EFFECTS OF COLOR TEMPERATURE ON PROJECTED FRACTAL LIGHT PATTERNS: VISUAL INTEREST AND EMOTIONAL RESPONSE

A Master's Thesis

by

BUSE SEZER

Department of
Interior Architecture and Environmental Design
İhsan Doğramacı Bilkent University
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BUSE SEZER
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To my parents,

Neziha & Selçuk

EFFECTS OF COLOR TEMPERATURE ON PROJECTED FRACTAL LIGHT PATTERNS: VISUAL INTEREST AND EMOTIONAL RESPONSE

The Graduate School of Economics and Social Sciences
of
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ABSTRACT

EFFECTS OF COLOR TEMPERATURE ON PROJECTED
FRACTAL LIGHT PATTERNS:
VISUAL INTEREST AND EMOTIONAL RESPONSE

Sezer, Buse
MFA, Department of Interior Architecture and Environmental Design
Supervisor: Assoc. Prof. Dr. Nilgün Olguntürk

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The aim of the present study is to examine the effects of color temperature of projected fractal patterns on visual interest and emotional response in interior spaces. The experiment consisted of two phases, which were carried out with two independent participant groups. In the first phase, the effects of five different complexity levels of two dimensional fractal patterns (D = 1.1, D = 1.3, D = 1.5, D = 1.7, D = 1.9) on visual interest and emotional response were examined. In the second phase, the effects of three different natural light color temperatures (noon sky – 4000K, overcast sky – 6500K, clear sky – 12000K) of three dimensional projected fractal patterns on visual interest and emotional response in interior spaces were evaluated. The participants consisted of sixty undergraduate and graduate students enrolled in İhsan Doğramacı Bilkent University. Results demonstrated that, in the first phase, the most visually interesting fractal pattern was high-complexity D = 1.7. Moreover, the results indicated that the complexity level of fractal patterns had no

significant influence on participants' *pleasure* state, whereas complexity level had positive significant effects on participants' *arousal* state. In the second phase, results indicated that the most visually interesting projected fractal pattern was high-complexity D = 1.7 for all color temperatures (4000K, 6500K, & 12000K). Therefore, color temperature had no significant influence on the choice of fractal pattern complexity level in terms of visual interest. Regarding emotional response, the findings also demonstrated that color temperature had no significant influence on *pleasure* and *arousal* state. Consequently, the most influential outcome of the study was that, compared with color temperature, complexity level is a more significant factor related to visual interest and emotional response. The findings of the present study guides designers on the implementation of natural light patterns to for visual interesting interior spaces.

Keywords: Color Temperature, Emotional Response, Fractal Patterns, Natural Light, Visual Interest

ÖZET

IŞIĞIN RENK SICAKLIĞININ YANSITILAN FRAKTAL MODELLER ÜZERİNDEKİ ETKİSİ: GÖRSEL İLGİ VE DUYGUSAL TEPKİ

Sezer, Buse
İç Mimarlık ve Çevre Tasarımı Yüksek Lisans Programı
Tez Danışmanı: Doç. Dr. Nilgün Olguntürk

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Bu çalışmanın amacı, yansıtılan fraktal modellerin renk sıcaklığının iç mekanlarda görsel ilgi ve duygu eğilimi üzerindeki etkilerini incelemektedir. İki aşamadan oluşan deney, iki bağımsız katılımcı grubu ile yürütülmüştür. İlk aşamada, beş farklı iki boyutlu fraktal model karmaşıklığının (D = 1.1, D = 1.3, D = 1.5, D = 1.7, D = 1.9) görsel ilgi ve duygu eğilimi üzerindeki etkileri incelenirken, ikinci aşamada, üç farklı doğal ışık renk sıcaklığıyla (öğlen gökyüzü – 4000K, bulutlu gökyüzü – 6500K, açık gökyüzü – 12000K) yansıtılan üç boyutlu fraktal modellerin iç mekanlarda görsel ilgi ve duygu eğilimi üzerindeki etkilerini incelemektedir. Katılımcılar, İhsan Doğramacı Bilkent Üniversitesi'ne kayıtlı altmış lisans ve lisansüstü öğrenciden oluşmaktadır. Görsel açıdan en ilginç modelin yüksek karmaşıklık düzeyi D = 1.7 olduğu bulunmuştur. Ayrıca, fraktal modellerin karmaşıklık düzeyinin, katılımcıların memnuniyet durumu üzerinde önemli bir etkisi olmadığı, fakat uyarılma durumu üzerinde önemli olumlu etkileri olduğu bulunmuştur. Çalışmanın ikinci aşamasının sonuçlarına göre, tüm doğal ışık renk sıcaklıkları (4000K, 6500K, 12000K) için

görsel açıdan en ilginç bulunan modelin yüksek karmaşıklık düzeyi D = 1.7 olduğu bulunmuştur. Bu nedenle, ışık renk sıcaklığının görsel ilgi açısından fraktal model karmaşıklık düzeyi üzerinde bir etkisi olmamıştır. Ayrıca, ışık renk sıcaklığının memnuniyet ve uyarılma durumu üzerinde önemli bir etkisinin olmadığı görülmüştür. Sonuç olarak, bu çalışmadan çıkarılacak en önemli netice, karmaşıklık düzeyinin ışık renk sıcaklığına kıyasla görsel ilgi ve duygusal tepki üzerinde daha önemli bir faktör olduğudur. Bu çalışmadaki bulgular tasarımcılara görsel açıdan ilginç iç mekanlar tasarlamak için doğal ışık modellerinin uygulanması konusunda rehberlik etmektedir.

Anahtar Kelimeler: Doğal Işık, Duygusal Tepki, Fraktal Modeller, Görsel İlgi, Renk Sıcaklığı

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LIST OF ABBREVIATIONS

ART	Attention Restoration Theory
CT	Color Temperature
CCT	Correlated Color Temperature
CRI	Color Rendering Index
M-R	Mehrabian and Russell
SRT	Stress Recovery Theory

CHAPTER I

INTRODUCTION

Today, nature is more significant than before in providing a healthy life to people. The rapid industrial and urban development pushed people away from natural scenes, thus making them stranger to nature (Gifford, 2007). This is why people do not even like imagining a developed world within natural settings. According to Gifford (2007), people may benefit from the nature in various ways. Ulrich (1981) defined two main benefits of nature, which are physiological and psychological that were later studied by many researchers. A previous study demonstrated that natural environments have higher restorative potential and more positive evaluation of recovery than urban environments (Staats, Kieviet, & Hartig, 2003). Another study demonstrated that walking in nature made people feel more positive compared with an urban environment (Hartig et al., 2003). Also, Hartig et al. (2003) demonstrated that sitting in a room with tree views is beneficial for people's diastolic blood pressure compared with sitting in a viewless room. Moreover, many hypotheses and theories were formulated with the aim to explain people's connection with nature. One of these hypotheses was formulated by Kellert (2005). Kellert (2005) suggested that people take advantage of the naturalistic and esthetical characteristics of nature.

The naturalistic characteristics refer to the diversity and variety perceived in nature, and the esthetical characteristics refer to the nature's beauty and attraction (Kellert, 2005). This hypothesis was based on Edward Wilson's biophilia hypothesis (Abboushi et al., 2019) where he offers deep understanding about people and their lives and the natural process as a biological need necessary for human developmental process, essentially in physical and mental growth (Kellert & Wilson, 1993). At this point, researchers started investigating the characteristics of natural scenes and mechanisms of visual perception, which provide positive responses to people (Abboushi et al., 2019). Those responses were related to the fractal characteristics of nature, such as clouds, trees, mountains, and rivers (Hagerhall et al., 2015; Joye & Berg, 2011; Purcell et al., 2001).

Fractal forms, which consist of similar repetitive patterns in finer extensions, are known as ''self-similarity'' of fractal patterns (Mandelbrot, 1982). Moreover, they are naturally complex that they create visual stimuli (Abboushi et al., 2019). Complexity level varies between different fractal forms in accordance with their repetitive patterns. Nature consists of extensive mid-complexity fractal patterns, which enable people easy adaptation to the environment with regard to visual system (Taylor & Spehar, 2016; Taylor et al., 2018). In the literature, this adaptation is described as the fractal fluency theory. Therefore, previous studies indicated that, for statistical fractals found in nature, mid-complexity fractal patterns D = 1.3 – 1.5 were preferred the most (Abboushi et al., 2019; Spehar et al., 2003; Spehar & Taylor, 2013; Taylor et al., 2005). Figure 1 presents one of the examples of mid-complexity fractal patterns D = 1.3 – D = 1.5.

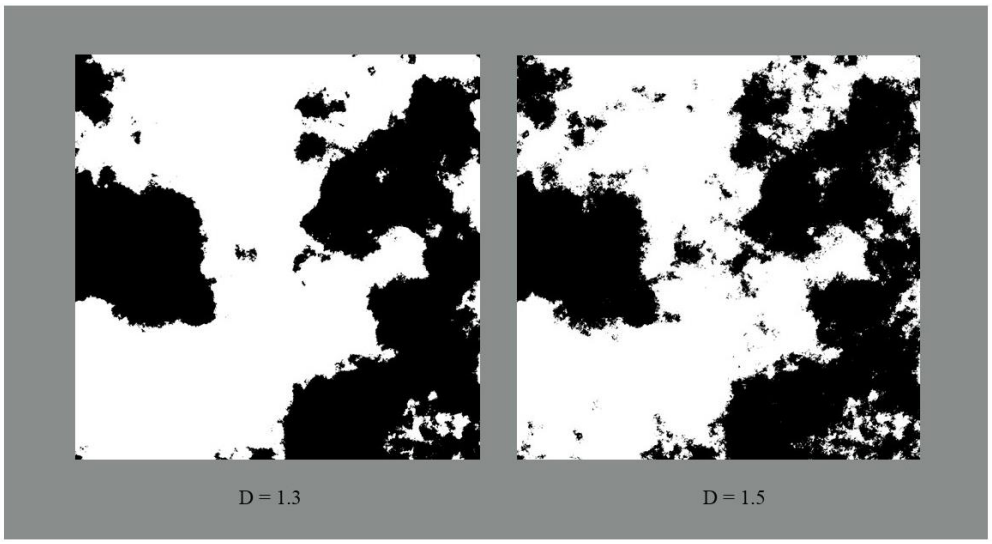

Figure 1. Examples of mid-complexity fractal patterns D = 1.1- 1.5 (fractal patterns adapted with the permission of Prof. Richard Taylor)

Previous studies also demonstrated that fractal patterns provoked stress recovery benefits (Taylor, 2006). Moreover, enhanced pattern identification (Taylor et al., 2017a,b; Taylor et al., 2018), increased navigation skills (Juliani et al., 2016), and aesthetic admiration (Aks & Sprott, 1996; Spehar et al., 2003) were positive outcomes of aesthetic attractiveness of fractal patterns (Taylor, 2002). Therefore, it is significant to analyze the implementation of fractal patterns in interior spaces where people spend the majority of their times.

Various environmental factors influence people's response to the simulated fractal patterns in interior spaces. Therefore, the implemented presentation methods of fractal patterns and research experimental settings are important. Previous studies, in environmental psychology, demonstrated four important variables influencing the effects of visual interest on projected fractal patterns in interior spaces, which were pattern type, pattern complexity, spatial variables, and light projections (Abboushi et al., 2019). However, most studies in the literature investigated the effects of fractal

patterns on perceptual responses by utilizing two-dimensional visualizations on computer screens (Hagerhall et al., 2008; Spehar et al., 2003; Spehar & Taylor, 2013; Taylor et al., 2011). Abboushi et al. (2019) examined the influence of projected fractal patterns on visual interest and preference. However, the study did not investigate the effects of color temperature (CT) of projected fractal patterns on visual interest and emotional response. Thus, based on the gaps in the previous literature, the present study examined the effects of projected fractal patterns with different CTs of natural light on visual interest and emotional response in interior spaces.

1.1 Aim of the Study

Despite the large amount of studies on physiological and psychological responses to nature and fractal patterns prevalent in natural scenes, there are no previous studies focusing on projected three dimensional fractal patterns with different CTs and complexity in interior spaces. Therefore, this study aimed at transferring the aesthetic values of nature into interior spaces in order to create visually interesting places. By bringing nature's effects, such as different CTs of natural light and fractal patterns, into interior spaces, this study examined people's visual interest and emotional response.

1.2 Structure of the Thesis

The present thesis is structured as follows: The first chapter presents the introduction, where the research topic, aims, and structure of the thesis are introduced. The second chapter investigates the influence of nature's effects on people by relating to biophilia hypothesis and fractal patterns prevalent in nature. Also, it presents a brief literature on the effects of fractal patterns on people's visual preference, visual interest, and aesthetic response.

The third chapter examines natural light's physiological and psychological effects on people in interior spaces by introducing previous research on natural light. Moreover, it covers the differences between color temperature and correlated color temperature. Also, the perception of interior spaces and its relation with natural light patterns are investigated. Besides, it covers a brief part on emotional response in interior spaces based on the *pleasure* and *arousal* dimensions of the Mehrabian and Russell (M-R) (1974) model.

The fourth chapter introduces the methodology of the study. Based on the previous literature, the aim, research question, hypotheses, sample group, and procedure of the experiment are described. The fifth chapter consists of the results, where the effects of fractal patterns complexity on visual interest and emotional response are investigated. In addition, the effects of projected fractal patterns created by different natural light CTs on people's visual interest and emotional response are examined in interior spaces.

The sixth chapter discusses the findings of the study by relating to the relevant previous literature. The final chapter concludes the present study and presents its contribution and limitations. Also, it discusses suggestions for future studies. This chapter is followed by the references and appendices covering sample items of the questionnaires used in phases 1 and 2 of the experiment. In adding, the appendices include statistical tables of the data results.

CHAPTER II

UNDERSTANDING FRACTAL PATTERNS

This chapter presents a brief literature on the effects of nature on people by emphasizing the impact of fractal patterns. Also, it describes more about properties of fractal patterns and complexity referred by D, which is the most important dimension related to fractal patterns. Furthermore, it investigates the effects of fractal patterns on visual interest and preference.

2.1 Attachment to Nature

The physiological and psychological benefits of nature have been examined by many researchers who suggested various hypotheses and theories about this interrelationship (Abboushi et al., 2019; Hagerhall et al., 2015). Most research in the literature was found in the field of environmental psychology. Environmental psychologists tried to identify the reason behind people's great attachment to nature. Kaplan (1995) and Ulrich (1993) stated that environmental psychologists linked people's attachment to nature to the early human evolution. Elements found in nature

allowed people to experience feelings of relaxation and restoration making them develop strong attachment to nature (Berg et al., 2003; Hartig & Staats, 2005; Purcell et al., 2001).

Gifford (2007) stated that many researchers generated a list, including 40 to 50 items, to determine the reasons behind people's attachment to nature. Furthermore, Gifford (2007) divided these items under ten categories; *cognitive freedom, sense of escape, experience nature, growth, challenge, guidance, social dimension, health, self-control, and ecosystem connectedness*. However, two of these categories, *challenge* and *guidance*, were out of the context of the present study, therefore, they were not explained in detail. *Cognitive freedom* provides feelings of freedom to whatever people wish in nature; *sense of escape* provides a chance to being excepted from society rules and everyday life; *experience nature* enables people to meet their needs for being in nature; *growth* provides people a chance to improve their self-awareness through natural environments; *social dimension* provides a feeling different from social life in the city; *health* improves people both mentally and physically by providing fresh air and exercise that nature offers; *self-control* is when people feel a therapeutic experience; and *ecosystem connectedness* provides a feeling that we are part of the nature (Gifford, 2007).

Natural environments are found more restorative than urban environments and have a great positive effect on the attention capacity recovery time (Abboushi et al., 2019). Researchers stated that people who live close to nature have healthier lives, less physical illness, and a better attention capacity recovery. Thus, they experienced and fulfilled needs that may not be easily acquired in urban environments (Gifford,

2007). Moreover, Ulrich (1981) investigated the psycho physiological influence of scene types, such as nature vs. urban. Results found that natural environments had a more positive influence. Also, Ulrich (1984) found that viewing natural scenes decreased hospitalization recovery time and demanded fewer pain medications. Another study demonstrated that walking in a natural environment had a higher positive effect when compared to walking in urban environments (Hartig et al., 2003). In addition, the latter study indicated that natural views in a room provided regulations in diastolic blood pressure. On the contrary, sitting in a viewless room caused a lesser decrease in diastolic blood pressure.

Gifford (2007) stated that living in nature or being enclosed by nature has a restorative effect on people. Research on restorative effect is generally based on the Attention Restoration Theory (ART) (Kaplan, 1995). The theory indicated that natural environments have a variety of characteristics necessary for restorative experiences. Kaplan (1995) answered the question of how nature relates to restoration. An approach was that the natural settings included four necessary restorative components that are *being away*, *fascination*, *extent*, and *compatibility.* These components were defined by Kaplan (1995) as follows. Natural settings, such as seaside, mountains, lakes, streams, forests, and meadows are often the preferred destinations for *being away*. Also, nature is enriched with *fascinating* objects, mostly soft fascinations, such as clouds, sunsets, snow patterns. These fascinations provide an opportunity to feel peaceful. Natural settings with trails and paths also create a sense of *extent*, which promotes the feeling of being in a larger world. Besides, natural environments are defined as high in *compatibility*. It makes people feel as if they have special resonance with the natural settings. Considering all of the previous

components, which are particularly met by the natural settings, nature plays a significant role on restorative experiences.

Apart from this, Kellert (2005) claimed that nature's variability and aesthetic values allow people to attach meanings or acquire benefits from nature. This concept is inspired from the biophilia hypothesis (Abboushi et al., 2019). This hypothesis implied that human beings' connection with nature is essential for their well-being (Kellert & Wilson, 1993). Inspired by the ART and biophilia hypothesis, many researchers focused on determining the features of nature influencing people's positive response (Abboushi et al., 2019). Some of these previous studies related people's positive response to nature's fractal properties (e.g. clouds, trees, mountains, rivers) (Hagerhall et al., 2015; Joye & Berg, 2011; Purcell et al., 2001). The present research is based on the ART and biophilia hypothesis, since the aim was to investigate the hypothesized effects of natural elements on people.

2.2 Properties of Fractal Patterns

Natural forms included in science, mathematics and even in arts are formed by Euclidean geometry. People desire to find simplicity and order in nature, hence, Euclidean geometry is observed as illustrations of natural forms, which may be essential and irregular (Hasting & Sugihara, 2011). For instance, shapes of the planets are roughly spheres, honeycombs are hexagons, pine trees are roughly cone-shaped and elm leaves are ellipses. By filtering out the complexity within the nature, we obtain simplicity with the class of geometrical shapes. However, nature has both

simple and complex shapes. Simple shapes consist of Euclidean and ordered forms, whereas complex shapes include irregular and random forms. Abstract painter Piet Mondrian's geometric forms and American abstract painter Jackson Pollock's random patterns both involve important elements of nature (Hasting & Sugihara, 2011). Furthermore, it is important to mention that fractals are the greatest representation for geometry combination of complexity and simplicity (Hastings & Sugihara, 2011). Mandelbrot (1989) defined fractal geometry as the link between the geometric order of Euclid and the geometric chaos of general mathematics.

