134	101	130
4	146	106	140
5	154	105	150
6	141	100	134
Row 8			
1	131	94	125
2	126	91	123
3	255	195	255
4	127	92	124
Row 9			
1	117	84	111
2	113	80	109
3	124	88	116
4	120	87	118
Row 10			
1	121	85	113
Mean	144	100	139

Seating units (Green)			
Row 1			
Point	**R**	**G**	**B**
1	116	152	114
Row 2			
1	80	110	74
2	162	222	158
3	141	194	138
4	144	194	143
5	110	158	108
6	78	100	64
Row 3			
1	80	107	74
2	80	107	74
3	80	107	74
4	100	136	100
5	75	100	68
6	75	99	67
7	73	97	63
8	76	98	62
Row 4			
1	78	105	72
2	78	105	72
3	78	105	72
4	63	87	61
5	73	98	68
6	73	97	65
7	71	95	63
8	71	92	61
Row 5			
1	76	103	70
2	76	103	70
3	76	103	70
4	72	97	67
5	69	94	64
6	69	89	61
7	67	88	57
Mean	85	114	79

Table C11. RGB values of Set 2 – Office 5.

SET 2 - OFFICE 5

Walls (Orange)			
Row 1			
Point	**R**	**G**	**B**
1	155	135	108
2	135	119	93
3	82	71	53
4	85	72	55
5	92	79	60
6	93	81	59
7	91	78	59
8	89	78	58
9	81	70	52
10	80	68	52
11	129	115	89
12	148	128	101
13	153	134	104
Row 2			
1	172	151	120
2	167	146	117
3	102	90	68
4	107	90	70
5	116	100	77
6	118	102	77
7	118	103	80
8	118	102	79
9	111	96	73
10	99	87	65
11	163	144	114
12	167	146	117
13	161	140	111
Row 3			
1	174	153	122
2	174	153	124
3	117	105	81
4	121	105	80
5	115	101	75
6	174	155	122
7	175	152	121
8	159	138	109
Row 4			
1	171	147	119
2	167	146	117
3	121	106	83
4	123	107	82
5	120	104	81
6	172	156	122
7	171	147	119
8	157	136	109
Row 5			
1	161	140	113
2	158	137	110
3	121	109	85
4	154	139	108
5	162	140	116
6	151	130	103
Row 6			
1	154	132	108
2	149	132	106
3	121	106	83
4	147	126	105
5	145	123	99
Row 7			
1	147	127	103
2	124	105	88
3	140	120	96
Row 8			
1	133	115	93
Mean	135	117	92

Table-bookshelf-coffeetable (Green)			
Row 1			
Point	**R**	**G**	**B**
1	48	72	40
2	39	64	35
3	51	78	45
4	48	78	44
5	44	71	40
Row 2			
1	63	93	59
2	55	86	52
3	69	104	64
4	66	100	63
5	64	96	59
Row 3			
1	63	93	59
2	48	77	46
3	69	104	64
4	68	103	63
5	64	96	59
Row 4			
1	95	130	90
2	48	78	44
3	60	92	53
4	58	90	51
5	52	82	48
Row 5			
1	95	130	90
2	101	140	96
3	105	143	102
4	102	143	99
5	99	138	94
Row 6			
1	94	126	89
2	175	242	171
3	179	251	177
4	180	252	179
5	174	243	176
6	164	229	161
7	152	211	147
Row 7			
1	88	122	85
2	92	124	87
3	90	119	89
4	96	127	93
5	94	133	89
6	92	124	87
Row 8			
1	86	115	84
2	83	113	79
3	172	242	170
4	82	111	80
Row 9			
1	78	105	74
2	73	99	70
3	80	107	74
4	77	106	75
Row 10			
1	79	106	73
Mean	88	125	84

Seating units (Purple)			
Row 1			
Point	**R**	**G**	**B**
1	185	138	180
Row 2			
1	129	90	119
2	169	126	171
3	161	102	156
4	153	94	150
5	183	125	183
6	121	82	103
Row 3			
1	127	88	117
2	127	88	117
3	127	88	117
4	151	113	150
5	120	82	105
6	117	9	100
7	118	80	101
8	118	79	100
Row 4			
1	121	85	113
2	122	86	114
3	122	86	114
4	100	72	97
5	116	81	105
6	114	79	101
7	113	78	100
8	114	76	97
Row 5			
1	118	84	111
2	119	85	112
3	121	85	111
4	115	80	104
5	111	76	100
6	108	75	96
7	107	72	92
Mean	127	86	117

Table C12. RGB values of Set 2 – Office 6.

SET 2 - OFFICE 6											
Walls (Purple)				**Table-bookshelf-coffeetable (Green)**				**Seating units (Orange)**			
Row 1				**Row 1**				**Row 1**			
Point	**R**	**G**	**B**	**Point**	**R**	**G**	**B**	**Point**	**R**	**G**	**B**
1	168	122	169	**1**	52	69	51	**1**	190	167	136
2	148	107	149	**2**	41	65	41	**Row 2**			
3	92	63	91	**3**	52	76	52	**1**	124	100	90
4	93	62	93	**4**	51	77	50	**2**	143	112	94
5	100	66	99	**5**	45	69	45	**3**	212	181	150
6	98	67	99	**Row 2**				**4**	220	189	158
7	101	70	101	**1**	81	112	80	**5**	171	144	115
8	96	65	96	**2**	57	91	58	**6**	120	86	85
9	90	60	88	**3**	89	127	88	**Row 3**			
10	88	59	87	**4**	88	126	89	**1**	120	95	88
11	140	102	141	**5**	83	121	84	**2**	120	95	88
12	159	113	159	**Row 3**				**3**	121	96	89
13	168	118	167	**1**	66	92	67	**4**	145	127	105
Row 2				**2**	66	101	68	**5**	117	90	83
1	188	135	189	**3**	72	103	72	**6**	115	87	83
2	181	131	182	**4**	70	101	70	**7**	116	87	83
3	113	79	112	**5**	64	95	64	**8**	115	84	82
4	116	78	117	**Row 4**				**Row 4**			
5	127	89	128	**1**	58	82	60	**1**	118	93	86
6	129	91	130	**2**	52	81	51	**2**	118	93	86
7	129	91	130	**3**	61	90	60	**3**	119	94	87
8	128	90	129	**4**	59	90	59	**4**	95	78	68
9	121	85	123	**5**	53	82	54	**5**	114	89	82
10	112	76	112	**Row 5**				**6**	110	85	80
11	177	129	177	**1**	97	128	97	**7**	111	83	80
12	181	131	184	**2**	104	139	106	**8**	109	81	78
13	175	125	176	**3**	105	143	104	**Row 5**			
Row 3				**4**	104	142	105	**1**	115	92	84
1	189	136	190	**5**	100	136	100	**2**	115	92	84
2	189	136	190	**Row 6**				**3**	116	93	85
3	128	94	127	**1**	96	125	95	**4**	111	88	82
4	131	93	132	**2**	175	241	177	**5**	109	84	79
5	125	87	126	**3**	180	249	182	**6**	105	80	75
6	188	138	189	**4**	180	251	183	**7**	65	47	47
7	189	136	190	**5**	176	245	178				
8	174	124	173	**6**	168	229	169				
Row 4				**7**	152	207	152				
1	185	132	186	**Row 7**							
2	181	131	184	**1**	92	123	92				
3	132	96	132	**2**	94	125	93				
4	136	95	137	**3**	90	121	87				
5	129	91	132	**4**	96	130	97				
6	185	139	185	**5**	95	131	93				
7	185	132	186	**6**	92	123	91				
8	170	120	169	**Row 8**							
Row 5				**1**	88	114	85				
1	175	125	176	**2**	80	109	79				
2	170	122	170	**3**	175	241	177				
3	132	98	131	**4**	82	111	81				
4	163	120	165	**Row 9**							
5	176	126	175	**1**	79	103	77				
6	163	115	165	**2**	72	98	71				
Row 6				**3**	81	105	81				
1	168	118	169	**4**	78	107	77				
2	160	117	163	**Row 10**							
3	130	96	129	**1**	80	104	80				
4	159	112	158								
5	157	109	157								
Row 7											
1	160	114	160								
2	142	100	140								
3	154	106	154								
Row 8											
1	145	102	147								
Mean	147	104	147	**Mean**	90	126	90	**Mean**	125	100	90

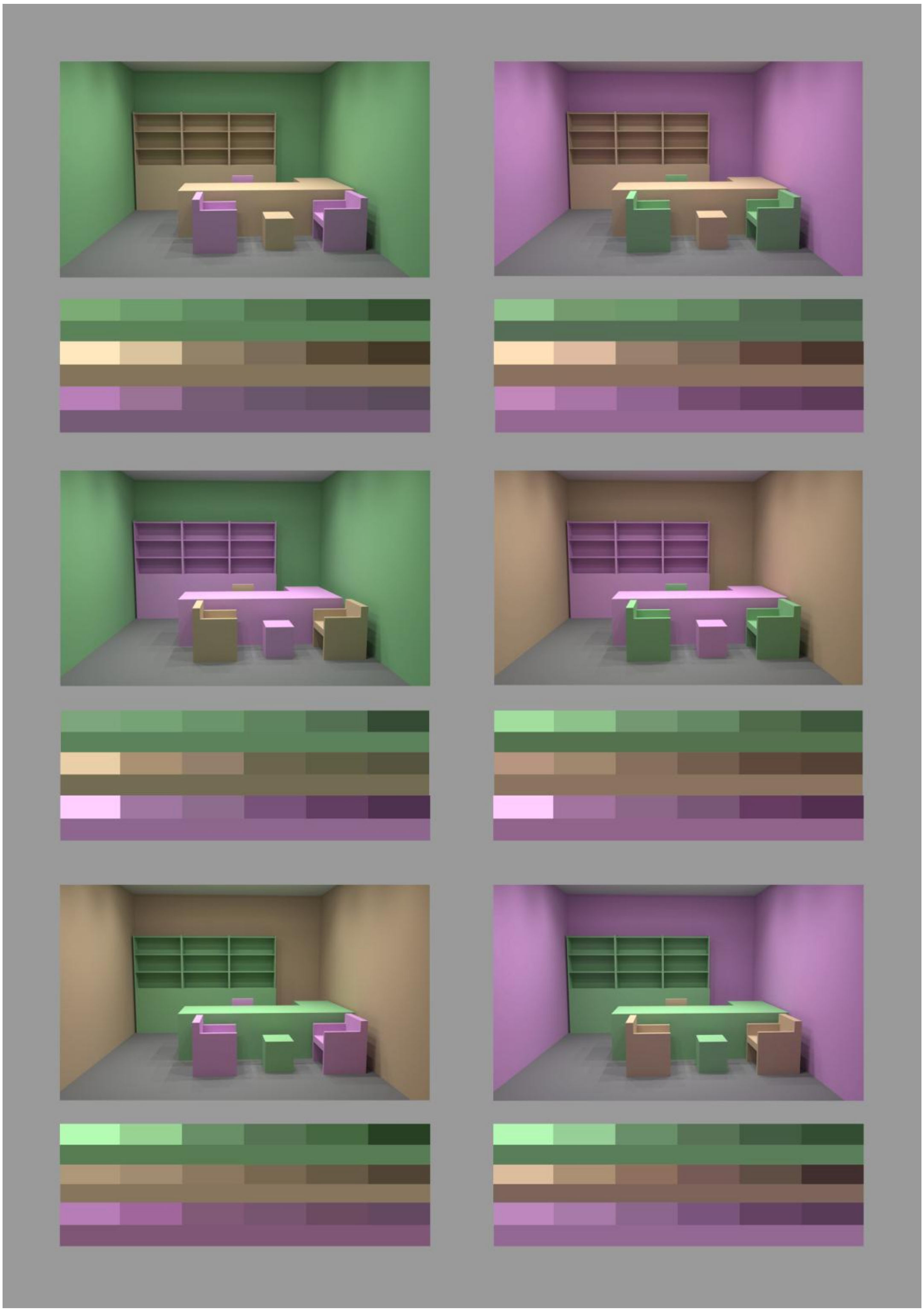

Figure C3. Colors of the 6 images related to the shadows and interreflections (Set 2).

Table C13. RGB values of Set 3 – Office 1.

SET 3 - OFFICE 1

Walls (Red)			
Row 1			
Point	**R**	**G**	**B**
1	173	122	119
2	153	108	105
3	96	62	60
4	99	64	62
5	108	70	67
6	104	66	63
7	105	67	64
8	103	65	62
9	95	62	57
10	94	60	58
11	148	103	100
12	164	115	111
13	173	119	117
Row 2			
1	192	136	135
2	186	132	130
3	117	79	76
4	122	81	79
5	133	89	88
6	136	92	91
7	137	93	90
8	134	90	89
9	129	85	82
10	117	77	75
11	183	130	126
12	188	133	130
13	180	126	126
Row 3			
1	196	140	139
2	195	140	135
3	129	92	86
4	138	93	90
5	134	90	89
6	198	140	136
7	193	138	133
8	179	124	121
Row 4			
1	189	133	132
2	187	133	131
3	138	97	95
4	141	96	93
5	139	95	92
6	197	140	133
7	192	134	132
8	176	122	120
Row 5			
1	181	127	127
2	175	124	121
3	139	100	95
4	174	125	121
5	180	126	124
6	167	116	115
Row 6			
1	171	121	120
2	166	118	116
3	135	95	93
4	162	114	114
5	162	112	111
Row 7			
1	164	116	116
2	136	96	97
3	157	108	111
Row 8			
1	148	104	105
Mean	152	105	103

Table-bookshelf-coffeetable (Yellow)			
Row 1			
Point	**R**	**G**	**B**
1	74	64	39
2	64	58	34
3	79	69	42
4	77	70	42
5	69	63	37
Row 2			
1	109	104	72
2	90	86	57
3	122	120	82
4	121	117	82
5	119	116	81
Row 3			
1	93	86	57
2	81	77	48
3	102	96	62
4	98	93	61
5	94	89	59
Row 4			
1	85	75	48
2	101	96	86
3	92	83	52
4	88	81	52
5	80	75	46
Row 5			
1	130	121	88
2	137	131	95
3	140	134	98
4	138	132	96
5	134	128	92
Row 6			
1	127	118	87
2	232	230	169
3	238	237	173
4	237	236	172
5	232	231	167
6	221	216	158
7	204	197	145
Row 7			
1	121	115	83
2	123	117	85
3	122	116	82
4	129	124	86
5	132	124	87
6	125	117	81
Row 8			
1	114	109	79
2	107	102	72
3	230	228	167
4	111	104	75
Row 9			
1	105	98	70
2	96	92	65
3	107	100	72
4	103	99	70
Row 10			
1	106	99	71
Mean	124	118	83

Seating units (Orange)			
Row 1			
Point	**R**	**G**	**B**
1	170	143	113
Row 2			
1	123	97	80
2	182	153	123
3	147	116	88
4	151	121	93
5	172	142	114
6	120	87	72
Row 3			
1	121	95	78
2	122	96	79
3	122	96	79
4	146	125	98
5	115	88	71
6	115	88	71
7	115	86	70
8	113	84	73
Row 4			
1	116	93	75
2	119	93	76
3	120	94	77
4	94	78	63
5	114	88	73
6	112	84	70
7	110	82	68
8	109	81	67
Row 5			
1	115	92	76
2	115	92	76
3	116	93	75
4	110	86	73
5	109	83	70
6	106	80	65
7	103	77	64
Mean	123	97	79

Table C14. RGB values of Set 3 – Office 2.

SET 3 - OFFICE 2											
Walls (Orange)				**Table-bookshelf-coffeetable (Yellow)**				**Seating units (Red)**			
Row 1				**Row 1**				**Row 1**			
Point	**R**	**G**	**B**	**Point**	**R**	**G**	**B**	**Point**	**R**	**G**	**B**
1	156	135	108	**1**	69	65	38	**1**	209	152	145
2	137	117	93	**2**	61	59	34	**Row 2**			
3	85	69	53	**3**	76	71	41	**1**	130	92	89
4	87	72	53	**4**	73	70	39	**2**	199	138	137
5	94	77	57	**5**	69	65	36	**3**	228	163	161
6	95	78	58	**Row 2**				**4**	184	123	120
7	96	79	59	**1**	104	103	72	**5**	190	129	128
8	91	74	54	**2**	94	93	63	**6**	123	82	76
9	85	70	51	**3**	122	120	82	**Row 3**			
10	82	66	50	**4**	119	116	81	**1**	127	89	86
11	132	112	88	**5**	117	114	79	**2**	128	90	87
12	147	125	101	**Row 3**				**3**	128	90	87
13	155	131	105	**1**	90	87	56	**4**	157	112	107
Row 2				**2**	77	76	48	**5**	122	85	79
1	173	149	121	**3**	101	97	60	**6**	121	84	78
2	169	146	115	**4**	96	93	58	**7**	120	81	76
3	105	88	68	**5**	91	91	57	**8**	120	79	73
4	106	89	69	**Row 4**				**Row 4**			
5	118	100	76	**1**	81	78	47	**1**	125	87	84
6	120	102	78	**2**	68	67	39	**2**	125	87	84
7	120	102	78	**3**	88	84	49	**3**	126	88	85
8	119	101	77	**4**	86	81	49	**4**	104	73	71
9	112	94	70	**5**	82	79	48	**5**	119	81	78
10	102	85	65	**Row 5**				**6**	118	81	75
11	163	142	111	**1**	126	122	85	**7**	116	79	73
12	170	147	115	**2**	134	132	93	**8**	115	78	70
13	163	139	111	**3**	136	134	95	**Row 5**			
Row 3				**4**	136	134	96	**1**	121	86	82
1	177	152	121	**5**	131	129	90	**2**	120	85	81
2	176	151	120	**Row 6**				**3**	124	86	83
3	118	102	79	**1**	122	119	84	**4**	116	81	77
4	123	103	79	**2**	231	229	168	**5**	113	78	74
5	117	99	77	**3**	234	234	170	**6**	108	75	70
6	178	153	122	**4**	235	235	171	**7**	106	72	70
7	176	149	119	**5**	231	229	168				
8	160	136	108	**6**	218	218	158				
Row 4				**7**	198	195	140				
1	170	147	116	**Row 7**							
2	169	146	115	**1**	119	116	81				
3	124	108	83	**2**	122	118	83				
4	123	105	81	**3**	124	113	81				
5	121	103	79	**4**	128	122	86				
6	178	154	120	**5**	130	125	85				
7	172	147	117	**6**	123	117	81				
8	156	135	106	**Row 8**							
Row 5				**1**	114	109	77				
1	162	141	114	**2**	108	103	71				
2	159	138	111	**3**	229	227	166				
3	125	109	86	**4**	110	105	73				
4	155	134	107	**Row 9**							
5	163	139	111	**1**	102	98	69				
6	150	129	102	**2**	96	92	65				
Row 6				**3**	106	101	71				
1	154	133	106	**4**	103	99	70				
2	149	129	104	**Row 10**							
3	122	106	83	**1**	104	99	70				
4	147	125	102								
5	144	122	98								
Row 7											
1	146	126	102								
2	124	106	86								
3	139	119	95								
Row 8											
1	134	114	90								
Mean	136	116	91	**Mean**	121	118	81	**Mean**	134	93	89

Table C15. RGB values of Set 3 – Office 3.