Fractal patterns, defined as the self-similarities occurring on an extension scale (Abboushi et al., 2019), represent the rough complex elements of the natural world. Also, they are described as the ''fingerprints of nature'' (Taylor et al., 2007) due to their repeating patterns existing in coastlines, clouds, mountain ranges, rivers, trees, plants (Gouyet, 1996; Mandelbrot, 1982).

In the literature, Mandelbrot is often known as the creator of the fractal geometry (Spehar et al., 2003). However, many of the fractals and their geometry were based on classical mathematics and mathematicians like Helge von Koch, Sierpinski, Waclaw Gaston Julia, Felix Hausdorff, and Georg Cantor (Peitgen et al., 2012). However, these mathematicians were not aware of the new geometry of nature they created. Later on, Mandelbrot (1989) demonstrated that nature included shapes with various features similar to mathematical fractals.

Unlike many geometrical fractals and human-made shapes, natural forms are characterized by their asymmetry and irregularity. The original intricacy of the natural forms is radically different from the traditional Euclidean geometry. Most

natural forms have self-similarity that differ by their repetitive scale, while Euclidean shapes are formed by more smooth lines (Spehar et al., 2003). Such natural fractal forms, composed of similar repetitive patterns in finer extensions, are known as ‘‘self-similarity’’ of fractal patterns (Mandelbrot, 1982) (see Figure 2). Researchers demonstrated that repeated patterns have the same statistical qualities even though their repetition is different (Spehar et al., 2003).

Figure 2. An example of natural fractal forms

(Image by author)

Since their discovery by Mandelbrot, fractals have achieved great success in determining the complex structures found in nature and have received great attention from artists and scientists (Spehar et al., 2003). Fingerprints of nature and the new aesthetics refer them. There are different methods to generate fractal patterns, which

may be categorized into three groups; *natural fractals, mathematical fractals, and human made fractals* (Spehar et al., 2003). *Natural fractals* are considered as natural scenes, such as clouds, trees, waves. *Mathematical fractals* are computer simulations of coastlines, mountains, and clouds. *Human made fractals* are often found in clipped parts of paintings by the American painter Jackson Pollock (Spehar et al., 2003) (see Figure 3). Based on the literature, people have consistent aesthetic preference of fractal patterns, in spite of the generation method (Spehar et al., 2003).

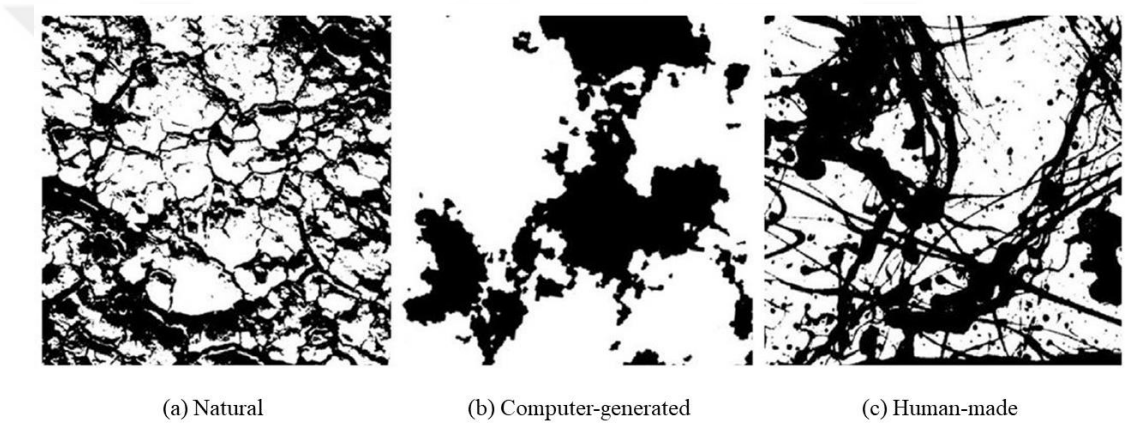

Figure 3. Representation of three different fractal pattern generation methods (Abboushi et al., 2019, p.59)

The fractal character of a pattern is quantified by the variable fractal dimension (D) (Spehar et al., 2003). This variable determines the complexity level of fractal patterns in different magnifications (Abboushi et al., 2019). Dimension for Euclidean shapes are explained by ordinal integer values of 0, 1, 2, and 3, which correspond to the following forms: points, lines, planes, and solids, respectively (Spehar et al., 2003). For instance, when D has a value of 1, a smooth line is generated, whereas when D has a value of 2, a totally filled area is generated. However, according to Spehar et al. (2003), for both values, D = 1 and D = 2 no fractal pattern is observed. As for fractal

patterns, D value varies from 1 to 2. Thus, when D value is closer to 1, the fractal patterns repeat at different magnifications and expand with smooth and rare shapes. However, when D value is closer to 2, the fractal patterns expand with more complex and detailed shapes (Cutting & Garvin, 1987; Geake & Landini, 1997). Research in behavioral studies indicated that D value is highly related to visual complexity. For instance, when D value increases, visual complexity increases (Taylor & Spehar, 2016).

In accordance with D value, fractal patterns can be classified into three groups; low-complexity (D = 1.1 – D = 1.3), mid-complexity (D = 1.3 – D = 1.5), and high-complexity (D = 1.5 – D = 1.9) (Abboushi et al., 2019). Table 1 demonstrated fractal dimensions of several common natural forms (Spehar et al., 2003). The extensiveness of mid-complexity fractal patterns in nature allowed people to easily adapt to the environment with respect to the visual system (Taylor & Spehar, 2016; Taylor et al., 2018). This adaptation is defined in the literature as the fractal fluency theory (Taylor & Spehar, 2016; Taylor et al., 2018). It is worth mentioning that this theory is associated with the previously discussed ART and biophilia hypothesis (Abboushi et al., 2019).

Table 1. D values of several common natural forms (Spehar et al., 2003, p. 815), reproduced by author

Natural form type	Fractal dimension (D)	Source
Coastlines of		
South Africa, Australia, Britain	1.05-1.25	Mandelbrot, 1982
Norway	1.52	Feder, 1988
Galaxies (modeled)	1.23	Mandelbrot, 1982
Cracks in ductile materials	1.25	Louis et al., 1986
Geothermal rock patterns	1.25-1.55	Cambel, 1993
Woody plants and trees	1.28-1.90	Morse et al., 1985
Waves	1.3	Werner, 1999
Clouds	1.30-1.33	Lovejoy, 1982
Sea Anemone	1.6	Burrough, 1981
Cracks in non-ductile materials	1.68	Skjeltorp, 1988
Snowflakes	1.7	Nittman and Stanley, 1987
Retinal blood vessels	1.7	Family et al., 1989
Bacteria growth pattern	1.7	Matsushitha&Fukiwara, 1993
Electrical discharges	1.75	Niemeyer et al., 1984
Mineral patterns	1.78	Chopard et al., 1991

Fractal patterns are also classified as statistical and exact (Abboushi et al., 2019). Statistical fractals are established in nature and characterized by irregularity and diversity in scale at various extensions where the statistical characteristics of the patterns exclusively replicate, whereas exact fractals identically repeat at various extensions (Fairbanks & Taylor, 2011; Hagerhall et al., 2015; Taylor & Spehar, 2016). In fact, both statistical and exact fractal patterns have complex structures in their repeating forms, however, they are not visually identical (Taylor & Spehar, 2016). Research in behavioral studies has mainly focused on people's assessment of statistical fractals (Spehar et al., 2003), due to their frequency in nature (Mandelbrot, 1982). Thus, in order to understand the effects of nature on people, the present research was mainly based on statistical fractals.

2.3 Responses to Fractal Patterns

Fractal patterns do not demonstrate equal characteristics in terms of people's response (visual preference, visual interest, emotional response). Previous studies found that, for statistical fractals, fractal dimensions D = 1.3 and D = 1.5 were preferred the most (Taylor et al., 2005; Spehar & Taylor, 2013). Another study demonstrated that people preferred fractal dimension D = 1.3 and D = 1.5 (Spehar et al., 2003). Aks and Sprott (1996) stated that fractal dimensions between D = 1.17 and D = 1.38 were preferred the most and differences in preferences were explained by differences in participants' personality features. In a later study, high visual preferences were recorded at fractal dimensions D = 1.25 and D = 1.5 (Spehar & Taylor, 2013). In general, most studies demonstrated that the fractal dimension D =

1.3 and D = 1.5 were the most visually preferred (Abboushi et al., 2019). Moreover, it is worth mentioning that most existing studies displayed two dimensional fractal patterns through monitors and evaluated visual preference and interest using a two alternative forced choice (2AFC) paired comparison test (Abboushi et al., 2019; Aks & Sprott, 1996; Spehar et al., 2015). The 2AFC test, which was presented by Cohn (1894) (as cited in Spehar et al., 2015), includes two images side-by-side in each trial. In this test, observers simply demonstrate which of the two images they visually prefer (Spehar et al., 2015). Moreover, Spehar et al. (2015) stated that this procedure is still believed as the best method to measure diverse forms of preference and visual interest.

Fractal patterns influence many of our visual experiences in nature. Researchers examined peoples' aesthetical responses to fractal patterns (Street et al., 2016). Moreover, another research stated that mid-complexity fractal patterns had a universal aesthetic appeal (Taylor et al., 2011). Aesthetic responses on the visual complexity of fractal patterns were studied more deeply by Berlyne (1970) and Forsythe et al. (2011). Berlyne (1970) discussed the existence of a curvilinear relationship between visual complexity, visual interest, and preference. Results indicated a positive significant relationship between visual complexity, visual interest, and preference until the feeling of stimulation reached its maximum level. However, excessive further increases in complexity would evoke exact opposite feelings of stimulation, thus, visual interest and preference would decrease. Therefore, when the complexity of visual stimuli decreased, interest and preference also decreased. Moreover, results indicated that highly aroused people desired certainty, while others who were less aroused wanted more stimulated and less

certain visual environments. Forsythe et al. (2011) demonstrated a linear relationship between visual complexity and beauty in the investigated images. Results suggested that visual complexity and fractal dimension made images more interesting and appealing. Therefore, visual complexity and fractal dimension are the factors that specify the visual interest of fractal patterns. For these kinds of studies, external factors, such as individual and cultural differences play a role on the aesthetic preferences. For instance, individual differences influence the aesthetic preferences, whereas cultural differences received slight attention in the research on fractal complexity and visual interest (Street et al., 2016).

Furthermore, apart from the visual preference, aesthetic preference, and visual interest, Taylor (2006) also discovered that the fractal dimensions D = 1.3 and D = 1.5 considerably reduced stress by 60%. Unlike previous studies, Taylor (2006) hanged the fractal patterns' images on a wall with a dimension of 3.2x6.5 feet (1.0x2.0m) for the participants to observe instead of displaying the images on a computer screen. Researchers also investigated participants' brain activity while observing displayed fractal patterns with the aim to examine the relation between physical mechanism and visual preference (Abboushi, 2019).

Moreover, Hagerhall et al. (2008) analyzed brain activity utilizing electroencephalograms and found that statistical fractal patterns caused an alpha response, which implied a wakefully relaxed state. Also, results showed that statistical fractal patterns received the highest beta response, which was an indicator of the alertness state. However, delta activity, which referred to the states of sleepiness and drowsiness, was the lowest for low-complexity fractal patterns of D =

1.32. Moreover, previous studies stated that fractal patterns provided esthetical admiration (Aks & Sprott, 1996; Spehar et al., 2003; Taylor, 1998), stress recovery benefits (Taylor, 2006), and feelings of relaxation and restorative effects (Hagerhall et al., 2008). These effects were associated with positive visual preferences of aesthetic attractiveness of fractal patterns. Therefore, it is significant to analyze the application of fractal patterns in interior spaces where people spend the majority of their times (Klepeis et al., 2001).

As previously mentioned, most studies investigating the influence of fractal patterns on visual preference and interest were conducted by presenting the two dimensional fractal patterns on computer screens (Spehar et al., 2003; Spehar & Taylor, 2013; Taylor et al., 2011). Abboushi et al. (2019) and Abboushi (2019) are some of the rare studies examining the visual preference and interest of three dimensional projected fractal patterns in interior spaces. People's response to the simulated fractal patterns may be affected by various environmental factors. Thus, the presentation methods and experimental settings should be taken into consideration in research on fractal patterns.

Research in the field of environmental psychology indicated four main variables affecting the impact of visual interest on projected fractal patterns, penetrating through a window or an opening with natural light and reflecting on a part of a wall or a floor, in interior spaces (Abboushi et al., 2019). These variables were *pattern types*, *pattern complexities*, *spatial variables*, and *light projections* (Abboushi et al., 2019). *Pattern type* refers to pattern geometry; Euclidean and fractal patterns. *Pattern complexity* is defined by the fractal dimension value D. *Spatial variables*

refer to projection surfaces (walls or floors), view direction, viewing angle, the distance between pattern and observer, size of pattern, and material properties. *Light projection* consists of the light source projecting these patterns defined by illumination variables, such as luminance variability, glare, contrast, and psychological effects of light. Therefore, based on the existing literature, these four variables influence the applicability of fractal patterns in interior spaces as these variables affect people's perceptual and psychological responses (Spehar et al., 2003; Taylor et al., 2005; Taylor & Spehar, 2016). The present study examined deeply the influence of the variables *pattern complexity* and *light projection* while keeping *pattern type* and *spatial variables* under control.

2.4 Fractal Light Patterns and Visual Interest in Interior Spaces

To avoid stability and boredom in interior spaces, an intermediate level of sensory stimulation is required and the functions of diversity, intensity, and complexity are considered as components that stimulate people in interior spaces (Evans & McCoy, 1998). The ART discussed that characteristics of natural environments provoked insensible attention, which required restoration from mental fatigue (Kaplan, 1995). Moreover, Stress Recovery Theory (SRT) claimed that the interrelation between nature and its elements decreased the psycho physiological stress and stressful stimuli, which may have provoked insensible attention (Ulrich, 1983). Therefore, characteristics of nature are observed as stimuli and perceived as visually interesting and pleasant.

Based on the previous literature, a variety of studies emphasized the role of natural light and its interplay with the decorative openings or windows in providing a flow for natural light in interior spaces. Salingaros (1999) stressed that patterns, which schematically imitate the characteristics of nature, were significant design elements when they were apparent in the space. Results indicated that seeing the patterns on the openings or semitransparent surfaces was more easily perceived than placing them on the building plan. Another study emphasized that these patterns were proposed to maintain beneficial visual similarities with nature (Joye, 2007).

In a sequence of related studies on the effect of fractal geometry on visual interest, Abboushi et al. (2018a,b) investigated the effects of façade conditions on visual interest, visual comfort, and satisfaction. The study focused on office spaces and included three different façade conditions, consisting of a clear window, fully covered by horizontal stripes window, and fully covered by fractal patterns window. Participants were located either parallel or perpendicular to the window and they evaluated the three window conditions in terms of visual interest, visual comfort, and satisfaction. Results showed that there was no significant difference between the visual comfort and façade variations in the existence of direct sunlight. Furthermore, results demonstrated that visual interest for fractal pattern and horizontal stripes façades changed according to participants' view direction. Therefore, fractal patterns were found more visually interesting than the horizontal stripes for a view direction based on the perpendicular window, whereas horizontal stripes were considered more visually interesting for a view direction based on the parallel window.

In a later study, Abboushi et al. (2019) compared the influence of different complexity levels of two and three dimensional fractal and non-fractal patterns on visual interest and mood response in two phases. In the first phase, they examined the visual interest and mood response by projecting the two dimensional fractal and non-fractal patterns on a wall. In the second phase, they investigated visual interest and mood response by projecting three dimensional fractal and non-fractal patterns with the sunlight in an interior space. Results demonstrated that, in the first phase, visual interest ratings were the highest for mid-complexity fractal patterns of D = 1.5. For mood responses, results indicated that participants reported great feelings of excitement and stimulation for fractal patterns of D = 1.5 and D = 1.7, respectively. However, in the second phase, findings showed that visual interest increased as fractal dimension increased. The most influential outcome of the study demonstrated that D = 1.7 was rated as the most visually interesting and that ratings for excitement and stimulation increased when D value increased.

While previous studies focused on fractal patterns as one of nature's most influential elements on peoples' positive responses, other studies focused on natural light as another influential element of nature, affecting peoples' responses. In the next chapter, the benefits of natural light on people in interior spaces are examined.

CHAPTER III

NATURAL LIGHT AND COLOR TEMPERATURE IN INTERIOR SPACES

This chapter discusses natural light's physiological and psychological benefits on people in interior spaces. Also, it includes a part comparing color temperature (CT) with correlated color temperature (CCT). Moreover, it covers in detail the perception of light in interior spaces and physical and psychological factors related to perception of interior spaces emphasizing the Mehrabian and Russell (M-R) (1974) model.

3.1 Natural Light

Natural light is an inconsistent light stream; rather it is a dynamic light changing according to time and location (Tregenza & Wilson, 2011). Due to its dynamic characteristic, it may either give a smooth effect or a chaotic one. The changes observed in natural light are not only dependent on time; it also relies on the weather condition changing between bright sunny days to cloudy rainy days.

Recently, natural light plays a significant role in defining the functional and aesthetical characteristics of an interior space. Thus, the application of natural light in interior spaces should be carefully planned and designed by architects and lighting designers (Özdamar, 1998).

Before getting more into natural light, it should be mentioned that, in the literature, natural light was referred by three terms that are *daylight*, *sunlight*, and *skylight* (Tregenza & Loe, 2014). Tregenza and Loe (2014) defined these terms as follows. *Daylight* is a broad term, often referred by as natural light. *Sunlight* is the light coming straight from the sun. *Skylight* or *diffuse daylight* is the light coming from the sky. In this research, daylight is referred by as natural light, which is a combination of sunlight and skylight, and defined as an independent light source with full spectrum and best color rendering index (CRI).

Spectrum is the distribution of the radiant energy transmitted by a light source across the visible spectrum (Fatios, 2011). Moreover, full spectrum light provides seeing details and colors more clearly, and support to concentrate for longer periods by diminishing eye fatigue. Many natural factors influence the illuminance and spectral property of natural light such as weather condition, time of the day, and analyzed sky. Research has demonstrated the occurrence of great changes in the spectral characteristics of natural light generating variation in the color of light during the day.

Natural light color rendering is a significant characteristic influencing the quality of interior spaces that should be taken into consideration. All light sources' CRI is based on natural light's standard color rendering (McNicholl, 1995). Color rendering

was described, by Rea (2000), as the impact of a light source on an object's appearance. The CRI measures to what extent a light source renders color (Egan & Olgyay, 2002). A CRI of 100 is recommended for the best color appearance (Flynn et al., 1988). Even when the spectral composition of light sources is different, they may be perceived the same, however, the color of objects observed under these lights will look different. Jones (1989) stated that the increase in the CRI helped in making the color seem closer to its natural appearance. Natural light is known as the free light source characterized with a full spectrum and excellent CRI (Kumoğlu, 2013).

These unique characteristics of natural light made it a preferred design element in interior spaces. Furthermore, few studies investigated the influence of different natural light effects on people's perception in interior spaces, such as natural light patterns. The following part highlights the role of natural light patterns in interior spaces.