SET 3- OFFICE 3			
Walls (Red)			
Row 1			
Point	**R**	**G**	**B**
1	175	121	121
2	155	107	105
3	98	63	61
4	99	64	62
5	108	68	66
6	107	67	65
7	109	69	67
8	104	64	62
9	99	61	58
10	94	60	58
11	150	102	100
12	165	114	111
13	174	120	120
Row 2			
1	193	135	134
2	188	132	131
3	122	81	79
4	119	79	77
5	121	80	78
6	135	91	90
7	135	91	90
8	135	89	89
9	130	85	82
10	117	75	76
11	184	129	126
12	188	133	130
13	180	126	124
Row 3			
1	197	139	137
2	196	138	134
3	137	93	90
4	141	93	91
5	131	87	86
6	198	139	135
7	195	137	133
8	179	123	122
Row 4			
1	189	133	132
2	188	132	131
3	141	97	96
4	143	95	96
5	137	91	91
6	199	138	135
7	191	133	131
8	176	123	119
Row 5			
1	180	126	126
2	176	125	124
3	142	98	97
4	169	119	118
5	180	126	124
6	167	116	113
Row 6			
1	172	121	120
2	165	117	117
3	134	96	93
4	160	114	114
5	160	112	112
Row 7			
1	162	116	116
2	136	96	97
3	156	108	108
Row 8			
1	149	105	106
Mean	153	105	103

Table-bookshelf-coffeetable (Orange)			
Row 1			
Point	**R**	**G**	**B**
1	83	60	44
2	72	53	38
3	90	64	47
4	91	65	48
5	82	61	44
Row 2			
1	122	100	79
2	101	83	63
3	136	114	91
4	136	111	89
5	127	105	84
Row 3			
1	106	81	61
2	111	89	68
3	116	89	70
4	115	90	70
5	107	84	66
Row 4			
1	96	70	55
2	91	70	51
3	105	78	57
4	103	76	57
5	92	69	51
Row 5			
1	142	116	93
2	151	124	103
3	155	129	106
4	154	128	105
5	148	122	99
Row 6			
1	138	113	93
2	254	220	182
3	255	227	187
4	255	228	188
5	255	224	185
6	243	209	172
7	224	189	157
Row 7			
1	134	109	89
2	136	111	89
3	131	111	87
4	141	117	93
5	145	117	93
6	137	111	88
Row 8			
1	127	105	84
2	120	99	80
3	255	220	182
4	122	101	82
Row 9			
1	113	95	75
2	107	90	72
3	118	95	77
4	122	101	82
Row 10			
1	117	94	76
Mean	137	113	90

Seating units (Yellow)			
Row 1			
Point	**R**	**G**	**B**
1	176	170	122
Row 2			
1	112	102	75
2	124	116	77
3	192	186	136
4	143	139	94
5	152	148	101
6	108	90	66
Row 3			
1	110	100	73
2	110	100	73
3	110	100	73
4	133	129	92
5	104	92	68
6	105	91	65
7	105	89	64
8	105	87	63
Row 4			
1	108	98	71
2	107	97	70
3	106	99	71
4	85	83	60
5	103	91	67
6	103	88	65
7	101	86	63
8	100	84	61
Row 5			
1	103	96	70
2	102	95	69
3	104	97	71
4	101	89	65
5	97	85	61
6	95	83	61
7	92	80	56
Mean	113	103	74

Table C16. RGB values of Set 3 – Office 4.

SET 3 - OFFICE 4

Walls (Yellow)			
Row 1			
Point	**R**	**G**	**B**
1	141	139	100
2	125	123	85
3	75	73	48
4	77	75	50
5	83	82	52
6	83	79	50
7	86	82	53
8	85	81	52
9	76	72	45
10	72	70	45
11	122	118	81
12	133	131	92
13	140	138	97
Row 2			
1	157	156	110
2	153	152	106
3	97	93	64
4	95	94	63
5	105	105	71
6	107	107	73
7	107	107	73
8	106	106	72
9	102	99	66
10	91	90	60
11	150	147	104
12	154	151	106
13	147	146	102
Row 3			
1	160	159	111
2	159	158	110
3	110	107	74
4	111	108	73
5	106	103	70
6	162	158	110
7	159	156	111
8	145	142	101
Row 4			
1	154	153	109
2	153	152	106
3	113	110	75
4	113	110	75
5	110	107	74
6	164	158	110
7	156	153	108
8	141	139	98
Row 5			
1	148	146	105
2	143	141	102
3	116	113	78
4	141	139	98
5	148	145	102
6	136	134	95
Row 6			
1	139	137	98
2	136	134	96
3	113	110	79
4	132	130	92
5	130	128	90
Row 7			
1	134	132	94
2	116	116	82
3	126	124	86
Row 8			
1	119	119	83
Mean	123	121	84

Table-bookshelf-coffeetable (Orange)			
Row 1			
Point	**R**	**G**	**B**
1	78	63	42
2	71	56	37
3	87	71	46
4	86	68	46
5	80	63	43
Row 2			
1	119	101	79
2	137	115	91
3	135	115	90
4	133	113	88
5	128	108	84
Row 3			
1	99	83	60
2	111	91	66
3	112	92	67
4	110	90	66
5	103	85	63
Row 4			
1	90	74	51
2	110	92	70
3	99	82	56
4	100	80	56
5	92	74	52
Row 5			
1	135	119	93
2	147	127	100
3	150	130	103
4	149	129	102
5	143	126	98
Row 6			
1	133	115	91
2	251	219	180
3	255	226	186
4	255	230	189
5	254	225	185
6	240	210	172
7	220	192	153
Row 7			
1	128	112	87
2	133	113	89
3	135	110	88
4	141	117	93
5	143	119	91
6	135	114	87
Row 8			
1	123	105	83
2	118	100	78
3	254	222	181
4	120	102	82
Row 9			
1	112	95	75
2	106	89	71
3	114	99	76
4	113	96	76
Row 10			
1	112	97	76
Mean	136	116	90

Seating units (Red)			
Row 1			
Point	**R**	**G**	**B**
1	217	156	151
Row 2			
1	127	92	88
2	199	139	138
3	224	160	158
4	179	118	115
5	189	130	126
6	118	86	75
Row 3			
1	124	91	84
2	124	91	84
3	124	91	84
4	163	115	111
5	118	85	78
6	122	89	82
7	114	84	73
8	113	83	72
Row 4			
1	122	89	84
2	122	89	84
3	122	89	84
4	103	73	71
5	113	83	75
6	112	82	74
7	111	81	71
8	109	79	69
Row 5			
1	118	87	82
2	117	86	81
3	118	87	82
4	113	83	75
5	108	79	73
6	105	76	68
7	103	74	66
Mean	131	94	88

Table C17. RGB values of Set 3 – Office 5.

SET 3 - OFFICE 5

Walls (Yellow)			
Row 1			
Point	**R**	**G**	**B**
1	141	138	97
2	125	121	86
3	78	74	49
4	78	74	49
5	84	80	53
6	88	83	54
7	88	83	54
8	86	80	54
9	78	72	48
10	75	71	46
11	121	117	82
12	133	129	91
13	139	137	96
Row 2			
1	158	155	112
2	155	150	108
3	98	93	64
4	96	92	63
5	105	102	71
6	109	106	75
7	108	105	74
8	107	104	71
9	103	98	68
10	93	89	60
11	153	146	104
12	155	151	106
13	148	145	102
Row 3			
1	161	158	113
2	161	157	112
3	113	107	75
4	114	109	77
5	107	102	72
6	165	158	112
7	160	156	111
8	145	142	101
Row 4			
1	155	154	110
2	155	150	108
3	117	112	80
4	115	112	77
5	111	108	75
6	167	156	111
7	157	153	108
8	140	138	97
Row 5			
1	148	146	105
2	145	141	103
3	117	112	82
4	152	143	102
5	148	145	102
6	136	134	95
Row 6			
1	140	138	99
2	136	134	96
3	111	108	77
4	129	129	91
5	130	128	90
Row 7			
1	134	132	94
2	109	108	77
3	124	124	88
Row 8			
1	119	119	83
Mean	124	121	85

Table-bookshelf-coffeetable (Red)			
Row 1			
Point	**R**	**G**	**B**
1	89	56	49
2	83	48	44
3	99	60	53
4	99	58	54
5	91	54	48
Row 2			
1	134	90	89
2	117	76	74
3	153	105	103
4	148	100	98
5	147	99	97
Row 3			
1	116	75	69
2	128	80	78
3	127	82	77
4	124	80	77
5	120	76	73
Row 4			
1	106	67	60
2	102	61	57
3	117	72	67
4	122	77	72
5	104	63	59
Row 5			
1	149	108	102
2	161	118	112
3	165	120	115
4	164	119	114
5	159	114	109
Row 6			
1	146	107	102
2	255	205	204
3	255	209	209
4	254	210	209
5	255	207	203
6	254	196	194
7	241	176	172
Row 7			
1	142	102	100
2	146	105	101
3	146	102	99
4	153	108	103
5	160	109	105
6	146	103	97
Row 8			
1	136	97	92
2	125	87	84
3	255	201	201
4	132	95	89
Row 9			
1	122	87	83
2	115	81	79
3	124	91	84
4	124	89	87
Row 10			
1	122	89	84
Mean	147	104	100

Seating units (Orange)			
Row 1			
Point	**R**	**G**	**B**
1	172	141	113
Row 2			
1	117	102	79
2	136	113	82
3	141	116	86
4	153	126	96
5	170	143	113
6	105	93	67
Row 3			
1	113	98	75
2	114	99	76
3	115	100	77
4	146	124	101
5	113	99	73
6	107	92	69
7	105	91	65
8	104	90	64
Row 4			
1	112	97	74
2	111	97	71
3	112	97	76
4	88	76	60
5	104	92	70
6	102	90	66
7	102	87	64
8	98	86	60
Row 5			
1	110	95	74
2	109	94	73
3	110	95	74
4	102	90	68
5	99	87	65
6	96	84	62
7	93	81	57
Mean	115	99	75

Table C18. RGB values of Set 3 – Office 6.

SET 3 - OFFICE 6

Walls (Orange)			
Row 1			
Point	**R**	**G**	**B**
1	156	132	106
2	141	116	94
3	86	69	53
4	87	70	54
5	92	73	56
6	93	72	55
7	95	74	57
8	92	71	54
9	87	68	53
10	84	67	51
11	135	110	88
12	148	124	100
13	156	132	106
Row 2			
1	176	149	120
2	171	144	115
3	109	88	69
4	110	89	70
5	120	99	78
6	122	102	78
7	121	100	79
8	122	100	79
9	115	93	72
10	105	84	65
11	171	141	113
12	171	144	115
13	163	137	110
Row 3			
1	177	152	122
2	177	150	121
3	124	102	81
4	127	102	80
5	119	97	76
6	181	150	121
7	179	150	120
8	162	136	109
Row 4			
1	171	145	118
2	170	144	117
3	128	106	85
4	127	105	82
5	124	102	81
6	183	149	121
7	172	145	116
8	157	133	107
Row 5			
1	163	139	113
2	159	135	111
3	128	106	85
4	159	131	107
5	163	139	111
6	152	128	102
Row 6			
1	153	131	107
2	150	128	104
3	125	104	85
4	145	125	101
5	142	122	97
Row 7			
1	148	126	102
2	127	111	88
3	138	118	94
Row 8			
1	134	114	90
Mean	138	115	92

Table-bookshelf-coffeetable (Red)			
Row 1			
Point	**R**	**G**	**B**
1	94	55	50
2	85	47	46
3	102	58	55
4	101	57	54
5	93	53	51
Row 2			
1	134	90	87
2	115	71	70
3	153	103	102
4	149	101	99
5	144	96	96
Row 3			
1	117	73	70
2	106	62	61
3	129	81	79
4	127	79	77
5	118	74	73
Row 4			
1	106	65	59
2	113	69	68
3	117	69	65
4	116	68	64
5	106	62	61
Row 5			
1	152	107	102
2	163	115	113
3	166	118	116
4	166	118	114
5	159	114	109
Row 6			
1	148	104	101
2	255	201	201
3	255	208	206
4	255	208	208
5	254	203	202
6	255	191	191
7	241	173	172
Row 7			
1	143	102	100
2	145	104	100
3	142	103	98
4	152	107	102
5	161	108	104
6	148	103	98
Row 8			
1	135	96	91
2	131	92	87
3	255	201	199
4	131	91	89
Row 9			
1	122	87	83
2	115	81	79
3	127	89	86
4	123	88	86
Row 10			
1	125	87	84
Mean	147	102	100

Seating units (Yellow)			
Row 1			
Point	**R**	**G**	**B**
1	157	145	103
Row 2			
1	108	103	71
2	213	211	154
3	125	122	77
4	135	132	87
5	151	149	101
6	101	95	63
Row 3			
1	106	101	71
2	106	101	71
3	106	101	71
4	134	128	92
5	100	95	66
6	99	94	64
7	99	92	63
8	97	91	59
Row 4			
1	104	99	69
2	104	99	69
3	104	99	69
4	84	82	59
5	98	93	64
6	96	91	62
7	95	90	61
8	94	89	60
Row 5			
1	100	96	67
2	100	96	67
3	101	98	67
4	96	92	63
5	93	87	61
6	90	86	57
7	87	83	54
Mean	109	104	72

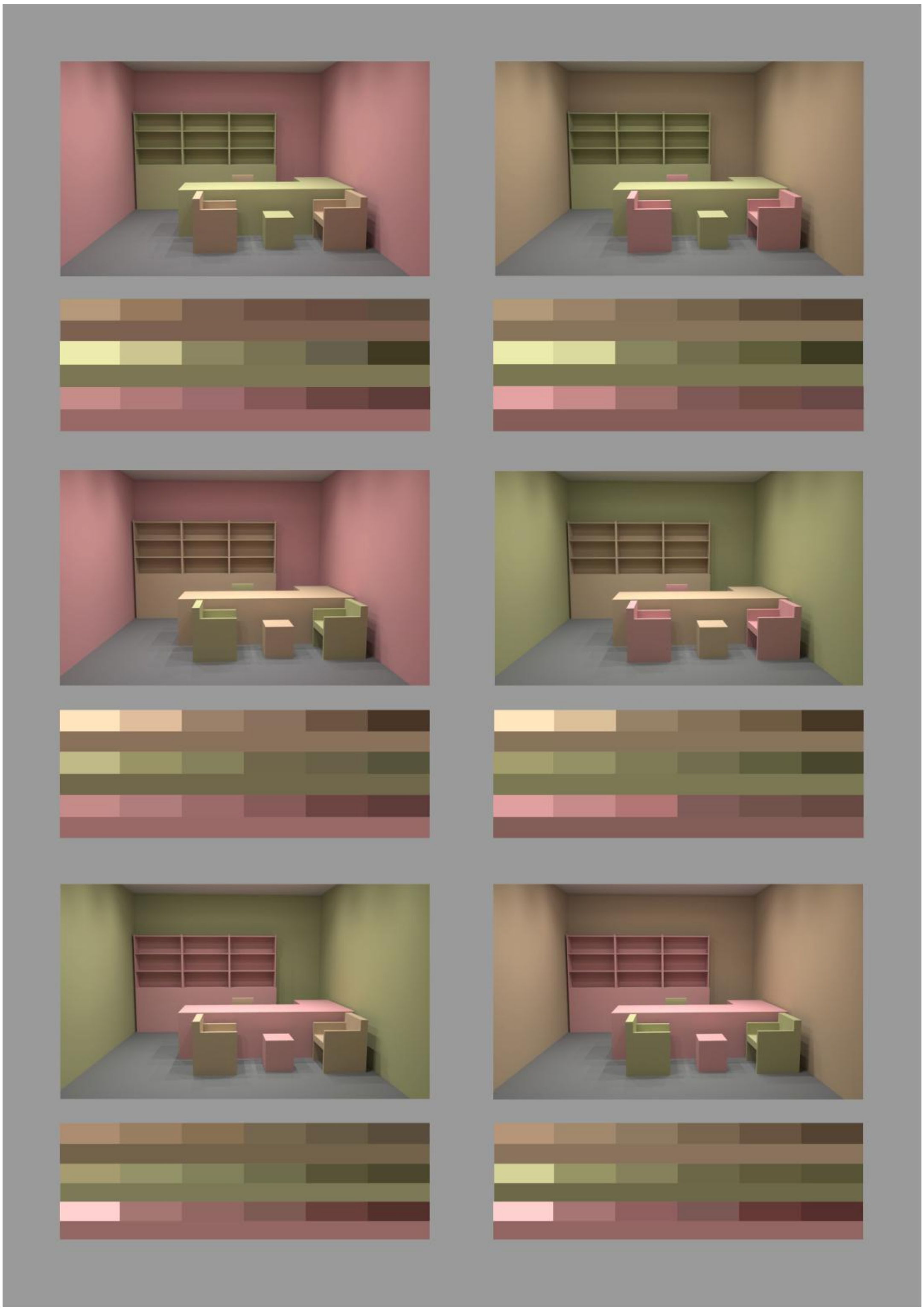

Figure C4. Colors of the 6 images related to the shadows and interreflections (Set 3).

Table C19. RGB values of Set 4 – Office 1.

SET 4 - OFFICE 1

Walls (Green)			
Row 1			
Point	**R**	**G**	**B**
1	105	150	109
2	92	132	97
3	51	79	57
4	54	82	57
5	56	86	60
6	59	89	63
7	58	88	64
8	56	88	64
9	50	78	56
10	49	77	54
11	87	127	93
12	96	141	102
13	103	148	105
Row 2			
1	116	168	120
2	115	164	119
3	66	99	72
4	67	102	70
5	76	113	80
6	78	115	81
7	78	115	81
8	77	114	80
9	73	108	76
10	64	97	68
11	112	158	119
12	115	164	119
13	109	156	110
Row 3			
1	118	170	122
2	121	170	123
3	80	114	87
4	79	119	85
5	72	109	76
6	120	171	130
7	120	169	124
8	107	154	110
Row 4			
1	116	166	117
2	115	164	119
3	84	119	89
4	79	119	84
5	79	116	82
6	123	171	133
7	116	163	119
8	105	150	107
Row 5			
1	110	158	110
2	107	152	109
3	85	122	91
4	106	151	112
5	110	155	114
6	98	143	100
Row 6			
1	103	148	105
2	103	145	107
3	82	117	85
4	98	141	98
5	95	138	95
Row 7			
1	100	143	100
2	84	118	83
3	92	134	94
Row 8			
1	89	130	90
Mean	90	131	94