3.2 Natural Light Patterns in Interior Spaces

A few research focused on peoples' responses to natural light patterns in interior spaces. Natural light and its interplay with the openings of a space play a significance role in the design of interior spaces. Natural light is the central source in a space that creates visual interest and stimulation for the spatial experience. However, there is little research on the influence of natural light and its interplay with the openings' geometry on people's perception of interior spaces. Corrodi and Spechtenhauser (2008) described the identity of interior spaces as openings through the nature and

the flow of light, and the rhythm of light and shadow. Therefore, alongside of the existence of natural light, it is important to provide light patterns with the interaction between light and shadow in the design of interior spaces.

In modern architecture, the necessity of the visual diversity was highlighted by Salingaros (1999). Moreover, in contemporary architecture, the importance of visual patterns was emphasized as a new aesthetic of veiling, which includes the use of decorative patterns, multilayered facades, and semitransparent surfaces through the natural light that flow the space (Corrodi & Spechtenhauser, 2008). Figure 4 demonstrates the use of natural light through patterned opening elements in interior spaces.

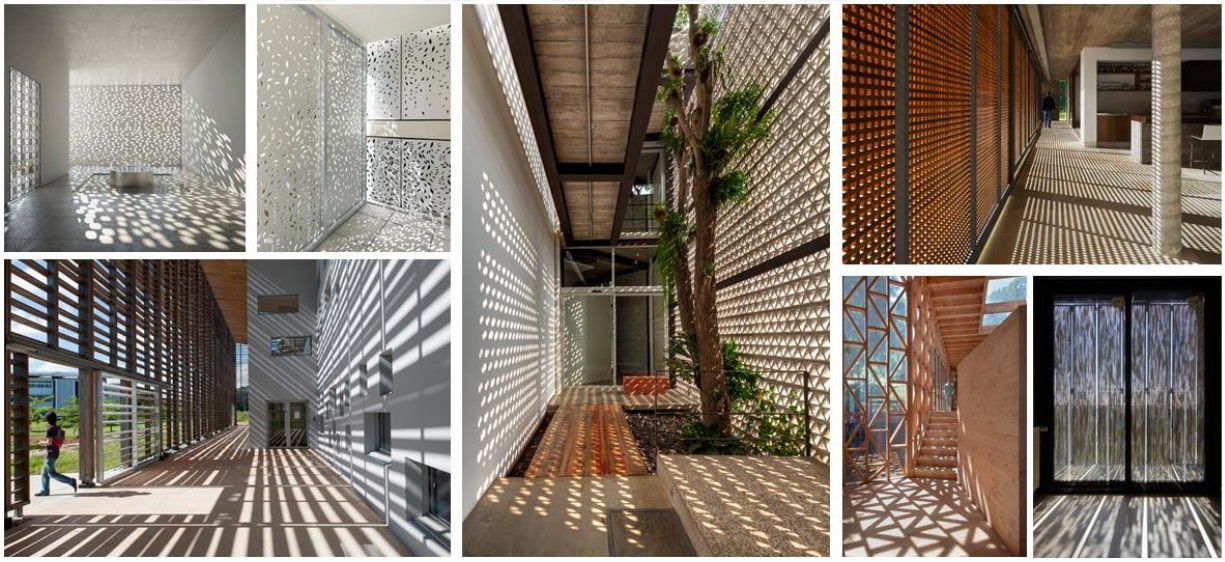

Figure 4. Use of natural light through patterned opening elements in interior spaces (Chamilothori et al., 2019, p. 4)

The interaction of natural light with those architectural elements plays an important role in the design of interior spaces. The architectural elements not only emphasized the openings design, but also demonstrated the interaction between natural light and the openings that generated various light patterns in interior spaces. However, it is important to examine how this interaction with the natural light and diversity of these decorative opening elements influence people's perception of interior spaces. The architectural elements of an opening form the way natural light penetrates an interior space and determine the variety of natural light patterns (Chamilothori et al., 2019).

Until now in the literature, studies on projected fractal patterns used natural light source without considering the role of CT even though it has been proven in the literature to influence people's perception. According to American National Standards, CT is one of the most important components determining the quality of light about human perception. Therefore, the present study focused on the influence of CT of projected fractal patterns in interior spaces. The following part develops on the characteristics of CT and CCT.

3.2.1 Color Temperature

In the literature, illuminance and luminance are the most common terms related to lighting (Kocaoğlu, 2015) and are used to measure the quality of light. Illuminance and luminance are referred by as the fundamental characteristics of light. Illuminance was defined, by Egan and Olgyay (2002), as the density of luminous flux present on a surface and is measured by the illuminance meter, in lux. Whereas luminance was

referred, by Egan and Olgyay (2002), as the degree of apparent brightness of a light source perceived by the eye divided by the area of that source and is measured with a luminance meter, cd/m2. These terminologies facilitate the understanding of light characteristics and CCT effect. Recently, a few amount of research is investigating the influence of CCT on user's comfort preferences in interior spaces (Wang et al., 2017). The present research is focused on the effect of natural light's CT in a more detailed matter.

CT is defined as the appearance of light color and is found as one of the most influential factors related to subjective perception (Egan & Olgyay, 2002). CT represents the warmth and coolness of a light source, such as yellowish white, bluish white, or neutral appearance (Egan & Olgyay, 2002). However, Egan and Olgyay (2002) stated that CT doesn't give an idea on energy distribution or physical temperature. When CT increases, the amount of blue tint increases, whereas when CT decreases the amount of red tint increases (Katsuura, 2000). The American National Standards (1987) stated that the quality of light was one of the most essential characteristics of lighting and that CT was one of the most crucial components determining the quality of light providing users with a comfortable and effective visual experience (Katsuura, 2000; Samani, 2011; Veitch & Newsham, 1998). Figure 5 presents the CIE Chromaticity chart that illustrates the CT of any light source, where its chromaticity coordinates, fall on the Planckian locus, and is equal to the blackbody temperature of the Planckian radiator (McCamy, 1992). The measurement level of CT is Kelvin (K). Rea (2000) stated that blackbody properties may be determined through the Planck's radiation law at different CTs. Also, Rea (2000) indicated that the chromaticity points that fall on the Planckian locus were

determined by CT, however, for the points that fell near the Planckian locus CCT was used.

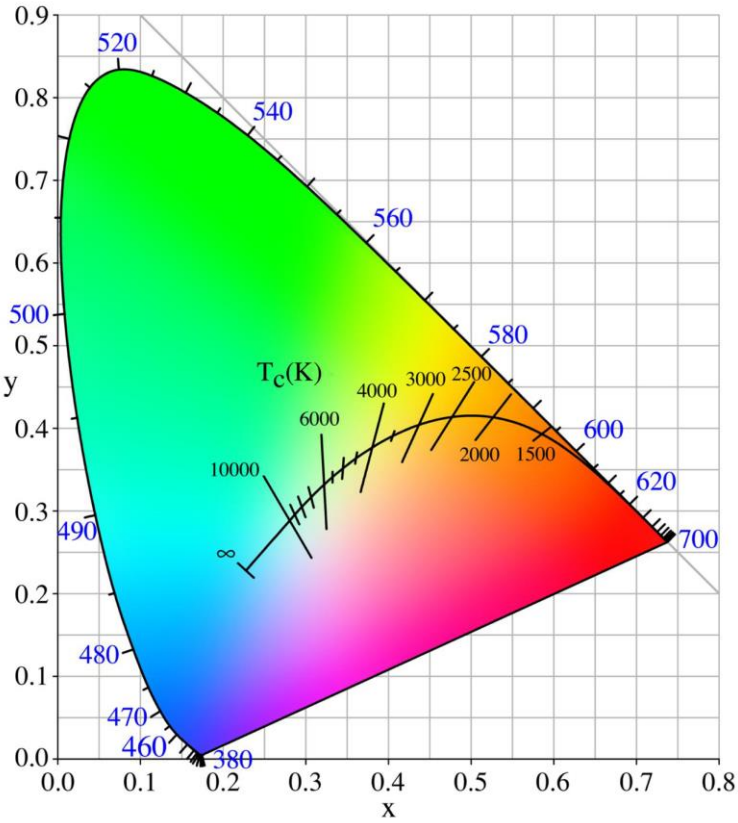

Figure 5. Black body locus on CIE chromaticity diagram (http://en.wikipedia.org/wiki/Planckian_locus)

Indoor lighting is generally fixed, thus the lighting illuminance and CCT are stable, whereas natural light changes during the day due to the changes in weather, sun position. A recent study by Ye et al. (2018) demonstrated that people working in settings providing dynamic lighting, where changing patterns of CT and illuminance occurred, were more involved with their work environment and had better performance than workers in the static lighting setting. The color and spectral characteristics of natural light were likely to vary among different weather conditions and time of the day (Peyvandi et al., 2016).

In the literature, three kinds of skies were defined for design applications, which were clear sky, cloudy sky, and overcast sky. Egan and Olgyay (2002) briefly defined each as follows. Clear sky is referred by the sky of a clear day where a large part of the illumination comes straight from the sun casting edgy shadows. Air mass is an important factor influencing the intensity of direct sunlight illumination on clear sky. It is lighter at sunrise and sunset for all latitudes. Also, at noon for high latitudes, where the sun is lower, it is less intense. In contrast with clear and overcast skies, the illumination of cloudy skies varies often from 23,000 to 100,000 lux, where sometimes it provides total sunlight, and sometimes clouds hide the sun. Overcast sky diminishes the sunlight by over 90%. Overcast sky is referred by the sky condition where the cloud layer is too opaque that the sun is hidden. Besides, its luminance distribution is the same for all sun altitudes.

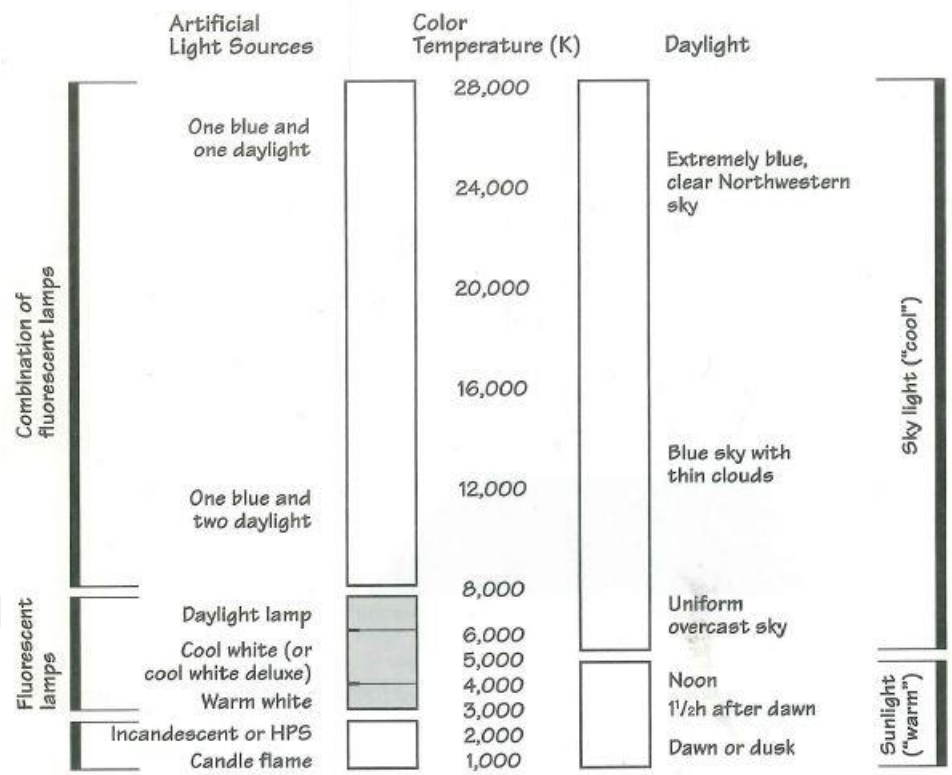

Figure 6. A chart illustrating CTs of artificial light sources and daylight (Egan & Olgyay, 2002, p. 76)

Figure 6 illustrates Egan and Olgyay's (2002) fundamental scale for artificial light's CCTs and natural light's CTs. Egan and Olgyay (2002) defined the Kelvin scale ranging from 1000K to 28000K referred by sunlight (Warm) to Skylight (Cool), respectively. No previous studies examined the effect of sky types on people's visual interest and emotional response. Thus, the present research investigated the effect of three sky types with three different CTs on people's visual interest and emotional response. These are noon, overcast sky, and blue sky with thin clouds. The latter is referred by, in this research, as clear sky.

3.2.2 Correlated Color Temperature

As mentioned in the previous part, the terminology CCT was used when the chromaticity points of a light source fell near the Planckian locus on CIE chromaticity diagram (Rea, 2000). Therefore, CCT refers to artificial lights, which mimic the natural light. Artificial light is referred to human-made light sources, which radiate from the electric lamps. Mostly, artificial light does not include the colors of the rainbow and always maintain the same static condition throughout the day, whereas the dynamic structure of natural light radiates all colors of the rainbow. In the literature, various studies examined the effect of CCT of artificial light on people's perception.

Viénot et al. (2009) examined the relationship between CCT, illuminance, and visual response. In this study, the following Kelvin degrees were observed; 2700K, 4000K, and 6500K with 150lx, 300lx, and 600lx respectively. Results indicated that higher CCTs were associated with feelings of brightness and clearness, while lower CCTs evoked feelings of relaxation, pleasantness, warmth, and comfort. Furthermore, Ju et al. (2011) investigated the influence of CCT on spatial brightness perception. Nine experimental lighting settings with different CCTs (3000K, 5000K, and 8000K) and illuminance levels (1000lx, 300lx, and 100lx) were developed for the experiment. Results indicated a significant relationship between CCT and spatial brightness perception, where high CCTs enabled a better spatial brightness perception. These results consist with Kim et al.'s (2014) study, where results indicated that for the same illuminance level, higher CCTs resulted in a brighter space perception.

In a later study, Baniya et al. (2015) investigated preferences in terms of illuminance level and CCT in an office room. The study developed random ordered combinations with the following CCTs 3000K, 4000K, and 5000K and illuminance levels 300lx, 500lx, and 750lx. Results indicated that the most preferred combination was for CCT 4000K with illuminance level correspondent to 750lx. Also, results demonstrated that for higher CCTs, participants perceived the room as more bright and felt more stimulated. Another study by Wang et al. (2017) found that CCT had a significant influence on the people's subjective comfort and preferences, where high CCTs provoked relaxing activities, whereas lower CCTs provoked tense activities. Huang et al. (2014) examined the influence of CCT on focused and sustained attention, where 3 different CCTs were studied (2700K, 4300K, & 6500K). Findings indicated that CCT had a significant influence on focused and sustained attention and that 4300K provoked better attention.

Rautkyla et al. (2010) examined the influence of CCT on daytime alertness in a lecture setting. Two CCTs were studied (4000K & 17000K); the experiment was conducted on two phases during spring and autumn. Participants reported their alertness level on a 9-point scale at the start and end of each lecture session. The findings indicated that, in spring, CCT had no significant influence on alertness, however, in autumn, CCT demonstrated a significant influence on alertness. Results also demonstrated that, when compared with 4000K setting, the subjects in the 17000K setting reported greater alertness levels.

Therefore, the literature demonstrated that higher CCT induced the perception of brightness and feelings of *arousal*, whereas lower CCT of light induced the feelings

of pleasantness, relaxation, and warmth. In the literature, effects of artificial light CCTs on people's perception has been frequently studied. However, no study considered the effects of natural light's CT on people's perception, even though artificial light's CCT is based on natural light's CT. Therefore, the present study examined the influence of three different natural light CTs on people's perception in interior spaces to indicate whether the effects of natural light's CTs are similar to those demonstrated in the literature using artificial light's CCTs.

3.3 Perception of Light in Interior Spaces

Light has many benefits on people's lives and it is essential for their survival. Light has many impacts on its users and highly influences their experience in a certain space (Katsuura, 2000). Besides, light adds senses and emotions to a space (Knez, 1995). Previous studies indicated that light has a great significant influence on space perception, and evaluation, emotional preference and response, and physiological and psychological comfort (Biner et al., 1989; Boyce & Cuttle, 1990; Davis & Ginther, 1990; Knez, 1995; Manav, 2007; Manav & Yener, 1999; Odabaşıoğlu & Olguntürk, 2015).

The existence of light, improves the perception of the physical characteristics of a certain space, therefore, light may be referred by as the core of architecture and visual experience (Egan & Olgyay, 2002). The visual experience of a space is associated with viewing and analyzing the elements in that space, referred by as space perception (Egan & Olgyay, 2002). Light should be well designed to improve

the quality of interior spaces, since light has a great influence on the way people perceive the physical characteristics of a certain space.

Briefly, light influences people's perception in various ways. Throughout the history of architecture, light was valued in forms and designs, and it is a powerful source in architecture and interior space designs (Tevfikler, 1996). Therefore, to improve the quality of interior spaces, the influence of light on people's perception should be taken into consideration. Thus, light is a fundamental design element that should be taken into consideration along with other factors, such as color and texture in creating interior spaces.

The human body evolved within the diurnal cycle of light and darkness and is regulated to the spectrum of the sun's radiation. Natural light influences people's lives in various ways, such as their health, interaction with people, and task achievement (Tregenza & Wilson, 2011). If it is carefully used in a space, it enables vertical and horizontal illuminance and attractive effects (Özdamar, 1998). Robbins (1986) indicated that, compared with artificial light, natural light provided many benefits in interior spaces such as quality of light, energy saving, need for natural light, physiological and psychological effects.

Veitch et al. (1993) demonstrated that the majority of university students showed higher performance in natural light conditions compared to artificial light conditions. Moreover, Cheung and Chung (2008) highlighted users' preference for natural light in residential spaces. Another study, based on a qualitative and quantitative survey, was conducted with Austrian workers and demonstrated that the presence of natural

light in office spaces was positively highly associated with users' well being and satisfaction (Ornetzeder et al., 2016).

Studies by Flynn et al. (1973) and Flynn et al. (1979) stated that lighting alterations influenced people's perception and proposed a framework for the assessment of subjective perception of natural light. Cheung & Chung (2008) defined natural light as the mean that facilitated users' understanding of a space, translated the information given by that space, and influenced its users' well being.
Previous studies demonstrated that the presence of a window providing natural light and view was an influential factor on user's satisfaction without regards to the building type (Butler & Biner, 1989; Kilic & Hasirci, 2011). Moreover, Heerwagen and Heerwagen (1986) conducted a study in an office in the US to observe users' well being and comfort during summer and winter. Results emphasized the importance of natural light for visual comfort and psychological state.

Natural light may not be studied apart from sunlight. It is considered as the major light source. (Özdamar, 1998). The dynamic visual and thermal characteristics of sunlight make it an influential source on people's comfort and well being. Direct sunlight is desirable in interior spaces when applied in the right orientation and amount. Therefore, a successful interior space design is achieved with the correct application of direct sunlight avoiding visual discomfort. Various research demonstrated that sunlight patterns in a space created a sense of cheerfulness and visual interest improving space quality and visual comfort (Abboushi, 2019). Another study conducted by Longmore & Ne'Erman (1974) in office spaces, indicated that 73% of participants reported feelings of *pleasure* associated with

sunlight, whereas 61% of the participants preferred quality view rather than indoor sunlight. In addition, some of the factors that make sunlight patterns seem pleasant in interior spaces are sparkle, brightness, and mental stimulus (Ne'Eman, 1974). These results were consistent with Boubekri et al. (1991). Results also demonstrated that sunlight related factors, such as size, season, and time had significant influence on users' emotional state and interior space satisfaction. Moreover, findings indicated that for sunlight, horizontal illuminance was greater than the required light amount for any visual task, thus visual perception of sunlight was generally dependent on quality rather than quantity of sunlight. Boubekri and Boyer (1992) demonstrated that the presence of indoor sunlight developed feelings of pleasantness and cheerfulness increasing users' tolerance of glare.

Another study observed the seating preferences for a paper-based task in a sunlit experimental setting (Wang & Boubekri, 2010). Results indicated that the majority of subjects preferred to sit within or nearby the sunlight pattern areas. Furthermore, Van den Wymelenberg, Inanici, and Johnson (2010) stated that the majority of subjects reported preferring sunlight patterns in indoor spaces. Researchers also stated that appropriate luminance variations generated interesting and stimulating spaces; increasing users' preferences. These results were consistent with Kim's (1997) study, which demonstrated that compared with natural light, in summer and winter, in classrooms, sunlight had an important influence on students' positive emotions.

The quality of natural light is the main reason behind its high demand and use in interior spaces, since it is a full spectrum natural light source that all other artificial light sources relate to. Compared with artificial light, less amount of natural light is

required to accomplish a task due to its quality. Villecco (1979) stated that people's biological and aesthetic needs, reference to time and space, which is essential for survival, were satisfied by natural light. The quality of natural light is comfortable for vision providing a good visual perception. The visual quality of a space influences the experience of its users, by affecting their proper perception of objects and differentiating first plan from second plan and, therefore, complete visual tasks (Tevfikler, 1996).

Natural light is an essential design element in all kind of spaces, where different amounts are required to create the spatial layout and overall shape of a space. Natural light has many applications in interior spaces, for instance, it may be used to emphasize a wall, corner or a piece of art or to give a specific atmosphere to a space (Tevfikler, 1996). Moreover, natural light has great physiological and psychological effects on people. The next subsections addressed the further information on physiological and psychological effects of natural light.

3.3.1 Physiological Effects of Natural Light

Evans (1987) stated that natural light had various positive physiological impacts on people. Since humans evolved in nature, their physiological needs were naturally satisfied by natural light's full-spectrum. For instance, natural light radiations are essential for the human body, such as ultraviolet radiations, which enables the body to produce vitamin D. Another physiological advantage would be natural light stimulus, which enabled people to stay alert and conscious.

People in their nature need change. This is why the natural alteration that occurs in natural light satisfies human's body and mind's need for change. However, excess of natural light may cause issues such as physical and emotional fatigue. Therefore, in lighting design, excess direct sunlight should be avoided while providing visual flexibility and visual stimuli. This positive effect of natural light may be provided in an interior space with the proper application. Another physiological need for the human body is orientation. Evans (1987) stated that the lack of orientation, defined by the lack of sense of time and outside weather, generates feelings of frustration and distraction. Besides the physiological effects, natural light provides psychological effects as well.

3.3.2 Psychological Effects of Natural Light

Unlike physiological effects, psychological effects of natural light cannot be measured, rather it may only be perceived. Providing natural light in a space fulfills human's greatest psychological needs. The calibration of light color on surfaces and elements of space are other psychological advantage of natural light, which are known as well as biological needs in human's nature. Evans (1987) stated that the human mind used natural light as a reference measurement to everything seen, as it has been associated with humans since their early lives.

Users of a space desire the existence of natural light. Natural light gives space the sensation of brightness and cheerfulness, which has significant positive psychological effects on the users of that space (Robbins, 1986). Moreover, sunlight is also desired in interior spaces, however, this desire differs according to the

building function (Robbins, 1986). This was demonstrated in the results of Longmore and Ne'man (1974) that indicated different sunlight preference percentages according to the building type. For instance, preference percentages varied as 42%, 73%, and 90% in school classrooms, private working areas, and residences, respectively. Therefore, light satisfies biological and psychological needs that influence people's health and well being. However, these effects of natural light, which are observed in interior spaces, are also influenced by the perception and characteristics of those spaces.

3.4 Perception of Interior Spaces

People spend the majority of their times in interior spaces and are indispensably connected to the space they live in (Odabaşıoğlu, 2009). Interior spaces are not only created by architectural elements, the dynamism and activities of users' lives also define the structure of an interior space (Kuban, 1992). The existence of spaces can only be possible with the presence of users, as the space may be defined and evaluated by users' perception (Kahvecioğlu, 1998). First, the space is perceived, then evaluated, and lastly emotional reactions are seen.

Perception of the spaces is divided into two categories, which are affective meaning and perceptual cognitive meaning (Russel & Pratt, 1980). The space is perceived and evaluated differently by different users due to distinctness of users' perception and psychology. Furthermore, space evaluation can be categorized into two classes; *environmental appraisals* and *environmental assessments* (Gifford, 2002). The

former, environmental appraisals, consists of personal feelings of a setting, which concentrate on users and how they feel about that setting. The latter, environmental assessments, include several users' ratings of more general evaluations for a setting, emphasizing space and quality (Gifford, 2002). To briefly summarize, environmental appraisals emphasize the feelings of users (person-centered), whereas environmental assessments emphasize physical properties and qualities of a setting (place-centered).

Four senses including seeing, hearing, touching, and smelling are essential factors in the evaluation of space quality. As previously mentioned, in the first step, a space is perceived by seeing then it is evaluated with the contribution of other senses. Moreover, psychology of users is an influential factor related to the assessment of space quality. Thus, physical characteristics of an interior space, such as space configuration, spatial properties, and psychological state of users are influential factors on the perception of interior spaces (Odabaşıoğlu, 2009).

3.4.1 Physical Factors

Space configuration and spatial properties are two main components in specifying the physical factors affecting space perception. The initial part includes size, composition, texture, and material of a space. The second part consists of existing lighting and color in a space (Odabaşıoğlu, 2009).

Space configuration is a significant factor facilitating space perception of users. Composition and form, texture and materials of the surfaces, size and proportion are

also significant properties in the perception of an interior space (Yıldız, 1995). Ching (1996) described form as a formal structure of a three-dimensional volume. Besides, composition is the term used for defining harmony, which includes various elements used in a space (Oxford English Dictionary, 2002). The combining composition and form defining an interior space influence users' visual perception, therefore, affecting space evaluation. To achieve balanced combination in a space, size, proportion, and form should be created. An imbalance between these properties make the perception of space become difficult and, therefore, perceived as unpleasant.

Texture and material properties also play an important role on the perception of space. Ching (1996) defined texture as the visual and tactile property of a material. Using rough materials with textures create a different perception than using smooth materials without any texture. Moreover, size and proportion of the elements used in interior spaces influence the space perception. Ching (1996) defined the size of a setting by the length, width, and depth of a space. Moreover, Ching 1996) added that these dimensions identified the proportion of a space. The dimensions of the setting can alter the perception of users (Odabaşıoğlu, 2009).

Light and color are essential spatial properties influencing the perception of an interior space. However, lighting and darkness affect the perception of interior spaces differently (Yıldız, 1995). Eyes are fundamental receivers that help people feel an environment. Therefore, light changes the perception of a space. Also, the perception of textures is based on the quality of light. Moreover, light creates strong psychological responses and has physiological effects on people (Yıldız, 1995). According to Galasiu and Veitch (2006), lighting is not only for seeing details, it also

determines spatial appearance and needed levels of visual performance. To briefly summarize, lighting quality and quantity are important factors, which may impact the perception and attraction of a space (Odabaşıoğlu, 2009).

Furthermore, besides lighting, surface color has a great impact on perception of space and emotions of people. Various studies demonstrated that color had a serious influence on perceived room dimensions (Savavibool & Moorapun, 2017). Color may give the impression that a space is small or large, deep or shallow. For instance, cool colors including blue and green made the space much more spacious (Yıldırım et al., 2011). On the contrary, warm colors including red, yellow, and orange made people perceive the space smaller than it actually is (Yıldırım et al., 2012). Moreover, warm deep colors with a lighter color made the space seem longer and narrower (Pile, 1997). In the present study, achromatic color scheme was used in order to eliminate the influence of color on perception of space.

3.4.2 Psychological Factors

Psychological factors, combined with physical factors, also have significant influences on people's perception and evaluation of spaces (Odabaşıoğlu, 2009). Kasmar (1970) believed that people required some tools and needed an appropriate scale for the description of the space. The English language supplies hundreds of words, such as lively, boring, relaxing, and disgusting as a tool to describe the emotional quality of spaces (Russel & Pratt, 1980). Although there was a large array of emotional descriptors, environmental psychologists focused their attention on only

a few of them (Russel & Pratt, 1980). M-R (1974) developed *pleasure*, *arousal*, and *dominance* dimensions in order to assess environmental perception, experience, and psychological response (Russell & Pratt, 1980). Various studies implemented these dimensions in the evaluation of physical environments' experience and perceived properties (Bakker et al., 2014). In the present study, M-R (1974) model was used and discussed in detail in the next part.

3.5 Emotional Response in Interior Spaces: Mehrabian and Russell (1974) Model

In the assessment of environments, one of the most used and reliable frameworks is the M-R (1974) model, which consists of three sections as follows: physical environment, emotional responses, and behavioral intentions (see Figure 7). The M-R model hypothesized that a physical environment (interior space) has an influence on user's emotional reactions on three different dimensions (*pleasure*, *arousal*, and *dominance*) and, therefore, affected their behavioral intentions.

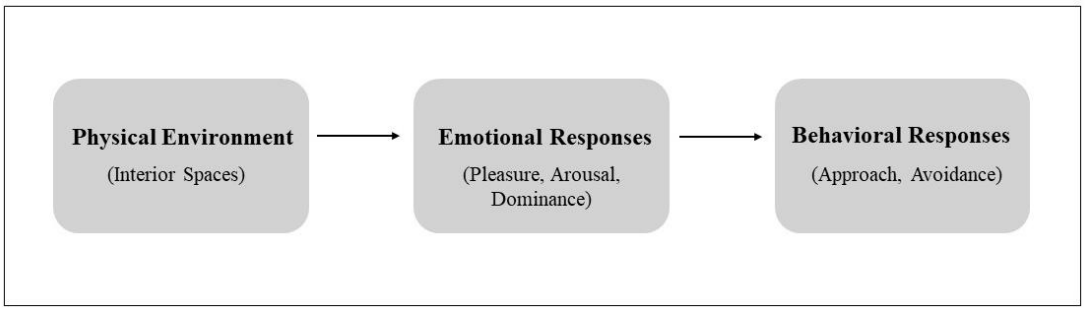

Figure 7. The M-R model

(Mehrabian & Russell, 1974, p. 8), redrawn by author

This model suggested that many factors in the environment such as color and lighting stimulated people and provoked different emotional reactions summarized under the three dimensions of *pleasure*, *arousal* and *dominance*. These emotional states determine people's approach-avoidance behavior in relation to an environment. The M-R (1974) model hypothesized that all emotional states may be interpreted as a combination of those three dimensions. *Pleasure* is the extent to which one experiences feelings of happiness or pleasantness and consists of six bipolar adjectives; bored-entertained, despair-hopeful, unhappy-happy, melancholic-contented, annoyed-pleased, and dissatisfied-satisfied. *Arousal* is defined as the extent to which one experiences feelings of excitement and stimulation and consists of six bipolar adjectives; calm-excited, unaroused-aroused, dull-jittery, relaxed-stimulated, sleepy-awake, and sluggish-wild. *Dominance* is the extent to which one experiences feelings of control and consists of the following bipolar adjectives; dominant-submissive, in control-cared for, autonomous-guided, and influential-influenced (Mehrabian & Russell, 1974).

Russell and Pratt (1980) stated that in order to better understand people's perception of a certain space, it was necessary to determine these emotional responses. Nevertheless, previous studies demonstrated that, among these dimensions, *dominance* was found to have the least influence on behavioral intensions (Russell & Pratt, 1980; Donovan & Rossiter, 1982; Donovan et al., 1994). Russell and Pratt (1980) suggested the elimination of the *dominance* dimension from the M-R (1974) model. Researchers further argued that *dominance* dimension demanded conscious analysis, thus, making it inapplicable in situations requiring emotional response. Furthermore, Russell and Pratt (1980) stated that *pleasure* and *arousal* dimensions

indicated sufficiently people's emotional response in a situation. For this reason, the *dominance* dimension was not included in the present research.

The behavioral intensions towards a space are observed in the form of approach and avoidance (Mehrabian & Russell, 1974). Approach is the desire to remain and interact with people in a space, whereas avoidance is the action of staying away from a space (Mehrabian & Russell, 1974). However, behavior intensions were not examined in this study because of the time limitation.

The effect of interior spaces on people's emotional response has been studied in the previous literature in terms of space size, composition, color, artificial and natural light. However, no studies investigated the effect of natural light patterns in an interior space on people's emotional response. Based on the gaps and findings of the previous literature covering research on fractal patterns, natural light, and interior space perception, the present research aimed at investigating the effects of natural light's CTs of different complexity level fractal patterns on visual interest and emotional response in interior spaces. The next chapter discussed the methodology of the study. It covered the aim, research questions, hypotheses, sample group, and procedure of the study.

CHAPTER IV

METHODOLOGY

This chapter introduces the methodology part covering the aim, research questions, and hypotheses of the study. Also, it describes the sample groups, phases and procedure of the experiment. Furthermore, this chapter is divided into two sections explaining in detail the first and second phases of the experiment, respectively.

4.1 Aim of the Study

An experiment consisting of two phases was conducted. The aim of the first phase was to determine which complexity level of two dimensional fractal patterns were more visually interesting. Also, people's emotional response to these different complexity levels of two dimensional fractal patterns were evaluated. In the first phase, it is important to emphasize two dimensional fractal patterns in order to understand dynamics of patterns. Moreover, the aim of the second phase was to determine whether different CTs of natural light influence the choice of three dimensional fractal pattern complexity. People's emotional response were also

evaluated (see Figure 8). In both phases, participants filled the questionnaires on a computer screen.

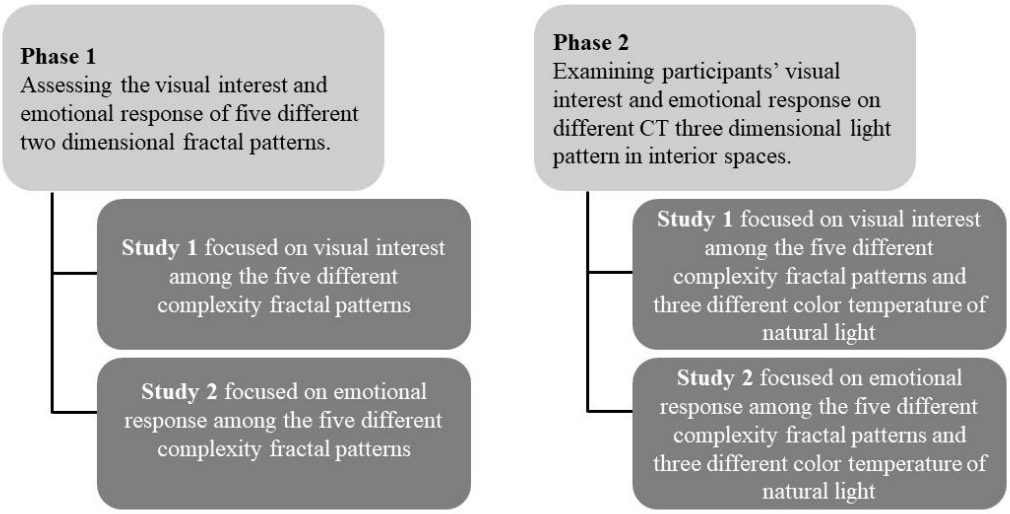

Figure 8. Diagram showing the framework of the experiment process (illustrated by author)

4.2 Research Questions and Hypotheses

As previously mentioned, this study consisted of two phases where the first phase aimed at defining the most visually interesting complexity level of fractal patterns and examining these complexity levels in accordance with people's emotional response. The related research questions and hypotheses to phase 1 were as follows:

RQ1.1 Which two dimensional fractal pattern complexity is the most visually interesting out of D = 1.1, D = 1.3, D = 1.5, D = 1.7, D = 1.9?

RQ1.2 Is there a significant difference between different complexity levels of two dimensional fractal patterns in terms of visual interest?

RQ1.3 What is the influence of different complexity levels on people's emotional response?

H1.1 The most visually interesting two dimensional fractal pattern complexity is mid-complexity level D = 1.3 – 1.5.

H1.2 There is a significant difference between different complexity levels of two dimensional fractal patterns in terms of visual interest.

H1.3a Decreased complexity levels induce increased *pleasure* state.

H1.3b Increased complexity levels induce increased *arousal* state.

The second phase of the experiment examined the effects of projecting fractal patterns with different natural light's CTs on people's visual interest and emotional response. The related research questions and hypotheses to phase 2 were as follows:

RQ2.1 Does different CTs of natural light influence the choice of three dimensional fractal pattern complexity?

RQ2.2 Is there a significant difference between different CTs of three dimensional fractal patterns in terms of visual interest?

RQ2.3 What is the effect of CTs of natural light on people's emotional response?

H2.1 CT of natural light influence the choice of three dimensional fractal pattern complexity.

H2.2 There is a significant difference between different CTs of projected three dimensional fractal patterns in terms of visual interest.

H2.3a Lower CTs of natural light provide people with a higher *pleasure* state.

H2.3b Higher CTs of natural light provide people with a higher *arousal* state.

4.3 Method of the Study – Phase 1

4.3.1 Specifying the Fractal Patterns

In accordance with the existing literature, fractals may be grouped under two categories; statistical and exact. These two groups are not visually identical despite the fact that they are both physically intricate resulting from their repetitive patterns (Taylor & Spehar, 2016). The difference between these two categorical patterns is that the statistical ones are found in nature and replicate randomly in various scales where the statistical characteristics of the patterns exclusively repeat, whereas the exact fractals come into sight identical at different extensions (Fairbanks & Taylor, 2011; Hagerhall et al., 2015). For instance, a tree that consists of increasingly smaller copies of it may be a great example for statistical fractals. However, the repeating self-similarity in natural structures breaks the given level of magnification (Taylor & Spehar, 2016). Because of their prevalence in nature (Mandelbrot, 1982), the present study has predominantly focused on people's response to statistical fractals.

Furthermore, the most important factor of fractal patterns is fractal dimension (D). This factor measures the scale of fractal relationship between the patterns at different extensions. D value varies from 1 to 2 (Abboushi et al., 2019), and behavioral studies stated that when the D value increases, the perceived visual complexity also increases in direct proportion to the D value (Taylor & Spehar, 2016). Based on the complexity level, fractal patterns may be classified into three groups; low-complexity (D = 1.1 – 1.3), mid-complexity (D = 1.3 – 1.5), and high-complexity (D = 1.5 – 1.9) (Abboushi et al., 2019). The present study focused on five different complexity levels of the same fractal pattern; D = 1.1, D = 1.3, D = 1.5, D = 1.7, and D = 1.9 (see Figure 9). It is worth mentioning that these fractal pattern images were provided with the permission of their original producer, Prof. Richard Taylor, Head of the Physics faculty at Oregon University.