Table-bookshelf-coffeetable (Blue)			
Row 1			
Point	**R**	**G**	**B**
1	56	65	96
2	53	57	95
3	62	69	111
4	64	69	111
5	58	63	105
Row 2			
1	99	102	147
2	88	91	136
3	114	117	68
4	111	114	165
5	109	110	164
Row 3			
1	78	86	125
2	75	77	125
3	87	93	141
4	88	91	142
5	83	87	134
Row 4			
1	68	76	113
2	67	71	116
3	75	83	129
4	76	80	128
5	69	73	118
Row 5			
1	113	121	158
2	125	129	174
3	129	133	180
4	127	131	178
5	123	127	172
Row 6			
1	112	117	155
2	217	222	254
3	225	229	255
4	229	231	254
5	221	225	254
6	210	213	254
7	190	194	255
Row 7			
1	109	115	151
2	112	115	156
3	118	111	162
4	118	118	168
5	119	122	177
6	112	114	162
Row 8			
1	105	107	146
2	100	102	143
3	219	222	255
4	101	103	142
Row 9			
1	94	97	132
2	89	91	129
3	95	102	130
4	95	97	135
Row 10			
1	92	99	128
Mean	112	116	155

Seating units (Purple)			
Row 1			
Point	**R**	**G**	**B**
1	174	129	188
Row 2			
1	119	93	120
2	190	136	194
3	151	101	154
4	152	97	154
5	184	128	189
6	101	87	102
Row 3			
1	115	91	117
2	115	91	117
3	115	91	117
4	152	113	160
5	106	87	107
6	104	85	105
7	102	85	103
8	98	84	99
Row 4			
1	114	90	116
2	114	90	116
3	114	90	116
4	100	74	103
5	104	85	105
6	102	83	103
7	99	82	98
8	95	81	96
Row 5			
1	110	86	110
2	111	87	111
3	112	88	112
4	106	84	105
5	98	81	100
6	95	78	96
7	89	75	90
Mean	118	91	120

Table C20. RGB values of Set 4 – Office 2.

SET 4 - OFFICE 2

Walls (Purple)

Point	R	G	B
Row 1			
1	168	121	175
2	149	105	156
3	93	61	100
4	95	61	98
5	101	66	108
6	105	68	111
7	103	67	111
8	101	65	109
9	91	59	100
10	89	57	94
11	143	101	151
12	159	112	166
13	167	118	173
Row 2			
1	188	132	193
2	182	131	190
3	117	80	124
4	116	77	121
5	129	87	133
6	131	89	137
7	131	89	135
8	130	88	134
9	123	84	131
10	110	73	117
11	177	127	188
12	181	130	189
13	174	123	179
Row 3			
1	191	136	194
2	190	136	196
3	131	93	142
4	134	91	144
5	125	85	135
6	190	135	202
7	189	135	195
8	173	122	178
Row 4			
1	184	130	188
2	181	130	187
3	133	95	142
4	137	93	142
5	132	90	140
6	189	136	208
7	183	132	191
8	168	120	172
Row 5			
1	176	125	181
2	171	123	175
3	137	98	145
4	169	119	180
5	172	125	179
6	163	115	167
Row 6			
1	166	118	168
2	163	116	168
3	131	94	137
4	158	112	159
5	157	109	159
Row 7			
1	159	113	160
2	131	93	132
3	151	105	152
Row 8			
1	145	102	147
Mean	147	103	154

Table-bookshelf-coffeetable (Blue)

Point	R	G	B
Row 1			
1	67	59	108
2	60	54	102
3	73	64	121
4	72	64	121
5	65	58	110
Row 2			
1	103	98	152
2	83	81	131
3	116	115	173
4	113	110	167
5	107	106	163
Row 3			
1	88	79	134
2	79	76	129
3	97	89	149
4	93	88	146
5	88	83	139
Row 4			
1	80	71	126
2	72	67	121
3	86	78	138
4	82	76	136
5	74	69	123
Row 5			
1	123	115	172
2	132	124	183
3	133	128	186
4	132	127	185
5	127	122	178
Row 6			
1	121	112	167
2	221	217	254
3	228	225	255
4	230	227	254
5	226	222	255
6	213	210	255
7	194	187	255
Row 7			
1	116	109	161
2	115	112	159
3	110	112	151
4	116	116	166
5	122	117	181
6	114	112	162
Row 8			
1	107	104	149
2	99	98	142
3	220	218	255
4	104	103	145
Row 9			
1	99	94	135
2	91	89	128
3	103	95	142
4	96	95	135
Row 10			
1	101	93	140
Mean	116	112	162

Seating units (Green)

Point	R	G	B
Row 1			
1	115	154	123
Row 2			
1	84	108	84
2	108	154	115
3	138	192	140
4	149	207	149
5	110	159	112
6	81	95	82
Row 3			
1	81	105	83
2	81	105	81
3	82	106	84
4	101	138	105
5	82	103	84
6	79	98	79
7	77	94	78
8	78	92	79
Row 4			
1	81	103	82
2	81	103	82
3	81	105	83
4	65	89	65
5	77	96	77
6	76	93	75
7	74	91	75
8	74	88	73
Row 5			
1	78	100	79
2	78	100	79
3	78	102	80
4	75	94	75
5	73	91	75
6	72	90	74
7	70	84	71
Mean	85	111	87

Table C21. RGB values of Set 4 – Office 3.

SET 4 - OFFICE 3

Walls (Green)			
Row 1			
Point	**R**	**G**	**B**
1	106	149	106
2	94	131	97
3	54	78	56
4	54	80	55
5	59	87	62
6	59	85	60
7	58	84	59
8	58	84	59
9	53	77	53
10	51	75	51
11	91	126	93
12	101	141	104
13	103	148	105
Row 2			
1	119	169	120
2	116	163	119
3	70	99	71
4	69	102	71
5	77	112	79
6	80	114	81
7	80	114	81
8	78	113	80
9	73	106	75
10	66	96	68
11	112	157	114
12	116	163	119
13	110	156	109
Row 3			
1	121	171	122
2	121	168	122
3	82	111	83
4	81	116	83
5	76	110	77
6	123	169	123
7	121	168	124
8	108	153	110
Row 4			
1	116	164	116
2	116	163	119
3	88	119	87
4	83	119	83
5	82	118	82
6	126	168	128
7	117	164	118
8	104	150	104
Row 5			
1	110	156	109
2	110	153	108
3	89	120	88
4	111	149	110
5	110	155	114
6	99	144	101
Row 6			
1	103	148	105
2	103	144	102
3	85	116	84
4	98	141	96
5	96	139	96
Row 7			
1	99	142	99
2	83	118	85
3	93	135	95
Row 8			
1	89	130	90
Mean	92	130	93

Table-bookshelf-coffeetable (Purple)			
Row 1			
Point	**R**	**G**	**B**
1	81	57	83
2	79	50	81
3	91	62	93
4	93	59	94
5	85	54	86
Row 2			
1	127	91	127
2	107	69	110
3	147	104	149
4	144	101	146
5	138	95	138
Row 3			
1	106	75	107
2	118	77	119
3	121	83	122
4	118	80	119
5	114	76	115
Row 4			
1	95	66	96
2	98	62	98
3	109	73	111
4	119	78	120
5	98	62	98
Row 5			
1	140	109	141
2	154	116	155
3	160	119	161
4	159	118	160
5	152	114	153
Row 6			
1	137	106	138
2	255	200	255
3	255	208	255
4	255	207	255
5	255	205	255
6	255	190	254
7	231	173	232
Row 7			
1	135	104	138
2	136	103	148
3	144	106	153
4	144	107	151
5	151	108	154
6	138	103	145
Row 8			
1	127	97	133
2	122	90	129
3	255	200	255
4	125	93	130
Row 9			
1	115	88	121
2	110	80	114
3	115	91	117
4	120	89	123
Row 10			
1	114	90	116
Mean	141	104	143

Seating units (Blue)			
Row 1			
Point	**R**	**G**	**B**
1	148	142	206
Row 2			
1	94	104	131
2	136	131	189
3	174	177	248
4	124	127	196
5	144	145	212
6	81	97	113
Row 3			
1	92	102	129
2	92	102	129
3	92	102	129
4	128	125	178
5	86	97	119
6	83	96	115
7	81	94	111
8	81	94	110
Row 4			
1	92	99	127
2	93	100	128
3	93	100	128
4	79	82	113
5	86	94	117
6	82	93	115
7	79	90	108
8	77	90	107
Row 5			
1	90	97	123
2	90	97	123
3	91	98	126
4	84	92	115
5	81	89	110
6	76	87	105
7	72	84	100
Mean	96	104	135

Table C22. RGB values of Set 4 – Office 4.