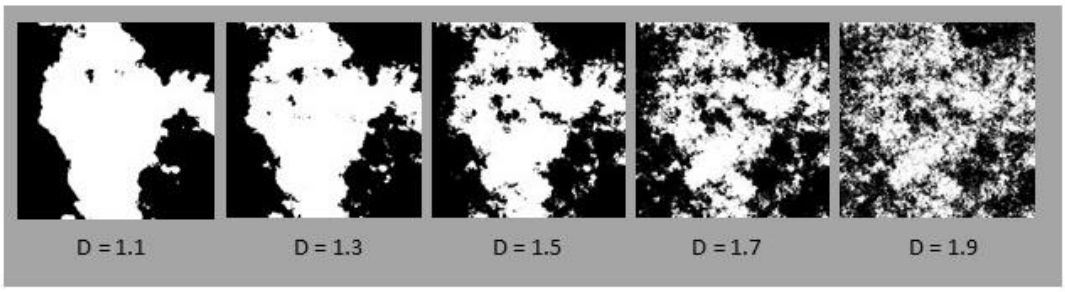

Figure 9. The five different complexity levels of fractal pattern used in the present study

(fractal patterns adapted with the permission of Prof. Richard Taylor)

4.3.2 Specifying the Emotional Response Dimensions

To measure participants' emotional responses for different complexity fractal patterns the M-R (1974) model, adapted from Bradley and Lang's (1994), was used in this study. Bradley and Lang's (1994) presented the PAD model as an independent emotional dimension to analyze people's emotional response on three different dimensions; *pleasure*, *arousal*, and *dominance*. However, as previously mentioned in the literature part, due to the non-significance of the *dominance* dimension, only the *pleasure* and *arousal* dimensions were evaluated in this study, in terms of emotional response.

Participants assessed their emotional states in terms of *pleasure* and *arousal* for the five different complexity fractal pattern images. The questionnaire consisted of two scales, *pleasure* and *arousal*, with six sets of bipolar adjective pairs each. The scale of *pleasure*, considered as a continuum ranging from extreme unhappiness to extreme happiness, included the following bipolar adjective pairs; unhappy-happy, annoyed-pleased, unsatisfied-satisfied, melancholic-contented, despairing-hopeful, and bored-relaxed (Bakker et al., 2014). Whereas the scale of *arousal*, defined as a mental activity describing the state of feeling along single dimension, included the following bipolar adjective pairs; relaxed-stimulated, calm-excited, sluggish-frenzied, dull-jittery, sleepy-wide awake, and unaroused-aroused (Bakker et al., 2014).

4.3.3 Sample Group

Before the experiment, a document including the study aims, methodology, procedure, instruments and participants were prepared for the approval of the ethics committee at Bilkent University (No: 2020_03_02_03). Students' consent form submitted to the ethics committee also included the aims of the study, procedure, benefits, and confidentiality issues about the study. Each participant was informed about the consent form and after they accepted all procedure of the experiment, the study started. The participants were selected by random sampling method. The participation in this study was entirely voluntarily and no reward was provided. The first phase of the study comprised of thirty undergraduate and graduate students enrolled in İhsan Doğramacı Bilkent University. Since this study investigated the effects of CT on both visual interest and emotional response, the sample was chosen among all undergraduate and graduate students except for design students with prior knowledge on color, since, according to Gifford (2007), people who took previous education on color observe the environment in a different way in respect to their emotions and preferences. Therefore, participants who had taken a course about lighting or color were not included in the study (see Table 2 for the distribution of participants' departments).

Table 2. Distribution of the participants' departments – Phase 1

Department	Frequency	Percent
LAW	2	6.7
PREP. SCHOOL	3	10
ENGINEERING	1	3.3
CS	4	13.3
EEE	1	3.3
IE	4	13.3
IR	1	3.3
ELIT	1	3.3
ECONOMICS	2	6.7
PSYCHOLOGY	1	3.3
MBG	2	6.7
POLS	1	3.3
EXECUTIVE MBA	1	3.3
COMD	1	3.3
MANAGEMENT	5	16.7
Total	30	100

Besides the consideration of taken courses criteria, there were also other requirements with respect to the selection of participants, such as participants' age, eye deficiencies, and use of vision correction equipment in case of eye deficiency. For instance, participants younger than 18 years and older than 65 years were not

included in the study. In addition, visual impairments and eye deficiencies were important criteria for this study. Thus, all participants with uncorrectable eye deficiency were not included in the study. Gender and educational level were the secondary criteria for sample selection in this study. These variables were only evaluated as a part of the demographic questionnaire, however, since most participants were female (female= 20; male= 10) and undergraduate students (undergrad = 27; grad = 3) the effect of gender and education level was not examined in the data analysis.

4.3.4 Description of the Setting

The study was conducted in İhsan Doğramacı Bilkent University Library, in one of the Multimedia Rooms, where, as its original purpose, students are able to watch films and listen to music from the Bilkent library collections (see Figure 10). The library consists of seventeen private rooms, which serve as multimedia rooms and isolated areas for studying in groups. These rooms provided students with isolation from the outside open study area by preventing any obvious interaction between inside and outside. The first reason why a multimedia room was chosen as an experiment setting was its isolation property. The second reason was the illumination property. The rooms had both artificial and natural light illumination. To get most variables under control within the experimental setting, the multimedia room without any natural light illumination was chosen. However, each room also had a window opening, which interact with the bigger open study area. Therefore, in order to prevent the distraction of the participants from the outside view, the window opening

was covered with black cardboards. Conducting the study in a multimedia room was also relevant for the sample group selection. The library is the center of the university providing students from all departments with various collections of sources, services, and materials for students. Thus, it is the common point to find students from different departments. This was the third reason why the multimedia room was chosen for the experiment.

Figure 10. Multimedia rooms in İhsan Doğramacı Bilkent University (Image by author)

After taking the previous variables, natural light and window opening, under control, the illuminance level was measured with Minolta Illuminance Meter T-10. The illuminance level in the room was 220 lux, which allowed a clear vision of both the patterns on computer screen and room surfaces where it remained constant during the

whole experiment. In the experiment room, the existent acritical lighting was a Philips Master TLD-18W/840 fluorescent lamp. Participants were seated in front of the computer and each participant had a clear and unobscured view (see Figure 11).

Figure 11. Participants in the experiment
(Image by author)

Participants completed the experiment from the computer screen. Since fractal patterns were shown from the monitor, the RGB color model of computer screen was an important factor in this study, as each computer screen may have a wide range of RGB colors. Therefore, to provide consistency during the whole experiment, the same computer was used in the study for both phases. In order to use the multimedia room for both phases of the experiment, a permission was sought from the Directory Department of the Library. Therefore, the experiment was conducted during library working hours; between 08:30-23:00 on weekdays and 09:00-17:00 on weekends. The whole study, consisting of phase 1 and 2, was conducted over one week from 03.03.2020 to 10.03.2020.

4.3.5 Procedure of the Experiment

For examining the relationship between complexity level and visual interest of fractal patterns, a two-alternative forced choice (2AFC) questionnaire showing two fractal images was prepared (for a sample item of the visual interest assessment questionnaire see Figure 12; for more sample items see Appendix A1**,** *the reason for not providing the full version of the questionnaire was that it consisted of 40 items*). The questionnaire started with the demographic information covering participants' age, gender, department, class, and eye deficiency. Then, it continued with the assessment of visual interest of fractal patterns with different complexity levels. The questionnaire was prepared and filled using the Qualtrics software. For the assessment of visual interest, random combinations consisting of two images were shown side by side to the participants and they were asked to choose the most visually interesting image. There was no time limit for the responses duration.

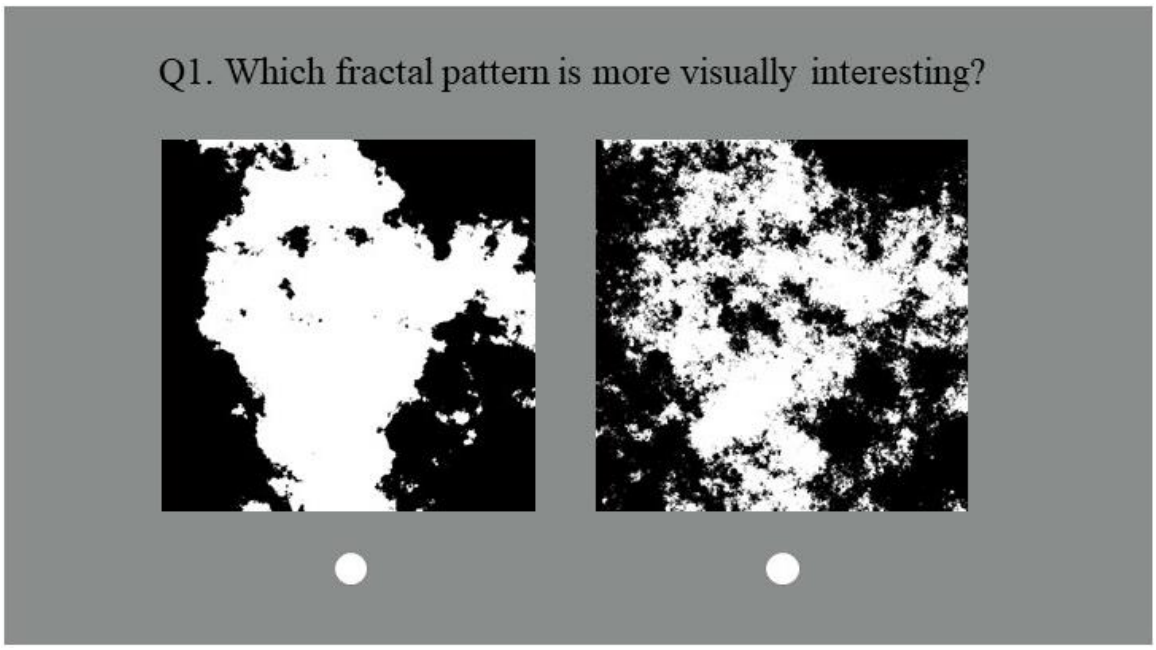

Figure 12. Example stimuli of the visual interest assessment questionnaire

Cohn (1894) (as cited in Spehar et al., 2015), introduced the paired comparison procedure, which is a reliable instrument for the evaluation of form preferences. In this procedure, fractal patterns of each complexity level were paired with all of the other complexity levels in its group, which creates 20 pairs in total. It is important that each fractal pattern is paired with every other pattern in its group and that the presentation frequency on the left and right sides of the pairs is equal for each pattern. All pairs were demonstrated twice in a random order, which creates 40 trials per experiment. Also, to assure eye comfort, a natural gray colored screen appeared for five seconds between each trial.

To analyze people's emotional response to fractal patterns' complexity, the second part of the first phase was conducted. Inspired from the M-R (1974) model the emotional response assessment questionnaire consisting of the *pleasure* and *arousal* dimensions was created. As previously mentioned, the *pleasure* and *arousal* dimensions each consisted of six bipolar adjective pairs (see Table 3). The adjectives were rated on a five-point semantic differential scale; extremely negative, negative, neutral, positive, and extremely positive (for a sample item of the emotional response assessment questionnaire see Figure 13; for more sample items see Appendix A2).

In this study, the questionnaire included both Turkish and English versions simultaneously. The Turkish version of the questionnaire was adapted from Yekanialibeiglou (2015). In the study of Yekanialibeiglou (2015), the English questionnaire was first improved and then translated into Turkish with the help of two native speakers, who were at the same time bilingual experts. This assured the correspondence between the translated items and their originals. The same experts

back-translated the Turkish version of the questionnaire into English. Moreover, in this process, the native speakers revised some items in the Turkish translation. Then, a pilot study with 10 participants was implemented in order to generate final the version of the questionnaire. Based on the results of the pilot study, some of the questionnaire items were revised. The final version of the questionnaire was used in the present study.

Table 3. Bipolar adjective pairs correspondent to the pleasure and arousal dimensions

Pleasure	Arousal
Unhappy-Happy	Relaxed-Stimulated
Annoyed-Pleased	Calm-Excited
Unsatisfied-Satisfied	Sluggish-Frenzied
Melancholic-Contented	Dull-Jittery
Despairing-Hopeful	Sleepy-Wide awake
Bored-Relaxed	Unaroused-Aroused

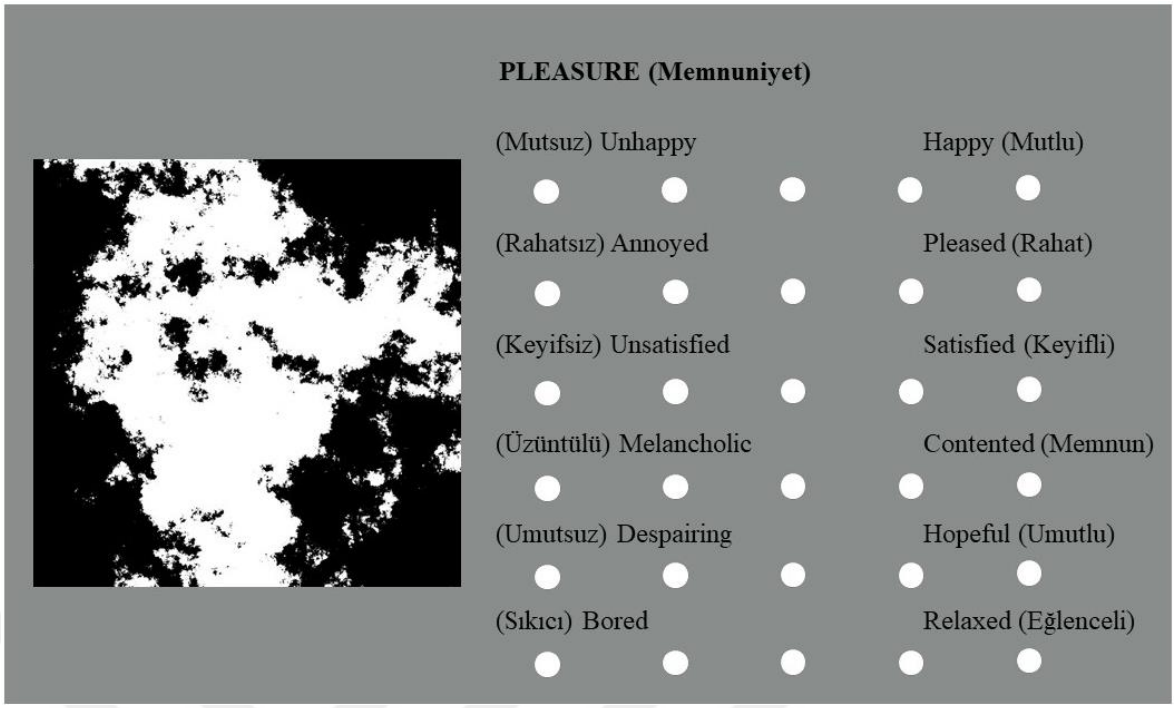

Figure 13. Example stimuli of the emotional response assessment questionnaire

4.4 Method of the Study – Phase 2

The second phase of the study contributed to understand whether natural light had a significant influence on people's preference of different fractal pattern complexities. Also, it contributed to figure out if projecting the pattern images as elements in an interior space would have the same effect on people's visual interest. Therefore, the aim of the second phase was to examine the influence of projected fractal patterns with different natural light's CTs on visual interest and emotional response.

4.4.1 Specifying Color Temperatures

In recent literature, effects of CCT on people's perception has been frequently studied with artificial light. However, no previous study has considered the effects of natural light's CT on people's perception. CCT is based on the natural light's CT. Therefore, this study used different natural light's CTs in order to examine their effects in interior spaces. By projecting the fractal patterns with different CTs of natural light, visual interest and emotional response were assessed. Based on Egan's fundamental CT scale (*previously discussed in the literature*, see Figure 6) three different CTs were considered from three different sky types. These were *Noon*, *Overcast sky* and *Clear Sky*. Therefore, the three examined CTs were chosen from warm to cool colors as 4000K, 6500K, and 12000K.

4.4.2 Sample Group

For the second phase of the experiment, a different participant group was recruited. Before the start of the second phase, each participant was informed about the aims, procedure, benefits, and confidentiality issues of the study. The participants were selected by random sampling method. A total of thirty participants at İhsan Doğramacı Bilkent University joined the second phase of the experiment. For the selection of participants, the same restrictions with the first phase were applied. Thus, participants with prior knowledge on color and design were not included in the experiment, since they may observe the environment in a different way with respect to their emotions and preferences. Moreover, the diversity of the participants was insured with the variety of departments for acquiring data from different groups of

people and, thus, be able to make general statements on the results (see Table 4 for the distribution of the participants' departments).

Table 4. Distribution of the participants' departments – Phase 2

Department	Frequency	Percent
ARCHAEOLOGY	7	23.3
IE	3	10.0
LAW	6	20.0
COMD	1	3.3
PSYCHOLOGY	3	10.0
BANKING&FINANCE	1	3.3
POLS	1	3.3
Other	8	26.7
Total	30	100.0

Participants' age, eye deficiencies, and use of vision correction equipment in case of eye deficiencies were recorded. As applied in the first phase, participants younger than 18 years and older than 65 years were not included in the study. Additionally, participants who had eye deficiency that may not be corrected by correction equipment were not included in the study. Gender and educational level were only evaluated as part of the demographic data, since most participants were female (female = 23; male = 7) and undergraduate students (undergrad = 12; grad = 7; master = 10; phd = 1). Thus, gender and educational level were not considered in the data analysis.

4.4.3 Description of the Setting

The second phase of the study was also conducted in İhsan Doğramacı Bilkent University Library, in the same multimedia room used for the first phase. There was no break taken between the conduction of both phases, since both phases were independent of each other and the participant groups were independent as well. Thus, phase 2 was immediately conducted after having completed the data collection for phase 1.

The same restrictions taken into consideration in the first phase were also applied for the second phase. For instance, the multimedia room was used in the same conditions (with the addition of black cardboards to windows). Moreover, the illuminance level and fluorescent lamp of the setting were the same. Also, as previously mentioned, the same computer was used in both phases to ensure RGB color model consistency during the whole experiment (see Figure 14).

Figure 14. Setting of the experiment

4.4.4 Procedure of the Experiment

The used renders of the projected fractal patterns were generated using Autodesk 3ds Max software (version 2017). The scenario consisted of an interior space with a window through which natural light patterns penetrated and reflected on the space's walls and floor. As previously discussed in the literature, size, color, and material are significant factors influencing users' perception of a space. The characteristics of the generated interior space were as follows. The size of the modeled space was 6.2x5m with a ceiling height of 3m. Also, achromatic colors were used to eliminate colors' impact on space perception. As for the projection surfaces, a smooth material with no texture was applied to the walls.

For analyzing the visual interest of different CT of projected fractal patterns, a two-alternative forced choice (2AFC) test was prepared (for a sample item see Figure 15; for more sample items see Appendix B1**,** *the reason for not providing the full version of the questionnaire was that it consisted of 120 items*). The questionnaire included a section on the participants' demographic information and it continued with the evaluation of visual interest of projected fractal patterns with different CTs. The second phase of the study was also prepared and filled using the Qualtrics software.

Three different CTs, including 4000 Kelvin, 6500 Kelvin, and 12000 Kelvin, were analyzed in the present study. The experiment emphasized the significant influence of the same CT on different complexity levels. Random combinations of two images were shown side by side to the participants, and they were asked to choose the most visually interesting image. In the experiment, projected fractal patterns of different

complexity levels were paired with each other under the same CT group, resulting in a total of 20 pairs. Also, the position of the paired items was important where each paired item was presented twice to ensure that all patterns' presentation frequency was equal on the left and right sides. All pairs were demonstrated twice, randomly, thus, each CT consisted of 40 paired items. Since the study evaluated three different CTs (4000K, 6500K, & 12000K), a questionnaire with a total of 120 items was created. Also, after each paired item, a F screen (RGB Hex decimal: #898e8c) was demonstrated for five seconds to assure eye comfort.

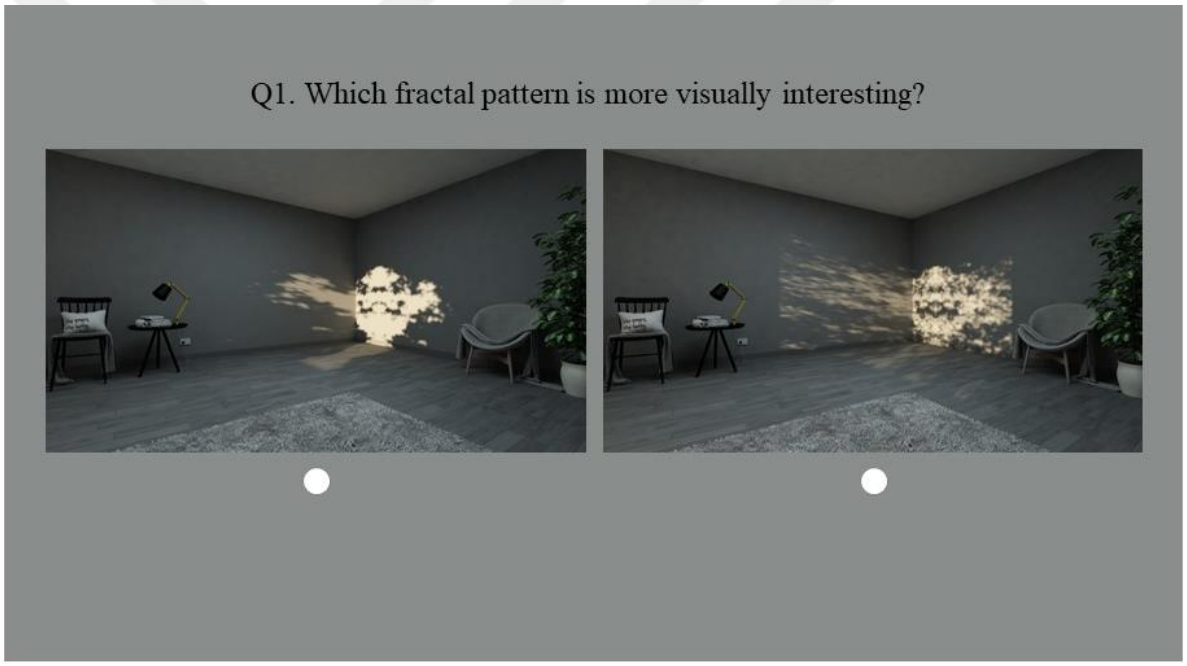

Figure 15. Sample item of the visual interest assessment questionnaire (4000K) – Phase 2

To examine the emotional response to different CTs of fractal patterns' complexity, the second part of the second phase was conducted. To assess participants' emotional states, the same emotional response questionnaire applied in the first phase was used in the second phase of the experiment (for a sample item see Figure 16; for more sample items see Appendix B2).

Figure 16. Sample item of the emotional response assessment questionnaire (4000K) – Phase 2

CHAPTER V

RESULTS

This chapter consists of the research findings and statistical analysis of the empirical study. It introduces the results on the influence of different fractal patterns' complexity on visual interest and emotional response. Furthermore, it presents the analysis results on the effect of different complexity fractal patterns projected with different natural light CTs on visual interest and emotional response in interior spaces.

5.1 Data Analysis

Statistical Package for Social Sciences (SPSS) software version 20.0 was used to analyze the collected data. Firstly, the data related to demographic information of the participants were analyzed. Secondly, for analyzing the rest of the data Shapiro-Wilk test and Wilcoxon Signed-rank test were used.

5.2 Results of the Experiment – Phase 1

In the following part, the results of the demographic, visual interest and emotional response questionnaires for phase 1 were presented.

5.2.1 Results of the Demographic Questionnaire

The study was conducted with 30 participants who were undergraduate and graduate students enrolled in the İhsan Doğramacı Bilkent University. In total, there were 20 females (66.67%) and 10 male participants (33.33%). The age of the sample group varied between 18 and 48 years, and the majority of the participants were between 18 and 27 years (93.3%). Due to the inequality of the number of participants in terms of gender, the effect of gender was not examined in the study (see Table 5).

Table 5. Demographic information of the participants – Phase 1

Characteristics	Category	Frequency	Percentages
Age	18-27	28	93.3
	28-37	1	3.3
	48 and older	1	3.3
Gender	Female	20	66.7
	Male	10	33.3
Class	Undergraduate	27	90.0
	Graduate	2	6.7
	Postgrad	1	3.3
Eye Defects	No	30	100.0

5.2.2 Results of the Visual Interest Assessment Questionnaire

Data analysis was conducted with the aim to examine the influence of fractal patterns complexity on visual interest. Before examining the differences between fractal pattern complexity groups in terms of visual interest, frequency tables were generated to understand which complexity level was chosen the most mostly chosen (see Table 6). Findings indicated that visual interest rating was the highest for high-complexity fractal pattern D = 1.7, (*Mean: 10.57, SD: 3.8*). Additionally, the visual interest for the other fractal pattern complexities were D = 1.5 (*Mean: 10.13, SD: 2.9*), D = 1.9 (*Mean: 8, SD: 5.9*), D = 1.3 (*Mean: 7.17, SD: 3.6*). Generally, fractal pattern of D = 1.3 (Mean: 4.13, SD: 4.9) was the least visually interesting among all the fractal patterns (see Table 6). Results also demonstrated no significant difference between visual interest of fractal patterns for D = 1.7 and D = 1.5.

Table 6. Frequency table of fractal pattern's complexity levels – Phase 1

Complexity Level	Frequency	Mean	Std. Deviation
1.1	124	4.13	4.939
1.3	215	7.17	3.630
1.5	304	10.13	2.968
1.7	317	10.57	3.803
1.9	240	8.00	5.965

Furthermore, the Wilcoxon Signed-rank test was conducted in order to analyze the differences between fractal pattern complexity groups in terms of visual interest. Before this test, to determine whether variables were normally distributed or not, the Kolmogorov-Smirnov and Shapiro-Wilk test were conducted. Results indicated that the variables were not normally distributed ($p<0.05$) (see Appendix C, Table 37). Therefore, for the data analysis, nonparametric tests were used. According to Berman and Wang (2012) the Wilcoxon Signed-rank test is the nonparametric alternative to the paired T-test. This is why the Wilcoxon Signed-rank test was conducted.

Results of the Wilcoxon Signed-rank test demonstrated a significant difference on visual interest ratings among most of the fractal patterns complexity levels. However, the following fractal pattern complexity levels did not demonstrate a significant difference in terms of visual interest ratings; D = 1.3 and D = 1.9, D = 1.5 and D = 1.7, and D = 1.5 and D = 1.9 **(**see Table 7**)**.

Table 7. Wilcoxon Signed-rank test results for visual interest of fractal patterns' different complexity levels – Phase 1

		Visual Interest (Z)	Asymp. Sig. (2 – Tailed)
1.1	**1.3**	-3.973	**0.000**
	1.5	-3.855	**0.000**
	1.7	-3.380	**0.001**
	1.9	-2.049	**0.040**
1.3	**1.5**	-3.855	**0.001**
	1.7	-2.117	**0.034**
	1.9	-0.721	0.471
1.5	**1.7**	-0.629	0.529
	1.9	-1.588	0.112
1.7	**1.9**	-2.373	**0.018**

5.2.3 Results of the Emotional Response Assessment Questionnaire

Before analyzing the statistical tests, reliability analysis was conducted to examine the internal consistency reliability of the emotional response questionnaire. To assure consistency of the questionnaire items, Cronbach's alphas were calculated. The Cronbach's alpha values were categorized by Mallery (1999) into five groups, excellent ($\alpha \geq 0.9$), good ($0.7 \leq \alpha < 0.9$), acceptable ($0.6 \leq \alpha < 0.7$), poor ($0.5 \leq \alpha < 0.6$), and unacceptable ($\alpha < 0.5$). According to the results, all parts of the questionnaire had an Alpha value over 0.70. Thus, the results of Cronbach's alpha

showed that the questionnaire had a good reliability and internal consistency (see Table 8).

Table 8. Cronbach's alpha values correspondent to different complexity levels of the pleasure and arousal dimensions – Phase 1

Complexity Level	Dimension	Cronbach's Alpha
1.1	Pleasure	0.927
	Arousal	0.900
1.3	Pleasure	0.899
	Arousal	0.852
1.5	Pleasure	0.851
	Arousal	0.819
1.7	Pleasure	0.916
	Arousal	0.760
1.9	Pleasure	0.937
	Arousal	0.763

The results of the mean scores of participants' emotional response were analyzed in order to understand how the *pleasure* and *arousal* states were influenced by different complexity levels of fractal patterns. Results indicated that the minimum and maximum mean scores belonged to the *arousal* dimension items; ''sluggish-frenzied'' with a mean score of 2.17 (negative) and ''sleepy-wide awake'' with a mean score of 3.93 (positive) (see Appendix C, Table 38-47). Among the items of *pleasure*, for all complexity levels, participants rated all six feelings as ''neutral''

(unhappy-happy, annoyed-pleased, unsatisfied-satisfied, melancholic-contented, despairing-hopeful, and bored-relaxed).

Among the items of *arousal*, for D= 1.1 participants felt ‘‘neutral’’ about the item sleepy-wide awake and ‘‘negative’’ about all the other five items relaxed, calm, sluggish, dull, and unaroused. For D= 1.3 and D= 1.5 participants rated all six feelings as ‘‘neutral’’ (relaxed-stimulated, calm-excited, sluggish-frenzied, dull-jittery, sleepy-wide awake, and unaroused-aroused). For D= 1.7 participants felt ‘‘positive’’ about the items stimulated, wide awake, aroused, whereas they felt ‘‘neutral’’ about three items calm-excite, sluggish-frenzied, and dull-jittery. Moreover, for D= 1.9 participants rated an item dull-jittery as ‘‘neutral’’ while they rated the other five items as ‘‘positive’’ (stimulated, excited, frenzied, wide awake, and aroused). Therefore, the complexity of fractal patterns had no significant influence on participants’ *pleasure* state, however, it had a significant positive influence on participants’ *arousal* state.

After calculating the mean scores of participants’ emotional response to different fractal patterns’ complexity levels, normality test was also applied. Results demonstrated that emotional states, which included the dimensions of *pleasure* and *arousal*, were not normally distributed among complexity levels ($p < 0.05$) (see Appendix C, Table 48).

5.2.3.1 Pleasure State

For examining the effects caused by different complexity levels of fractal patterns on people's *pleasure* state, Wilcoxon Signed-rank test was used. The data was analyzed and accepted for the significance levels 0.05 and 0.01. According to the Wilcoxon Signed-rank test results, there was a significant difference between the effect of complexity levels on participants' *pleasure* state for the levels D = 1.1 and D = 1.9 (**s**ee Table 9). However, there was no significant difference in the *pleasure* state of participants in all other different complexity levels except between D = 1.1 and D = 1.9, where a significant difference was demonstrated.

Table 9. Wilcoxon Signed-rank test results for the pleasure and arousal dimensions – Phase 1

		Pleasure		**Arousal**	
		Z	**Asymp. Sig. (2-Tailed)**	**Z**	**Asymp. Sig. (2-Tailed)**
1.1	1.3	-0.95	0.339	-3.16	**0.002**
	1.5	-0.23	0.811	-2.89	**0.004**
	1.7	-0.31	0.757	-3.78	**0.000**
	1.9	-2.66	**0.008**	-3.61	**0.000**
1.3	1.5	-0.19	0.848	-1.43	0.153
	1.7	-0.09	0.927	-3.05	**0.002**
	1.9	-0.25	0.802	-3.02	**0.003**
1.5	1.7	-0.08	0.929	-2.79	**0.005**
	1.9	-0.58	0.556	-2.81	**0.005**
1.7	1.9	-0.59	0.552	-1.50	0.132

*represents $p < 0.05$

5.2.3.2 Arousal State

In order to evaluate the effects of different complexity levels of fractal patterns on people's *arousal* state, Wilcoxon Signed-rank test was used. The test results demonstrated that there was a significant difference between the effect of complexity levels on participants' *arousal* state among the following levels; [D = 1.1 and D = 1.3], [D = 1.1 and D = 1.5], [D = 1.1 and D = 1.7], [D = 1.1 and D = 1.9], [D = 1.3 and D = 1.7], [D = 1.3 and D = 1.9], [D = 1.5 and D = 1.7], and [D = 1.5 and D = 1.9] (**s**ee Table 9). Therefore, there was a significant difference in the *arousal* state of participants between different complexity levels except for the levels D = 1.3 and D = 1.5, and D = 1.7 and D = 1.9 where a significant difference was not demonstrated.

5.2.3.3 Itemized Analysis

In order to further examine in details, the influence of complexity levels on the *pleasure* and *arousal* dimensions, Wilcoxon Signed-rank test was used to investigate the effects caused by different complexity levels of fractal patterns on individual items by using adjective pairs.

Pleasure Dimension

For all items of the *pleasure* dimension, results indicated no significant difference between the complexity levels (see Tables 10-19).

Table 10. *Findings of the itemized analysis for D = 1.1 and D = 1.3 – Phase 1*

Items	Significant difference	No significant difference
unhappy-happy		p = 0.803
annoyed-pleased		p = 0.479
unsatisfied-satisfied		p = 0.632
melancholic-contented		p = 0.667
despairing - hopeful		p = 0.311
bored-relaxed		p = 0.665

Table 11. Findings of the itemized analysis for D = 1.1 and D = 1.5 – Phase 1

Items	Significant difference	No significant difference
unhappy-happy		p = 0.924
annoyed-pleased		p = 0.889
unsatisfied-satisfied		p = 0.339
melancholic-contented		p = 0.915
despairing - hopeful		p = 0.714
bored-relaxed		p = 0.474

Table 12. Findings of the itemized analysis for D = 1.1 and D = 1.7 – Phase 1

Items	Significant difference	No significant difference
unhappy-happy		p = 0.924
annoyed-pleased		p = 0.821
unsatisfied-satisfied		p = 0. 840
melancholic-contented		p = 0.870
despairing - hopeful		p = 0.478
bored-relaxed		p = 0.066

Table 13. Findings of the itemized analysis for D = 1.1 and D = 1.9 – Phase 1

Items	Significant difference	No significant difference
unhappy-happy		p = 0.600
annoyed-pleased		p = 0.897
unsatisfied-satisfied		p = 0.416
melancholic-contented		p = 0.921
despairing - hopeful		p = 0.854
bored-relaxed		p = 0.052

Table 14. Findings of the itemized analysis for D = 1.3 and D = 1.5 – Phase 1

Items	Significant difference	No significant difference
unhappy-happy		p = 0.866
annoyed-pleased		p = 0.489
unsatisfied-satisfied		p = 0.235
melancholic-contented		p = 0.441
despairing - hopeful		p = 0.158
bored-relaxed		p = 0.752

Table 15. Findings of the itemized analysis for D = 1.3 and D = 1.7 – Phase 1

Items	Significant difference	No significant difference
unhappy-happy		p = 1.000
annoyed-pleased		p = 0.506
unsatisfied-satisfied		p = 0.958
melancholic-contented		p = 0.720
despairing - hopeful		p = 0.158
bored-relaxed		p = 0.227

Table 16. Findings of the itemized analysis for D = 1.3 and D = 1.9 – Phase 1

Items	Significant difference	No significant difference
unhappy-happy		p = 0.684
annoyed-pleased		p = 0.951
unsatisfied-satisfied		p = 0.934
melancholic-contented		p = 0.774
despairing - hopeful		p = 0.893
bored-relaxed		p = 0.178

Table 17. Findings of the itemized analysis for D = 1.5 and D = 1.7 – Phase 1

Items	Significant difference	No significant difference
unhappy-happy		p = 0.862
annoyed-pleased		p = 0.951
unsatisfied-satisfied		p = 0.436
melancholic-contented		p = 0.432
despairing - hopeful		p = 0.612
bored-relaxed		p = 0.179

Table 18. Findings of the itemized analysis for D = 1.5 and D = 1.9 – Phase 1

Items	Significant difference	No significant difference
unhappy-happy		p = 0.684
annoyed-pleased		p = 0.951
unsatisfied-satisfied		p = 0.934
melancholic-contented		p = 0.774
despairing - hopeful		p = 0.893
bored-relaxed		p = 0.178

Table 19. Findings of the itemized analysis for D = 1.7 and D = 1.9 – Phase 1

Items	Significant difference	No significant difference
unhappy-happy		p = 0.695
annoyed-pleased		p = 0.858
unsatisfied-satisfied		p = 0.156
melancholic-contented		p = 0.847
despairing - hopeful		p = 0.302
bored-relaxed		p = 0.666

Arousal Dimension

For D = 1.1 and D = 1.3, results demonstrated that there was a significant difference on the effect of *arousal* dimension items relaxed – stimulated and sluggish – frenzied. However, for the rest of the items there was no significant difference (see Table 20).

Table 20. *Findings of the itemized analysis for arousal dimension (D = 1.1 & D = 1.3) – Phase 1*

Items	Significant difference	No significant difference
relaxed - stimulated	p = 0.004	
calm - excited		p = 0.088
sluggish - frenzied	p = 0.001	
dull - jittery		p = 0.148
sleepy – wide awake		p = 0.600
unaroused - aroused		p = 0.082

For D = 1.1 and D = 1.5, results demonstrated that there was a significant difference on the effect of *arousal* dimension items relaxed – stimulated, calm – excited, sluggish – frenzied, and unaroused – aroused. However, for the rest of the items there was no significant difference (see Table 21).

Table 21. Findings of the itemized analysis for arousal dimension (D = 1.1 & D = 1.5) – Phase 1

Items	Significant difference	No significant difference
relaxed - stimulated	p = 0.008	
calm - excited	p = 0.033	
sluggish - frenzied	p = 0.008	
dull - jittery		p = 0.092
sleepy – wide awake		p = 0.154
unaroused - aroused	p = 0.005	

For D = 1.1 and D = 1.7, the test results demonstrated a significant difference on the effects of *arousal* dimension items relaxed – stimulated, calm – excited, sluggish – frenzied, dull – jittery, sleepy – wide awake, and unaroused – aroused (see Table 22).