SET 4 - OFFICE 4											
Walls (Blue)				**Table-bookshelf-coffeetable (Purple)**				**Seating units (Green)**			
Row 1				**Row 1**				**Row 1**			
Point	**R**	**G**	**B**	**Point**	**R**	**G**	**B**	**Point**	**R**	**G**	**B**
1	134	133	193	**1**	84	53	97	**1**	123	168	129
2	120	117	174	**2**	79	47	86	**Row 2**			
3	74	68	112	**3**	94	57	108	**1**	78	110	87
4	73	70	115	**4**	93	55	102	**2**	118	170	124
5	79	76	123	**5**	88	51	95	**3**	136	193	140
6	77	73	123	**Row 2**				**4**	148	208	154
7	78	71	122	**1**	130	88	136	**5**	107	159	111
8	77	71	119	**2**	111	69	115	**6**	72	100	86
9	72	66	112	**3**	148	101	155	**Row 3**			
10	69	66	109	**4**	146	99	151	**1**	77	106	84
11	115	110	166	**5**	140	94	143	**2**	76	108	85
12	127	126	184	**Row 3**				**3**	76	108	85
13	133	132	192	**1**	110	72	121	**4**	101	136	104
Row 2				**2**	125	78	130	**5**	72	101	83
1	149	148	214	**3**	122	79	132	**6**	70	98	83
2	146	144	209	**4**	120	78	128	**7**	70	98	84
3	94	87	139	**5**	115	73	121	**8**	70	98	86
4	90	88	138	**Row 4**				**Row 4**			
5	100	97	150	**1**	99	62	113	**1**	76	105	83
6	103	100	153	**2**	96	59	103	**2**	76	105	83
7	102	102	156	**3**	109	69	122	**3**	77	106	84
8	102	99	154	**4**	109	66	119	**4**	62	87	65
9	97	94	147	**5**	98	59	106	**5**	71	100	82
10	89	85	136	**Row 5**				**6**	70	97	82
11	145	140	207	**1**	145	104	160	**7**	67	95	80
12	146	144	209	**2**	157	114	168	**8**	66	92	79
13	138	138	202	**3**	160	117	170	**Row 5**			
Row 3				**4**	160	115	170	**1**	75	104	82
1	152	151	219	**5**	155	112	165	**2**	73	102	80
2	152	149	216	**Row 6**				**3**	75	104	82
3	107	100	152	**1**	141	103	154	**4**	70	99	81
4	106	102	161	**2**	255	200	255	**5**	67	94	77
5	101	96	152	**3**	254	204	255	**6**	64	91	74
6	157	151	223	**4**	255	205	254	**7**	64	88	75
7	151	148	215	**5**	255	203	255				
8	137	135	198	**6**	255	190	254				
Row 4				**7**	234	170	246				
1	147	145	210	**Row 7**							
2	146	144	209	**1**	139	101	150				
3	110	105	159	**2**	139	103	149				
4	107	104	161	**3**	132	102	138				
5	104	101	156	**4**	144	106	153				
6	157	149	226	**5**	154	106	164				
7	148	145	212	**6**	138	100	149				
8	133	133	193	**Row 8**							
Row 5				**1**	129	96	139				
1	138	138	200	**2**	121	89	128				
2	136	135	195	**3**	255	198	255				
3	112	105	159	**4**	125	93	134				
4	138	132	196	**Row 9**							
5	138	138	198	**1**	116	86	124				
6	127	127	187	**2**	110	80	116				
Row 6				**3**	120	87	134				
1	132	132	192	**4**	118	86	123				
2	129	128	185	**Row 10**							
3	108	104	154	**1**	119	86	131				
4	123	124	178								
5	121	122	179								
Row 7											
1	126	127	181								
2	104	105	151								
3	117	118	174								
Row 8											
1	114	116	167								
Mean	117	114	172	**Mean**	142	103	150	**Mean**	81	162	90

Table C23. RGB values of Set 4 – Office 5.

SET 4 - OFFICE 5			
Walls (Blue)			
Row 1			
Point	**R**	**G**	**B**
1	134	135	191
2	116	119	170
3	69	73	108
4	69	71	110
5	74	77	118
6	73	76	117
7	76	79	120
8	71	75	113
9	66	70	107
10	65	68	103
11	111	115	163
12	123	126	179
13	132	133	190
Row 2			
1	149	151	212
2	144	146	205
3	87	92	132
4	88	91	136
5	97	99	148
6	99	103	150
7	99	103	150
8	99	101	149
9	93	97	144
10	84	87	130
11	138	143	201
12	144	146	207
13	138	140	201
Row 3			
1	152	153	217
2	149	153	214
3	100	105	145
4	101	105	153
5	98	100	148
6	150	155	211
7	149	151	212
8	135	137	198
Row 4			
1	146	148	209
2	144	146	205
3	104	109	149
4	104	106	155
5	102	106	153
6	148	154	210
7	146	147	211
8	134	134	194
Row 5			
1	138	140	199
2	135	137	196
3	106	111	151
4	130	133	184
5	140	140	202
6	128	129	186
Row 6			
1	133	134	191
2	129	130	184
3	102	105	146
4	126	125	182
5	122	123	180
Row 7			
1	126	127	181
2	113	113	163
3	118	117	174
Row 8			
1	114	116	167
Mean	115	117	168

Table-bookshelf-coffeetable (Green)			
Row 1			
Point	**R**	**G**	**B**
1	45	72	55
2	38	68	44
3	47	79	56
4	47	79	55
5	41	70	48
Row 2			
1	97	136	107
2	106	150	114
3	89	129	92
4	106	154	114
5	81	121	84
Row 3			
1	61	93	70
2	52	87	57
3	68	105	74
4	66	103	72
5	61	96	66
Row 4			
1	52	84	61
2	55	90	60
3	56	92	66
4	55	91	63
5	52	86	59
Row 5			
1	94	130	102
2	99	140	106
3	102	143	109
4	102	144	108
5	97	138	104
Row 6			
1	91	127	101
2	175	244	179
3	182	253	185
4	183	254	186
5	177	248	180
6	169	235	171
7	151	211	157
Row 7			
1	89	123	96
2	91	125	98
3	91	121	95
4	95	129	102
5	92	134	98
6	90	124	97
Row 8			
1	86	116	92
2	79	109	85
3	174	243	178
4	82	112	86
Row 9			
1	76	106	82
2	70	98	75
3	76	108	85
4	77	107	81
Row 10			
1	77	106	84
Mean	90	130	96

Seating units (Purple)			
Row 1			
Point	**R**	**G**	**B**
1	205	154	213
Row 2			
1	124	91	138
2	149	99	158
3	158	103	168
4	153	94	160
5	186	127	191
6	113	82	139
Row 3			
1	121	88	135
2	121	89	136
3	121	89	136
4	152	113	157
5	112	83	131
6	110	82	131
7	110	80	132
8	108	79	133
Row 4			
1	119	88	132
2	120	87	132
3	120	87	134
4	100	73	106
5	110	81	127
6	109	80	128
7	107	77	127
8	104	76	125
Row 5			
1	116	85	129
2	117	86	130
3	116	85	129
4	109	80	126
5	105	78	123
6	102	75	120
7	99	72	117
Mean	123	88	138

Table C24. RGB values of Set 4 – Office 6.

SET 4 - OFFICE 6											
Walls (Purple)				**Table-bookshelf-coffeetable (Green)**				**Seating units (Blue)**			
Row 1				**Row 1**				**Row 1**			
Point	**R**	**G**	**B**	**Point**	**R**	**G**	**B**	**Point**	**R**	**G**	**B**
1	168	120	168	**1**	52	71	52	**1**	140	143	196
2	148	107	149	**2**	40	64	42	**Row 2**			
3	91	62	92	**3**	53	77	55	**1**	106	98	149
4	93	64	95	**4**	50	76	51	**2**	182	183	248
5	99	68	102	**5**	46	70	48	**3**	198	197	255
6	98	67	101	**Row 2**				**4**	135	131	207
7	97	66	98	**1**	80	111	79	**5**	145	143	216
8	96	65	97	**2**	68	101	70	**6**	103	85	143
9	90	61	91	**3**	91	129	90	**Row 3**			
10	88	59	89	**4**	87	125	88	**1**	104	94	146
11	141	103	142	**5**	82	120	83	**2**	105	97	146
12	157	114	160	**Row 3**				**3**	105	97	146
13	167	119	169	**1**	66	92	65	**4**	124	125	173
Row 2				**2**	67	101	68	**5**	100	88	138
1	187	134	188	**3**	73	104	73	**6**	99	87	137
2	181	131	182	**4**	68	101	70	**7**	100	85	140
3	113	79	112	**5**	64	97	66	**8**	100	83	138
4	116	80	118	**Row 4**				**Row 4**			
5	127	89	130	**1**	59	83	61	**1**	103	94	141
6	129	91	132	**2**	52	83	52	**2**	103	93	143
7	130	92	133	**3**	66	97	66	**3**	103	95	144
8	128	90	131	**4**	72	107	74	**4**	76	75	109
9	121	85	123	**5**	66	100	67	**5**	99	87	135
10	112	76	112	**Row 5**				**6**	97	85	133
11	176	130	179	**1**	97	128	97	**7**	96	82	133
12	181	131	184	**2**	102	137	104	**8**	95	81	132
13	174	124	177	**3**	105	143	106	**Row 5**			
Row 3				**4**	104	142	105	**1**	100	92	139
1	190	137	193	**5**	100	136	100	**2**	99	91	138
2	189	136	190	**Row 6**				**3**	100	92	139
3	127	93	126	**1**	96	125	95	**4**	94	85	132
4	132	94	135	**2**	176	245	178	**5**	92	83	130
5	125	87	126	**3**	180	250	183	**6**	92	80	126
6	189	141	193	**4**	180	251	183	**7**	87	75	121
7	189	136	190	**5**	178	247	180				
8	174	124	175	**6**	169	230	170				
Row 4				**7**	155	210	153				
1	185	132	186	**Row 7**							
2	181	131	182	**1**	92	123	92				
3	130	96	131	**2**	93	123	95				
4	135	94	138	**3**	89	122	95				
5	130	92	131	**4**	96	129	100				
6	186	140	189	**5**	96	134	97				
7	183	132	188	**6**	91	124	95				
8	171	121	172	**Row 8**							
Row 5				**1**	86	114	89				
1	175	125	176	**2**	83	113	87				
2	172	124	172	**3**	176	243	176				
3	131	97	132	**4**	83	111	86				
4	169	126	171	**Row 9**							
5	175	124	180	**1**	79	104	82				
6	163	115	165	**2**	71	99	74				
Row 6				**3**	82	106	84				
1	167	119	169	**4**	77	105	80				
2	161	118	164	**Row 10**							
3	105	93	105	**1**	80	104	82				
4	158	111	163								
5	157	109	159								
Row 7											
1	160	114	160								
2	135	94	138								
3	152	106	153								
Row 8											
1	146	103	146								
Mean	146	104	148	**Mean**	91	127	93	**Mean**	109	100	152