Table 22. Findings of the itemized analysis for arousal dimension (D = 1.1 & D = 1.7) – Phase 1

Items	Significant difference	No significant difference
relaxed - stimulated	p = 0.001	
calm - excited	p = 0.005	
sluggish - frenzied	p = 0.000	
dull - jittery	p = 0.004	
sleepy – wide awake	p = 0.008	
unaroused - aroused	p = 0.000	

For D = 1.1 and D = 1.9, the test results demonstrated a significant difference on the effects of *arousal* dimension items relaxed – stimulated, calm – excited, sluggish – frenzied, dull – jittery, sleepy – wide awake, and unaroused – aroused (see Table 23).

Table 23. Findings of the itemized analysis for arousal dimension (D = 1.1 & D = 1.9) – Phase 1

Items	Significant difference	No significant difference
relaxed - stimulated	p = 0.004	
calm - excited	p = 0.001	
sluggish - frenzied	p = 0.000	
dull - jittery	p = 0.022	
sleepy – wide awake	p = 0.002	
unaroused - aroused	p = 0.001	

For D = 1.3 and D = 1.5, results demonstrated that there was no significant difference for all items on the effect of *arousal* dimension (see Table 24).

Table 24. Findings of the itemized analysis for arousal dimension (D = 1.3 & D = 1.5) – Phase 1

Items	Significant difference	No significant difference
relaxed - stimulated		p = 0.195
calm - excited		p = 0.433
sluggish - frenzied		p = 0.512
dull - jittery		p = 0.576
sleepy – wide awake		p = 0.180
unaroused - aroused		p = 0.360

For D = 1.3 and D = 1.7, the test results demonstrated that there was a significant difference on the effect of *arousal* dimension items relaxed – stimulated, sluggish – frenzied, sleepy – wide awake, and unaroused- aroused. However, for the rest of the items there was no significant difference (see Table 25).

Table 25. Findings of the itemized analysis for arousal dimension (D = 1.3 & D = 1.7) – Phase 1

Items	Significant difference	No significant difference
relaxed - stimulated	p = 0.044	
calm - excited		p = 0.090
sluggish - frenzied	p = 0.011	
dull - jittery		p = 0.061
sleepy – wide awake	p = 0.013	
unaroused - aroused	p = 0.002	

For D = 1.3 and D = 1.9, the test results demonstrated that there was a significant difference on the effect of *arousal* dimension items calm – excited, sluggish – frenzied, sleepy – wide awake, and unaroused – aroused. However, for the rest of the items there was no significant difference (see Table 26).

Table 26. Findings of the itemized analysis for arousal dimension (D = 1.3 & D = 1.9) – Phase 1

Items	Significant difference	No significant difference
relaxed - stimulated		p = 0.195
calm - excited	p = 0.013	
sluggish - frenzied	p = 0.007	
dull - jittery		p = 0.060
sleepy – wide awake	p = 0.013	
unaroused - aroused	p = 0.002	

For D = 1.5 and D = 1.7, the test results demonstrated that there was a significant difference on the effect of *arousal* dimension items relaxed – stimulated, sluggish – frenzied, dull – jittery, and unaroused – aroused. However, for the rest of the items there was no significant difference (see Table 27).

Table 27. Findings of the itemized analysis for arousal dimension (D = 1.5 & D = 1.7) – Phase 1

Items	Significant difference	No significant difference
relaxed - stimulated	p = 0.043	
calm - excited		p = 0.104
sluggish - frenzied	p = 0.027	
dull - jittery	p = 0.044	
sleepy – wide awake		p = 0.193
unaroused - aroused	p = 0.036	

For D = 1.5 and D = 1.9, the test results demonstrated that there was a significant difference on the effect of *arousal* dimension items calm – excited, sluggish – frenzied, sleepy – wide awake, and unaroused – aroused. However, for the rest of the items there was no significant difference (see Table 28).

Table 28. Findings of the itemized analysis for arousal dimension (D = 1.5 & D = 1.9) – Phase 1

Items	Significant difference	No significant difference
relaxed - stimulated		p = 0.114
calm - excited	p = 0.011	
sluggish - frenzied	p = 0.005	
dull - jittery		p = 0.116
sleepy – wide awake	p = 0.036	
unaroused - aroused	p = 0.011	

For D = 1.7 and D = 1.9, results demonstrated that there was no significant difference for all items on the effect of *arousal* dimension. (see Table 29).

Table 29. Findings of the itemized analysis for arousal dimension (D = 1.7 & D = 1.9) – Phase 1

Items	Significant difference	No significant difference
relaxed - stimulated		p = 0.866
calm - excited		p = 0.064
sluggish - frenzied		p = 0.064
dull - jittery		p = 0.817
sleepy – wide awake		p = 0.110
unaroused - aroused		p = 0.469

Therefore, in general, the results indicated that there was a significant difference between the complexity levels D = 1.1 and D = 1.5, D = 1.1 and D = 1.7, D = 1.1 and D = 1.9, D = 1.3 and D = 1.7, D = 1.3 and D = 1.9, D = 1.5 and D = 1.7, and D = 1.5 and D = 1.9 on the *arousal* states of participants. Therefore, findings reported a significant influence of fractal patterns complexity levels on *arousal* state.

5.3 Results of the Experiment – Phase 2

In the following part, the results of the demographic, visual interest and emotional response questionnaires for phase 2 were presented.

5.3.1 Results of the Demographic Questionnaire

The study included 30 participants from İhsan Doğramacı Bilkent University. The participants were selected by random sampling method. Diversity of the participants was also significant for the experiment in order to obtain general statement on the results. Thus, large groups of people took part in the study. However, the same restrictions of participants' selection with the first phase were applied. Table 30 demonstrated the demographic information of the participants in phase 2.

Table 30. Demographic information of the participants - Phase 2

Characteristics	Category	Frequency	Percentages
Age	18-27	23	76.7
	28-37	6	20.0
	38-47	1	3.3
Gender	Female	23	76.7
	Male	7	23.3
Class	Undergraduate	12	40.0
	Graduate	7	23.3
	Postgrad	11	36.6
Eye Defects	No	30	100.0

In the second phase of the experiment, there were 23 female participants (76.7%) and 7 male participants (23.3%). As a result of unequal distribution of the participants, the gender effect was not considered in the data analysis. The age group of participants varied between 18 and 48 years, and the majority of the participants were between 18 and 27 years (76.7%).

5.3.2 Results of the Visual Interest Assessments Questionnaire

In the second phase of the study, data were analyzed to find out the effects of projected fractal patterns' complexity levels with three different CTs (4000K, 6500K, and 12000K) on visual interest ratings. Each CT of projected fractal pattern group was analyzed on itself. Before analyzing the data, in order to understand whether there is a significant difference between the visual interest of complexity levels under different CTs, frequency tables were generated to determine which complexity level was chosen the most to understand which complexity level was mostly chosen (see Table 31).

Table 31. Frequency table of projected fractal patterns' complexity levels with different CTs – Phase 2

CT	Complexity Level	Frequency
4000K	1.1	79
	1.3	155
	1.5	272
	1.7	351
	1.9	343
6500K	1.1	115
	1.3	200
	1.5	268
	1.7	326
	1.9	291
12000K	1.1	145
	1.3	199
	1.5	273
	1.7	315
	1.9	268

According to the results, visual interest for the projected fractal pattern with 4000K peaked for high-complexity D = 1.7 (*Mean = 11.70; SD = 4*); 6500K peaked for high-complexity D = 1.7 (*Mean = 10.87; SD = 4.5*); 12000K peaked for high-complexity D = 1.7 (*Mean = 10.50; SD = 4.7*). Additionally, the least visually interesting projected fractal pattern for 4000K was low-complexity D = 1.1 (*Mean = 2.63; SD = 3.6*); for 6500K was low-complexity D = 1.1 (*Mean = 3.38; SD = 5*); for 12000K was low-complexity D = 1.1 (*Mean = 4.83; SD = 5.9*). Furthermore, the visual interest for the other projected fractal pattern complexities for 4000K were D

= 1.3 (*Mean = 5.17; SD = 2.6*), D = 1.5 (*Mean = 9.07; SD = 2.6*), and D = 1.9 (*Mean = 11.43; SD = 4.7*); for 6500K were D = 1.3 (*Mean = 6.67; SD = 3.2*), D = 1.5 (*Mean = 8.93; SD = 3.7*), and D = 1.9 (*Mean = 9.70; SD = 6.1*); for 12000K were D = 1.3 (*Mean = 6.63; SD = 3.1*), D = 1.5 (*Mean = 9.10; SD = 4.2*), and D = 1.9 (*Mean = 8.93; SD = 5.9*) (see Table 32).

Table 32. Mean scores of projected fractal pattern's complexity levels with different CTs – Phase 2

CT	Complexity Level	Mean	Std. Deviation
4000K	1.1	2.63	3.672
	1.3	5.17	2.627
	1.5	9.07	2.612
	1.7	11.70	4.001
	1.9	11.43	4.725
6500K	1.1	3.83	5.004
	1.3	6.67	3.273
	1.5	8.93	3.741
	1.7	10.87	4.569
	1.9	9.70	6.143
12000K	1.1	4.83	5.972
	1.3	6.63	3.157
	1.5	9.10	4.262
	1.7	10.50	4.790
	1.9	8.93	5.988

Results indicated that, for all natural light's CTs, high-complexity projected fractal patterns were the most visually interesting and lower complexity projected fractal patterns were the least visually interesting patterns. However, the results demonstrated that the frequency percentages of lower complexity projected fractal patterns gradually increased while the CT increased. Thus, low-complexity projected fractal patterns were found more visually interesting for high CT of natural light. Furthermore, results demonstrated that the most visually interesting CT was that of 4000K with the high-complexity D = 1.7 (*Mean = 11.70; SD = 4*) and the least visually interesting one was 4000K with the low-complexity D = 1.1 (*Mean = 2.63; SD = 3.6*).

Before conducting any statistical test, to measure significant difference between the complexity level of projected fractal pattern, Shapiro-Wilk test was used to determine whether variables are normally distributed or not. Based on the Kolmogorov-Smirnov and Shapiro-Wilk normality tests, the variables were not normally distributed ($p<0.05$) (see Appendix C, Table 49). Thus, Wilcoxon Signed-rank test-nonparametric test- was used in order to analyze the differences in visual interest among the different complexity levels for each CT of natural light.

The test results demonstrated that, for D= 1.1, there was a significant difference between the CTs [4000K and 6500K], [4000K and 12000K], and [6500K and 12000K]. For D = 1.3, results indicated a significant difference between the CTs [4000K and 6500], [4000K and 12000K]. For D = 1.7, results indicated a significant difference between the CTs [4000K and 12000K]; For D = 1.9 results indicated a

significant difference between the CTs [4000K and 12000K]. However, for the rest of the color temperatures there was no significant difference (see Table 33).

Table 33. Wilcoxon Signed-rank test results for visual interest of projected fractal patterns' complexity levels and CTs – Phase 2

		Visual Interest (Z)	Asymp. Sig. (2 – Tailed)
1.1 – 4000K	1.1 – 6500K	-2.143	**0.032**
	1.1 – 12000K	-2.229	**0.026**
1.3 – 4000K	1.3 – 6500K	-3.368	**0.001**
	1.3 – 12000K	-2.215	**0.027**
1.5 – 4000K	1.5 – 6500K	-0.053	0.958
	1.5 – 12000K	-0.393	0.694
1.7 – 4000K	1.7 – 6500K	-1.114	0.265
	1.7 – 12000K	-2.050	**0.040**
1.9 – 4000K	1.9 – 6500K	-1.920	0.055
	1.9 – 12000K	-2.536	**0.011**
1.1 – 6500K	1.1 – 12000K	-2.031	**0.042**
1.3 – 6500K	1.3 – 12000K	-0.122	0.903
1.5 – 6500K	1.5 – 12000K	-0.523	0.601
1.7 – 6500K	1.7 – 12000K	-1.195	0.232
1.9 – 6500K	1.9 – 12000K	-0.863	0.388

5.3.3 Results of the Emotional Response Assessment Questionnaire

Before analyzing the statistical tests, reliability test was carried out in order to examine the internal consistency reliability of the emotional states questionnaire. Results demonstrated that all items of the questionnaire had a good reliability and internal consistency with a Cronbach's alpha value over 0.70 (see Table 34).

Table 34. Cronbach's alpha values correspondent to different complexity levels projected with different CTs for pleasure and arousal dimensions – Phase 2

CT	Complexity Level	Part	Cronbach's Alpha
4000K	1.1	Pleasure	0.959
		Arousal	0.965
	1.3	Pleasure	0.960
		Arousal	0.926
	1.5	Pleasure	0.950
		Arousal	0.842
	1.7	Pleasure	0.903
		Arousal	0.905
	1.9	Pleasure	0.944
		Arousal	0.900
6500K	1.1	Pleasure	0.961
		Arousal	0.952
	1.3	Pleasure	0.953
		Arousal	0.941

Cont'd **(Table 34)**

CT	Complexity Level	Part	Cronbach's Alpha
6500K	1.5	Pleasure	0.960
		Arousal	0.867
	1.7	Pleasure	0.956
		Arousal	0.911
	1.9	Pleasure	0.942
		Arousal	0.917
12000K	1.1	Pleasure	0.975
		Arousal	0.952
	1.3	Pleasure	0.957
		Arousal	0.941
	1.5	Pleasure	0.970
		Arousal	0.925
	1.7	Pleasure	0.971
		Arousal	0.956
	1.9	Pleasure	0.964
		Arousal	0.922

The mean scores of participants' *pleasure* and *arousal* states were evaluated to examine the effects of different complexity levels projected with different CTs on people's emotional response. For 4000K, results demonstrated that the minimum and maximum mean scores belonged to the *arousal* dimension items; ''unaroused-

aroused'' with a minimum mean score of 2.67 (neutral) and again ''unaroused-aroused'' with a maximum mean score of 3.83 (positive).

However, for 6500K, the minimum score belonged to the *pleasure* dimension item ''bored-relaxed'' with a mean score of 2.77 (neutral), and the maximum score belonged to the *arousal* dimension item ''unaroused-aroused'' with a mean score of 3.97 (positive). As for 12000K, the minimum and maximum scores belonged to the *arousal* dimension item ''unaroused-aroused'' with a mean score of 2.27 (neutral) and again ''unaroused-aroused'' with a mean score of 3.93 (Positive) (see Appendix C, Table 50-79). After analyzing the minimum and maximum mean scores of the *pleasure* and *arousal* dimensions, the mean scores of the items were then examined one by one according to different CTs and complexity levels of fractal patterns.

Firstly, for 4000K and for all complexity levels, D = 1.1, D = 1.3, D = 1.5, D = 1.7, and D = 1.9, participants rated all six feelings under the *pleasure* dimension as ''neutral'' (unhappy-happy, melancholic-contented, despairing-hopeful), except for the complexity level of D = 1.9 where participants rated the *pleasure* item of annoyed-pleased, unsatisfied-satisfied, and bored-relaxed as positive with a mean score of 3.57, 3.53, and 3.50 respectively. As for the *arousal* dimension, for D = 1.1, participants felt ''neutral'' about all items (relaxed-stimulated, calm-excited, sluggish-frenzied, dull-jittery, sleepy-wide awake, and unaroused-aroused). For D = 1.3, participants felt ''neutral'' about the items calm-excited, sluggish-frenzied, dull-jittery, sleepy-wide awake, and unaroused-aroused and ''positive'' about stimulated item of the *arousal* dimension. For D = 1.5, within the *arousal* dimension, participants felt ''neutral'' about the items calm-excited, sluggish-frenzied, and dull-

jittery, while they felt ‘‘positive’’ about the items stimulated, wide awake, and aroused. For D = 1.7, among the items of *arousal* dimension, participants rated the items relaxed-stimulated, and calm-excited as ‘‘neutral’’ and the items frenzied, jittery, wide awake, and aroused as ‘‘positive’’. Moreover, for D = 1.9, participants rated the items calm-excited and dull-jittery as ‘‘neutral’’ while they rated the items stimulated, frenzied, wide awake, and aroused as ‘‘positive’’ (see Appendix C, Table 50-59).

Secondly, for 6500K and for D = 1.1, D = 1.3, and D = 1.5, participants rated all items of *pleasure* dimension as ‘‘neutral’’ (unhappy-happy, annoyed-pleased, unsatisfied-satisfied, melancholic-contented, despairing-hopeful, and bored-relaxed). For D = 1.7, participants felt ‘‘neutral’’ about the items annoyed-pleased, unsatisfied-satisfied, melancholic-contented, and despairing-hopeful while they felt ‘‘positive’’ about happy and relaxed items of the *pleasure* dimension. For D = 1.9, participants felt ‘‘positive’’ about the items happy, pleased, satisfied, contented, and relaxed and they felt ‘‘neutral’’ about the bored-relaxed item of *pleasure* dimension.

As for the *arousal* dimension, for D = 1.1, participants felt ‘‘neutral’’ about the items relaxed-stimulated, calm-excited, sluggish-frenzied, dull-jittery, sleepy-wide awake, and unaroused-aroused. For D = 1.3, participants felt ‘‘neutral’’ about the items calm-excited, sluggish-frenzied, dull-jittery, sleepy-wide awake, and unaroused-aroused items and they felt ‘‘positive’’ about the stimulated item. For D = 1.5, participants felt ‘‘neutral’’ about the items relaxed-stimulated, and dull-jittery and they felt ‘‘positive’’ about the items excited, frenzied, wide awake, and aroused. For D = 1.7, participants felt ‘‘neutral’’ about the dull-jittery items and they felt

‘‘positive’’ about the stimulated, excited, frenzied, wide awake, aroused items. For D = 1.9, participants felt ‘‘neutral’’ about the calm-excited and dull-jittery items and they felt ‘‘positive’’ about the items stimulated, frenzied, wide awake, aroused (see Appendix C, Table 60-69).

Thirdly, for 12000K, and for D = 1.1, D = 1.3, D = 1.5 and D = 1.7, participants felt ‘‘neutral’’ about the items unhappy-happy, annoyed-pleased, unsatisfied-satisfied, melancholic-contented, despairing-hopeful, and bored-relaxed, except for D = 1.5 of the item bored-relaxed. For D = 1.9, participants felt ‘‘positive’’ about the items happy, pleased, satisfied, contented, hopeful, and relaxed. As for the *arousal* dimension, for D = 1.1, participants felt ‘‘neutral’’ about the relaxed-stimulated, calm-excited, dull-jittery, sleepy-wide awake, and unaroused-aroused and they felt ‘‘positive’’ about the frenzied items. For D = 1.3, participants felt ‘‘neutral’’ about all items of *pleasure* dimension. For D = 1.5, participants rated the item dull-jittery as ‘‘neutral’’ and they rated the five items stimulated, excited, frenzied, wide awake, and aroused as ‘‘positive’’. For D = 1.7, participants rated the items calm-excited and dull-jittery as ‘‘neutral’’ and they rated the items stimulated, frenzied, wide awake, and aroused as ‘‘positive’’. For D = 1.9, participants felt ‘‘neutral’’ about the items calm-excited, dull-jittery, and sleepy-wide awake while they felt ‘‘positive’’ about the items stimulated, frenzied, and aroused (see Appendix C, Table 70-79).

After analyzing the mean scores of all complexity levels of projected fractal patterns with different CTs of natural light, normality test was conducted to understand whether the variables were normally distributed or not. The test results demonstrated that the variables of emotional states, which included the *pleasure* and *arousal*

dimensions were not normally distributed (see Appendix C, Table 80). Thus, Wilcoxon Signed-rank nonparametric test was applied for the analysis of the data.