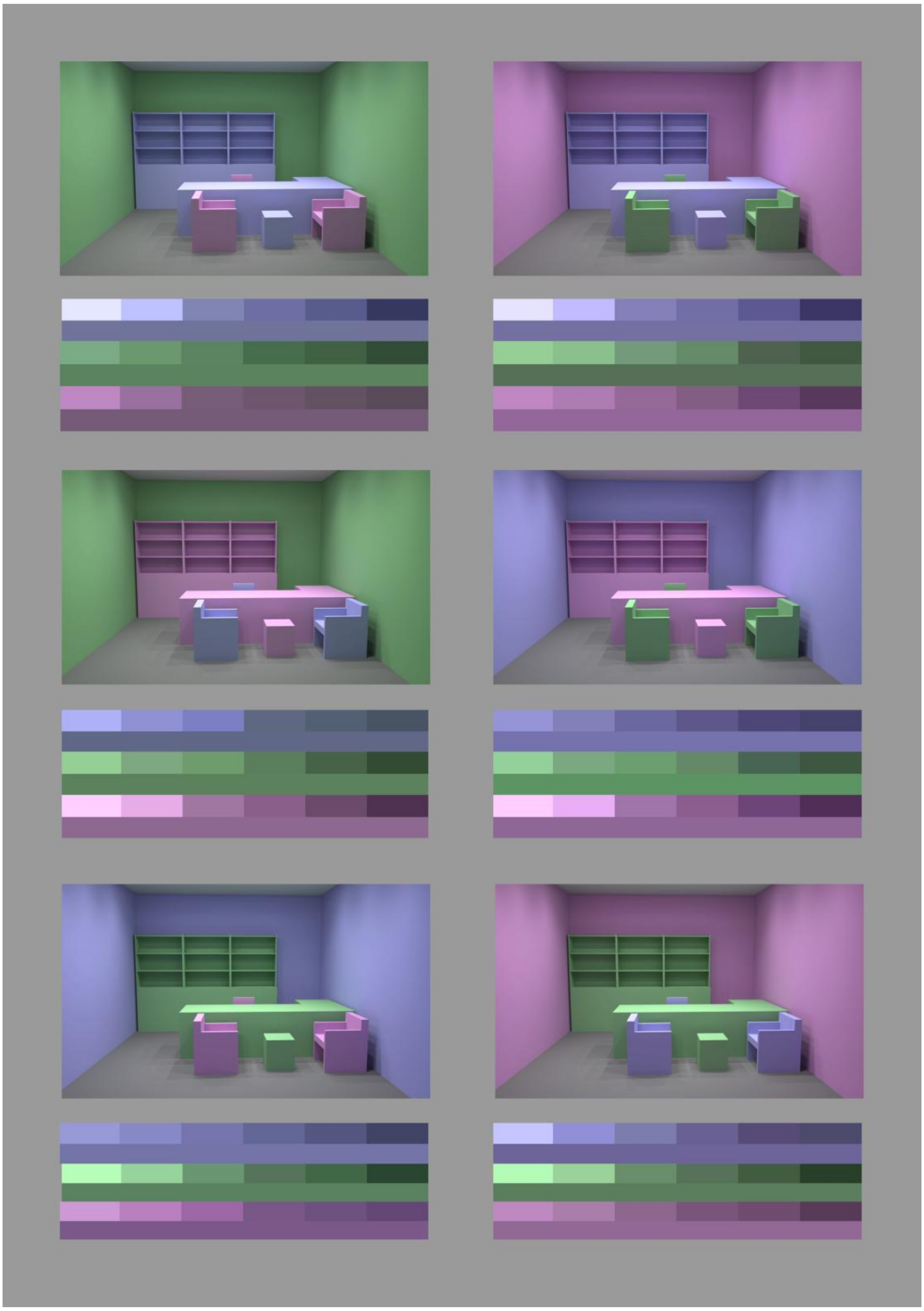

Figure C5. Colors of the 6 images related to the shadows and interreflections (Set 4).

APPENDIX D

QUESTIONNAIRE

APPENDIX D.1 Questionnaire (in English)

SET NO: **SUBJECT NO:** **Date:** **Hour:**

Personal Information

1. Gender: Female ☐ Male ☐

2. Age: ____________________

3. Department: ____________________

Eye and Color Vision Deficiency

1. Do you have any eye or vision deficiencies? If yes, please explain.

____

2. Do you use any correction equipment (contact lenses, eyeglasses, etc.) for any eye or vision deficiency you have? Are you wearing this equipment now?

____

3. Color Deficiency **(Ishihara's Test for Color Blindness)**

Yes ☐ No ☐

In this study, images of an office interior will be shown to you. The study consists of two phases.

PHASE 1: Please compare the colors used in the space by evaluating their harmony content and select the one that is more harmonious for you.

PHASE 2: Please select the appropriate word for the color combinations used in the space.

Pleasant	Unpleasant	Pleasant	Unpleasant
Analogous	Contrast	Analogous	Contrast
Balanced	Imbalanced	Balanced	Imbalanced
Like	Dislike	Like	Dislike
Light	Dark	Light	Dark
Spacious	Cramped	Spacious	Cramped
Relaxed	Tense	Relaxed	Tense
Warm	Cool	Warm	Cool
Proportional	Not proportional	Proportional	Not proportional
Natural	Unnatural	Natural	Unnatural
Positive association	Negative association	Positive association	Negative association
Positive effect	Negative effect	Positive effect	Negative effect
Well placed	Not well placed	Well placed	Not well placed
Pleasant	Unpleasant	Pleasant	Unpleasant
Analogous	Contrast	Analogous	Contrast
Balanced	Imbalanced	Balanced	Imbalanced
Like	Dislike	Like	Dislike
Light	Dark	Light	Dark
Spacious	Cramped	Spacious	Cramped
Relaxed	Tense	Relaxed	Tense
Warm	Cool	Warm	Cool
Proportional	Not proportional	Proportional	Not proportional
Natural	Unnatural	Natural	Unnatural
Positive association	Negative association	Positive association	Negative association
Positive effect	Negative effect	Positive effect	Negative effect
Well placed	Not well placed	Well placed	Not well placed
Pleasant	Unpleasant	Pleasant	Unpleasant
Analogous	Contrast	Analogous	Contrast
Balanced	Imbalanced	Balanced	Imbalanced
Like	Dislike	Like	Dislike
Light	Dark	Light	Dark
Spacious	Cramped	Spacious	Cramped
Relaxed	Tense	Relaxed	Tense
Warm	Cool	Warm	Cool
Proportional	Not proportional	Proportional	Not proportional
Natural	Unnatural	Natural	Unnatural
Positive association	Negative association	Positive association	Negative association
Positive effect	Negative effect	Positive effect	Negative effect
Well placed	Not well placed	Well placed	Not well placed

APPENDIX D.2 Questionnaire (in Turkish)

SET NO: **DENEK NO:** **Tarih:** **Saat:**

Kişisel Bilgiler

1. Cinsiyet: Kız ☐ Erkek ☐

2. Yaş: ______________________________

3. Bölüm: ______________________________

Göz ve Renk Görme Bozukluğu

1. Herhangi bir göz bozukluğunuz var mı? Varsa, lütfen açıklayınız.

____

2. Bu göz bozukluğunuzu giderecek herhangi bir araç (lens, gözlük, vb.) kullanıyor musunuz? Bu araç şu an üzerinizde mi?

____

3. Renk Görme Kusuru **(Ishihara Renk Körlüğü Testi)**

Var ☐ Yok ☐

Bu çalışmada size bir ofis mekanına ait görseller gösterilecektir. Çalışma iki aşamadan oluşmaktadır.

1.AŞAMA: Lütfen mekanda kullanılan renklerin uyumluluğunu değerlendirerek karşılaştırınız ve size daha uyumlu geleni seçiniz.

2.AŞAMA: Lütfen mekanda kullanılan renk kombinasyonları için size uygun gelen kelimeyi seçiniz.

Hoş	Hoş değil	Hoş	Hoş değil
Benzer	Zıt	Benzer	Zıt
Dengeli	Dengeli değil	Dengeli	Dengeli değil
Beğendim	Beğenmedim	Beğendim	Beğenmedim
Açık	Koyu	Açık	Koyu
Ferah	Boğucu	Ferah	Boğucu
Sakinleştirici	Gerginleştirici	Sakinleştirici	Gerginleştirici
Sıcak	Soğuk	Sıcak	Soğuk
Orantılı	Orantısız	Orantılı	Orantısız
Doğal	Yapay	Doğal	Yapay
Olumlu çağrışım	Olumsuz çağrışım	Olumlu çağrışım	Olumsuz çağrışım
Olumlu etki	Olumsuz etki	Olumlu etki	Olumsuz etki
İyi yerleştirilmiş	İyi yerleştirilmemiş	İyi yerleştirilmiş	İyi yerleştirilmemiş
Hoş	Hoş değil	Hoş	Hoş değil
Benzer	Zıt	Benzer	Zıt
Dengeli	Dengeli değil	Dengeli	Dengeli değil
Beğendim	Beğenmedim	Beğendim	Beğenmedim
Açık	Koyu	Açık	Koyu
Ferah	Boğucu	Ferah	Boğucu
Sakinleştirici	Gerginleştirici	Sakinleştirici	Gerginleştirici
Sıcak	Soğuk	Sıcak	Soğuk
Orantılı	Orantısız	Orantılı	Orantısız
Doğal	Yapay	Doğal	Yapay
Olumlu çağrışım	Olumsuz çağrışım	Olumlu çağrışım	Olumsuz çağrışım
Olumlu etki	Olumsuz etki	Olumlu etki	Olumsuz etki
İyi yerleştirilmiş	İyi yerleştirilmemiş	İyi yerleştirilmiş	İyi yerleştirilmemiş
Hoş	Hoş değil	Hoş	Hoş değil
Benzer	Zıt	Benzer	Zıt
Dengeli	Dengeli değil	Dengeli	Dengeli değil
Beğendim	Beğenmedim	Beğendim	Beğenmedim
Açık	Koyu	Açık	Koyu
Ferah	Boğucu	Ferah	Boğucu
Sakinleştirici	Gerginleştirici	Sakinleştirici	Gerginleştirici
Sıcak	Soğuk	Sıcak	Soğuk
Orantılı	Orantısız	Orantılı	Orantısız
Doğal	Yapay	Doğal	Yapay
Olumlu çağrışım	Olumsuz çağrışım	Olumlu çağrışım	Olumsuz çağrışım
Olumlu etki	Olumsuz etki	Olumlu etki	Olumsuz etki
İyi yerleştirilmiş	İyi yerleştirilmemiş	İyi yerleştirilmiş	İyi yerleştirilmemiş

APPENDIX E

DESCRIPTION OF THE WORDS

Orantılı / Orantısız: Orantı “bir şeyi oluşturan parçaların kendi aralarında ve parçalarla bütün arasında bulunan uygunluk, oran” (TDK Büyük Türkçe Sözlük, t.y.) anlamına gelmektedir. Parçaların kendi aralarında ve parçalarla bütün arasındaki bu ilişki miktar veya boyut açısından olabilir. Bu çalışmada, kullanılan renklerin orantılı olup olmadıkları uygulandıkları yüzeylerin boyutlarıyla ilişkili olarak değerlendirilmektedir.

Beğendim / Beğenmedim: Beğenmek bir şeyi “iyi veya güzel bulmak” (TDK Büyük Türkçe Sözlük, t.y.) anlamına gelmektedir.

Olumlu / Olumsuz çağrışım: Çağrışım, zihinde, farklı şeyler (düşünce, kavram, vb.) arasında kurulan bağlantıdır. Bu çalışmada, kullanılan renk kombinasyonlarının neden olduğu duygusal çağrışımlar göz önünde bulundurulmaktadır.

Doğal / Yapay: Doğal “doğanın kendi düzeni içinde oluşan, yapay olarak hazırlanmamış olan” (TDK Büyük Türkçe Sözlük, t.y.) anlamına gelmektedir. Yapay ise insanlar tarafından yapılmış anlamındadır.

Sıcak / Soğuk: Sıcak renkler insana canlılık ve sıcaklık hissi veren renklerdir. Soğuk renkler ise insana sakinlik ve serinlik hissi veren renklerdir.

Sakinleştirici / Gerginleştirici: Sakin “durgun, dingin” (TDK Büyük Türkçe Sözlük, t.y.), rahat olmak, gergin ise “huzursuz” (TDK Büyük Türkçe Sözlük, t.y.), endişeli ve rahatsız olmak anlamına gelmektedir.

Ferah / Boğucu: Ferah “bol, geniş, havadar, aydınlık” (TDK Büyük Türkçe Sözlük, t.y.) anlamına, boğucu ise dar ve sıkıntılı anlamına gelmektedir.

Olumlu / Olumsuz etki: Bu kelime çifti, uygulanan renk kombinasyonlarının bıraktığı etkiyi değerlendirmek içindir.

Hoş / Hoş değil: Hoş “beğenilen” (TDK Büyük Türkçe Sözlük, t.y.), çekici bulunan anlamına gelmektedir.

İyi yerleştirilmiş / İyi yerleştirilmemiş: Bu kelime çifti, renklerin düzenlenişlerini (ofis mekanı içerisinde doğru yerde konumlanıp konumlanmadıklarını) değerlendirmek içindir.

Benzer / Zıt: Zıt, “nitelikleri ve durumları birbirine büsbütün aykırı olan” (TDK Büyük Türkçe Sözlük, t.y.), benzer ise “nitelik, görünüş ve yapı bakımından bir başkasına benzeyen veya ona eş olan” (TDK Büyük Türkçe Sözlük, t.y.) anlamına gelmektedir.

Açık / Koyu: Açık “rengi koyu olmayan” (TDK Büyük Türkçe Sözlük, t.y.), koyu ise “rengi açık olmayan” (TDK Büyük Türkçe Sözlük, t.y.) anlamına gelmektedir.

Dengeli / Dengeli değil: Denge, zıt güçlerin ya da etkilerin eşit ya da doğru miktarlarda olması durumudur.

APPENDIX F

GLOSSARY

Achromatic colors: Neutral colors possessing no hue.

Adaptation point: The point in w space corresponding to the state of adaptation of the eye.

Additive mixture: A method of obtaining colors by mixing light primaries of which are red, green and blue.

Afterimage: An image appearing after exposure to the original image has ended.

Analogous colors: Colors which are adjacent on a color wheel.

Area: Attribute of color harmony that refers to the scale of the color areas.

Association: Attribute of color harmony that links color harmony with the affective responses based on traditional color association and symbolism.

Attitude: Attribute of color harmony that refers to the innate personality of a color or a color combination that evokes a feeling of an individual.

Balance: Equilibrium in areas, energies and light degrees of colors.

Balance point: The point corresponding to the color obtained by disk mixture of the component colors of a combination.

Brightness: An attribute of visual perception in which a stimulus appears to emit more or less light. It is one of the parameters of color appearance.

Chroma: An attribute of visual perception in which the degree of a chromatic color differs from the achromatic color of the same lightness. It is the measure of chromatic intensity and one of the parameters of color appearance.

Chromatic colors: Colors possessing hue.

Color atlas: Systematic collection of color chips or color prints consisting of a large range of possible colors of a color system

Color order system: System that systematically arranges color experiences.

Color rendering index (CRI): A rating scale assessing the ability of a lamp to render the colors of objects based on the color shift occurred under that lamp compared to a reference standard lamp.

Color solid: Occupied color space with the possible object color stimuli.

Color space: Specific organization of colors in a three-dimensional coordinate system.

Color temperature: The temperature at which a black-body radiates light of the color same with the light source. The unit of color temperature is Kelvin (K) that is the unit of absolute temperature. Lower color temperatures indicate warmer colors whereas higher color temperatures indicate cooler colors.

Color wheel: Organization of hues around a circle.

Coloroid: Color system developed by Antal Nemcsics that has been registered as Hungarian Standard.

Coloroid hue: Hue dimension of color denoted by A in the Coloroid Color System

Coloroid luminosity: Luminosity dimension of color denoted by V in the Coloroid Color System.

Coloroid saturation: Saturation dimension of color denoted by T in the Coloroid Color System.

Complementary colors: Colors that are directly opposite of each other on the color wheel.

Configuration: Overall design of the colors influencing the interrelationship of colors.

Cool colors: Colors which are near the violet end of the spectrum: green, blue and violet.

Dyes: Natural or synthetic colorants which are soluble in the substrate.

Hue: An attribute of color appearance which gives a chromatic color its name such as red or yellow and refers to a pure color.

Intensity: Refers to hue and light intensity. Hue intensity is purity of a color and light intensity is light-reflecting quality of a color.

Interaction: A physiological phenomenon which includes the effects related to adaptation of the eyes such as afterimage and simultaneous contrast.

Lightness: An attribute of visual perception in which a stimulus appears to emit more or less light compared to a perfect white. It can be also called as relative brightness.

Monochromatic colors: Colors containing only one hue.

Opponent color theory: The term for Hering's theory opposing three pairs (yellow-blue, red-green, white-black) based on the cells with opponent character in the retina.

Order: Color interval and refers to the color combinations selected according to an orderly plan from a color system such as triad, tetrad or complementary.

Pigments: Natural or synthetic colorants which are insoluble in the substrate.

Pointillism: A style of painting, in which small dots of different colors are placed side by side to be perceived additively blended when viewed from a distance.

Primary colors: Sets of simplest colors that are combined to obtain a range of colors.

Saturation: An attribute of visual perception according to which a color appears to be more or less chromatic judged in proportion to its brightness.

Scalar moment: The multiplication of the area of a color patch and the distance between the adaptation point and the color point in the metric space.

Secondary colors: Colors obtained from the mixture of two primary colors.

Shade: Dark values of a color obtained by adding black.

Similarity: A shared characteristic of colors perceived by the viewer that may be caused by predominant hue, value or chroma.

Simultaneous contrast: A change in apparent brightness, hue and/or chroma of a color caused by an adjacent or surrounding color.

Spectrophotometer: The instrument for measuring the spectral reflectance of a material.

Subtractive mixture: A method of obtaining colors by mixing dyes, inks and pigments.

Tertiary colors: Colors obtained from the mixture of three primary colors.

Tint: Light values of a color obtained by adding white.

Tone: Reduction in saturation of colors between tints and shades.

Triad colors: Three equally spaced colors on a color circle forming an equilateral triangle or an isosceles triangle.

Uniform color space: A color space in which the geometric distances between points representing color perceptions are equal to their mean perceptual distances.

Value: See lightness.

Warm colors: Colors which are near the red end of the spectrum: red, orange and yellow.