5.3.3.1 Pleasure State

To analyze the effects of different CTs of natural light on emotional responses of participants, nonparametric Wilcoxon signed-rank test was applied. The data was analyzed to understand whether there is a significant difference between different CTs (4000K, 6500K, 12000K) of projected fractal patterns on participants' *pleasure* state. For analyzing the data, the significance levels of 0.05 and 0.01 were accepted.

Results demonstrated that there was no significant difference between for all CT groups (4000K, 6500K, 12000K) for different complexity levels in terms of *pleasure* state (see Table 35). Therefore, the results showed that the CT of projected fractal pattern had no significant influence on the participants' *pleasure* state.

Table 35. Wilcoxon Signed-rank test results for the pleasure and arousal dimensions correspondent to different complexity levels projected with different CTs – Phase 2

		Pleasure		Arousal	
		Visual Interest (Z)	Asymp. Sig. (2 – Tailed)	Visual Interest (Z)	Asymp. Sig. (2 – Tailed)
1.1 – 4000K	1.1 – 6500K	-1.159	0.246	-0.960	0.337
	1.1 – 12000K	-0.587	0.557	-0.202	0.840
1.3 – 4000K	1.3 – 6500K	-1.011	0.312	-0.593	0.553
	1.3 – 12000K	-0.869	0.385	-0.445	0.657
1.5 – 4000K	1.5 – 6500K	0.000	1.000	-0.122	0.903
	1.5 – 12000K	-1.829	0.067	-0.644	0.519
1.7 – 4000K	1.7 – 6500K	-1.076	0.282	-1.049	0.294
	1.7 – 12000K	-1.275	0.202	-0.930	0.352
1.9 – 4000K	1.9 – 6500K	-0.342	0.732	-0.893	0.372
	1.9 – 12000K	-1.010	0.313	-0.166	0.869
1.1 – 6500K	1.1 – 12000K	-1.085	0.278	-0.459	0.647
1.3 – 6500K	1.3 – 12000K	-0.153	0.879	-0.183	0.855
1.5 – 6500K	1.5 – 12000K	-1.128	0.260	-0.057	0.954
1.7 – 6500K	1.7 – 12000K	-0.261	0.794	-0.407	0.684
1.9 – 6500K	1.9 – 12000K	-0.627	0.531	-1.007	0.314

Test conducted for $\alpha = 0.05$ & $\alpha = 0.01$

5.3.3.2 Arousal State

For analyzing the effects of different CTs of natural light on emotional response of participants', Wilcoxon signed-rank test was applied. The data was analyzed to understand whether there is a significant difference between different CTs (4000K,

6500K, 12000K) of projected fractal patterns on participants' *arousal* state. Results demonstrated that there was no significant difference between for all CT groups (4000K, 6500K, 12000K) for different complexity levels in terms of *arousal* state (see Table 35). Therefore, the results showed that the CT of projected fractal pattern had no significant influence on the participants' *arousal* state.

5.3.3.3. Itemized Analysis

The significant differences provoked by different CTs of projected fractal patterns were further analyzed based on the individual items of the *pleasure* and *arousal* dimensions using the Wilcoxon Signed-rank test. Therefore, under each CT group (4000K, 6500K, & 12000K) all items were analyzed individually. For D = 1.1, results demonstrated that there was a significant difference between the effect of the CTs 6500K and 12000K on sleepy-wide awake; for D = 1.5, results indicated a significant difference between the effect of the CTs 6500K and 12000K on bored-relaxed; for D = 1.7, results demonstrated that there was a significant difference between the effect of the CTs 4000K and 6500K on relaxed-stimulated; for D = 1.9, results indicated a significant difference between the effect of the CTs 4000K and 12000K on despairing-hopeful; and between the CTs 6500K and 12000K on dull-jittery. However, the findings demonstrated that there was no significant difference between any of the other items between CT groups (see Appendix C, Table 81-110).

In the following chapter, the results of the data analysis are further discussed. The findings of the study are addressed based on the previous literature, where the research questions and hypotheses suggested in earlier chapters are answered.

CHAPTER VI

DISCUSSION

Based on the previous literature, this chapter discusses the findings of the study. The experiment consisted of two phases, where the first phase aimed at determining the most visually interesting complexity level of two dimensional fractal patterns. Also, the first phase aimed at investigating the influence of these complexity levels on people's emotional response. Furthermore, the second phase of the experiment examined the influence of projected three dimensional fractal patterns with three different CTs (4000K, 6500K, 12000K) on visual interest and emotional response in interior spaces.

6.1 Discussion on the Influence of Complexity Level on Visual Interest – Phase 1

In the first phase of the experiment, participants' visual interest assessments were compared among five different complexity levels of fractal patterns (D = 1.1, D = 1.3, D = 1.5, D = 1.7, D = 1.9). It was hypothesized that the most visually interesting

fractal pattern complexity is mid-complexity levels (D = 1.3 – 1.5). The hypothesis was grounded on the Fractal Fluency Theory, which argued that the mid-complexity fractal patterns found in nature allowed human's visual system to easily adapt to an environment (Taylor & Spehar, 2016; Taylor et al., 2018).

In the experiment, it was found that visual interest peaked for high-complexity fractal pattern D = 1.7 (*Mean: 10.57, SD: 3.8*). Moreover, results demonstrated that as D value increased from D = 1.1 to D = 1.7, visual interest increased gradually, after which visual interest dropped for D = 1.9 (*Mean: 8, SD: 5.9*). These results do not support the hypothesis, which suggested that fractals, particularly, mid-complexity fractal patterns, are more visually interesting than other complexity levels. These results are also different than the literature, where mid-complexity level fractal patterns (D = 1.3 – D = 1.5) were found as the most visually interesting (Abboushi et al., 2019; Spehar & Taylor, 2013; Taylor et al., 2005; Taylor, 2006).

This difference may be explained by the fact that, for instance, Abboushi et al (2019) did not include complexity level D = 1.9 in their study, whereas the present study considered D = 1.9, provoking some variance based on the wide range of complexity level of fractal patterns. For instance, in Abboushi et al.'s (2019) study where the highest complexity level included was D = 1.7, mid-complexity level D = 1.5 was found the most visually interesting, whereas in the present study where the highest complexity level shown to the participants was D = 1.9, high-complexity level D = 1.7 was found as the most visually interesting. In fact, these results indicated that when people are presented with more complex fractal patterns, their visual interest ratings increase for higher complexity fractal patterns. As for the other studies, which

included complexity level D = 1.9 in their experiments, the difference in the results may be explained by the fact that, compared with the type of fractal images used in the present research (black and white fractal patterns), most of these studies examined other types of fractal images (e.g. gray scale and noise images) (Spehar & Taylor, 2013; Taylor et al., 2005; Taylor, 2006). However, some of the results of the present study were similar with Abboushi et al. (2019)'s study where both studies demonstrated that people do not prefer low-complexity fractal patterns.

Furthermore, based on the results of the present research, there was a significant difference between visual interest ratings among most of the fractal pattern complexity levels; [D = 1.1 – D = 1.3], [D = 1.1 – D = 1.5], [D = 1.1 – D = 1.7], [D = 1.1 – D = 1.9], [D = 1.3 – D = 1.5], [D = 1.3 – D = 1.7], [D = 1.7 – D = 1.9] (see Table 7). However, the following fractal pattern complexity levels did not indicate a significant difference with respect to visual interest ratings; [D = 1.3 – D = 1.9], [D = 1.5 – D = 1.7] and [D = 1.5 – D = 1.9] (see Table 7). These results demonstrated that, in general, fractal pattern complexities had a positive significant influence on people's visual interest.

However, the results indicating that visual interest ratings were not significantly different between the complexities of D = 1.3 and D = 1.9, may be explained that both fractal pattern complexities had the same influence on the participants. This may be interpreted as both low-complexity level (D = 1.3) and highest complexity level (D = 1.9) were the least visually interesting fractal patterns. Complexity level of D = 1.3 was found too simple and complexity level of D = 1.9 was found too complex. This is why these patterns were not preferred mostly and, therefore, had the

same influence on visual interest (low visual interest). While comparing the results of the present research with the previous literature, both similarities and differences were found in terms of the influence of complexity level of fractal patterns on visual interest.

6.2 Discussion on the Influence of Complexity Level on Emotional Response – Phase 1

Regarding emotional response, participants' emotional responses, related to *pleasure* and *arousal* states, on five different complexity level of fractal patterns (D = 1.1, D = 1.3, D = 1.5, D = 1.7, D = 1.9) were evaluated. It was hypothesized that decreasing complexity levels induce increased pleasantness, whereas increasing complexity levels induce increased *arousal* states.

In the present study, the results demonstrated that the complexity level of fractal patterns had no significant influence on participants' *pleasure* state, whereas complexity levels had significant positive effects on participants' *arousal* states. Furthermore, the results indicated that, for all complexity levels, the majority of participants rated all feelings as neutral under the pleasantness dimension demonstrating that complexity level had no significant influence on the *pleasure* state. These results do not support the first hypothesis, which claimed that low-complexity levels induce increased pleasantness. Also, these results are different than Abboushi et al's (2019) and Hagerhall et al.'s (2015) studies where fractal patterns of complexity D = 1.1 provoked high feelings of relaxation. Furthermore, the results

showed that *arousal* response was the highest for D = 1.9 with the emotion of 'wide-awake' indicating that participants' felt the most wide-awake for complexity level D = 1.9. However, *Arousal* response was rated the lowest for D = 1.1 with the emotion of 'sluggish', indicating that participants felt the most sluggish for low-complexity D = 1.1. These results support the second hypothesis, which suggested that increasing complexity levels induce increased *arousal* states. These results are similar with some of the previous studies where fractal patterns of complexity levels D = 1.5 and D = 1.7 provoked higher feelings of *arousal* (Boubekri et al., 1991; Hagerhall et al., 2008; Abboushi et al., 2019).

An exact conclusion may not be made about the relationship between fractal pattern complexity levels and emotional response. Based on the results of the present research, there were no significant difference in the *pleasure* state of participants between fractal pattern complexity levels except between D = 1.1 and D = 1.9 where a significant difference was demonstrated. These results may be explained by the huge difference between these two extremes; D = 1.1 represented the lowest complexity level studied in this experiment, while D = 1.9 represented the highest complexity level examined. However, the results showed that there was a significant difference in the *arousal* state of participants between the complexity levels except between D = 1.3 and D = 1.5 also between D = 1.7 and D = 1.9 where no significant difference was demonstrated. The reason behind these results is that both values of D = 1.3 and D = 1.5 represent (belong to the same category) mid-complexity fractal patterns and both values of D = 1.7 and D = 1.9 represent high-complexity fractal patterns. Therefore, no significant difference was observed between these patterns, belonging to the same group.

6.3 Discussion on the Influence of Complexity Level and CT on Visual Interest – Phase 2

In the second phase of the experiment, the effects of projected fractal patterns with different CTs on people's visual interest in interior spaces were examined. It was hypothesized that CT of natural light influenced the choice of fractal pattern complexity in terms of visual interest. The participants' visual interest assessments for projected fractal patterns with different complexities in interior spaces were compared under three different CTs; 4000K (noon sky), 6500K (overcast sky), and 12000K (clear sky). In addition, each CT of projected fractal pattern group was analyzed on itself.

In this experiment, it was found that visual interest for the projected fractal patterns with 4000K peaked for high-complexity fractal pattern of D = 1.7 (*Mean = 11.70; SD = 4*); with 6500K peaked for high-complexity fractal pattern of D = 1.7 (Mean = 10.87; SD = 4.5); with 12000K peaked for high-complexity fractal pattern of D = 1.7 (Mean = 10.50; SD = 5.9). These results do not support the hypothesis, which suggested that CT of natural light influenced the choice of fractal pattern complexity in terms of visual interest. Therefore, it may be concluded that, compared with CT, complexity level is a more significant influential factor related to visual interest. Furthermore, these results are consistent with the literature where high-complexity level of projected fractal patterns, for D = 1.7, was found as the most visually interesting in interior spaces (Abboushi et al., 2019).

Based on the results of the present research, for low-complexity levels D = 1.1 and D = 1.3, there was a significant difference between the influence of noon sky (4000K), overcast sky (6500K), and clear sky (12000K). However, for complexity level D = 1.3, there was no significant difference between the influence of clear sky (6500K) and overcast sky (12000K). Moreover, for mid-complexity levels D = 1.3 and D = 1.5, there was no significance difference between the influence of noon sky (4000K), overcast sky (6500K), and clear sky (12000K). For high-complexity levels D = 1.5 and D = 1.9, there was no significant difference between the influence of noon sky (4000K), overcast sky (6500K), and clear sky (12000K). However, the results also demonstrated that for D = 1.7, there was a significant difference between the influence of noon sky (4000K) and overcast sky (6500K). Findings demonstrated that CT had a high significant influence on low-complexity fractal patterns and no significant influence on mid and high-complexity level of fractal patterns. This may be further explained as when complexity level increased the influence of CT on visual interest decreased.

6.4 Discussion on the Influence of Complexity level and CT on Emotional Response – Phase 2

Regarding emotional response, the effects of different complexity level fractal patterns projected with three different natural light CTs on participants' emotional response in interior spaces were evaluated. It was hypothesized that lower CTs of natural light provided people with a more pleasantness state, whereas higher CTs of natural light allowed people to experience higher *arousal* states.

Based on the results of the present research, regarding the *pleasure* state, for all complexity levels (low-, mid-, & high-complexities), participants felt neutral for the noon sky CT (4000K). However, for high-complexity level D = 1.9, they felt relaxed for the noon sky CT (4000K). For low and mid-complexity levels (D = 1.1 – D = 1.3 and D = 1.3 – D= 1.5), participants felt neutral for overcast sky CT (6500K). However, for high-complexity level D = 1.7 and D = 1.9, they felt happy, relaxed, pleased, satisfied, and contented for the overcast sky CT (6500K). Moreover, for all complexity levels (low-mid-high), participants felt neutral for the clear sky CT (12000K). However, for high-complexity level D = 1.9, they felt happy, pleased, satisfied, contented, hopeful, and relaxed. Results demonstrated that CT had no significant influence on *pleasure* state of people. This may be further explained that as complexity level of fractal pattern increased, the *pleasure* state increased as well regardless all sky types CT. These results do not support the first hypothesis, which suggested that lower CTs of natural light allowed people to experience a higher pleasantness state.

A study by Viénot et al. (2009) indicted that lower CCTs provoked feelings of relaxation, pleasantness, warmth, and comfort. Another study, Wang et al. (2017) stated that lower CCTs provoked tense activities. The results of these studies are different than the present study, because CTs had no significant influence on the pleasantness state.

Based on the results of the present research, regarding the *arousal* state, for low-complexity levels D = 1.1 and D = 1.3, participants felt neutral for three type of skies; noon sky CT (4000K), overcast sky (6500K), and clear sky (12000K).

However, for mid- and high-complexity levels, they felt stimulated, wide-awake, excited, and aroused for three type of skies; noon sky CT (4000K), overcast sky (6500K), and clear sky (12000K). Moreover, findings demonstrated that for low-complexity levels D = 1.1 and D = 1.3, CT had no significant influence on the *arousal* state. For all CTs (4000K, 6500K, & 12000K) the majority of participants felt neutral about the *arousal* state. Similarly, for mid- and high-complexity levels D = 1.3 – D = 1.5 and D = 1.5 – D = 1.9, CT had no significant influence on the *arousal* state where the majority of participants experienced high *arousal* states for all sky types. Furthermore, findings indicated that complexity level had a positive strong influence on *arousal* state, when complexity level increased the *arousal* state increased as well. These results do not support the second hypothesis, which suggested that higher CT of natural light allowed people to experience a higher *arousal* state.

Previous studies demonstrated that higher CCTs were associated with feelings of brightness and clearness (Vienot et al., 2009). Another study by Ju et al. (2011) stated that high CCTs enabled a better spatial brightness perception. Moreover, Baniya et al. (2015) indicated that people perceived the room as more bright and felt more stimulated under higher CCTs. The results of these studies are different than the present study, where CT had no significant influence on the *arousal* state.

A recent study focused on the effects of projected fractal patterns with natural light on visual interest and mood response (Abboushi et al., 2019). Another study by Abboushi (2019), which was conducted in day lit offices, demonstrated the influence of sunlight pattern geometry on people’s visual interest and visual comfort. With this

respect, this study is the first to investigate the effects of natural light CT of projected fractal patterns on visual interest and emotional response in interior spaces. The hypotheses, findings of the study, and decisions are summarized in Table 36. The study findings guide for future research, which concentrate on the influence and application of projected fractal patterns with different CT of natural light in interior spaces.

Table 36. A summary of the hypotheses, findings, and decisions of the study

Hypotheses	Findings	Decision	Similar with	Different than
H1.1 Mid-complexity fractal patterns are the most visually interesting.	High-complexity level D = 1.7 is the most visually interesting.	Reject hypothesis		Spehar & Taylor, 2013; Taylor et al., 2005; Abboushi et al., 2019; Taylor, 2006
H1.2 There is a significant difference between complexity levels in terms of visual interest.	Visual interest ratings had a significant influence on the majority of fractal pattern complexities.	Do not reject hypothesis	Abboushi et al., 2019	
H1.3a Decreased complexity levels induce increased *pleasure* state.	Complexity level of fractal patterns had no significant influence on participants' *pleasure* state.	Reject hypothesis		Abboushi et al., 2019; Hagerhall et al., 2015
H1.3b Increased complexity levels induce increased *arousal* state.	Complexity levels had positive significant effect on participants' *arousal* state.	Do not reject hypothesis	Boubekri et al., 1991; Hagerhall et al., 2008; Abboushi et al., 2019	
H2.1 CT of natural light influences the choice of fractal pattern complexity.	CT of natural light does not influence the choice of fractal pattern complexity in terms of visual complexity.	Reject hypothesis		
H2.2 There is a significant difference between CTs of projected fractal patterns in terms of visual interest.	CT had a high significant influence on low-complexity fractal patterns and no significant influence on mid & high complexity level fractal patterns.	Do not reject hypothesis		
H2.3a Lower CT of natural light provides people with a higher *pleasure* state.	CT had no significant influence on *pleasure* state of people.	Reject hypothesis		Viénot et al., 2009; Wang et al., 2017
H2.3b Higher CT of natural light provides people with a higher *arousal* state.	CT had no significant influence on *arousal* state of people.	Reject hypothesis		Viénot et al., 2009; Ju et al., 2011; Baniya et al., 2015

CHAPTER VII

CONCLUSION

In the present research, the effects of different CTs of projected fractal patterns with different complexity levels on visual interest and emotional response in interior spaces were examined. The present study focused on transferring aesthetic values of nature into interior spaces by projecting three dimensional fractal patterns with different CTs into an interior space, in order to create visually interesting places. By bringing nature's effects, such as fractal patterns and different CTs of natural light, into interior spaces where people spend most of their times (Klepeis et al., 2001), the study investigated people's visual interest and emotional response in terms of *pleasure* and *arousal*. The study consisted of two phases. The first phase intended to determine which complexity level of two dimensional fractal patterns was the most visually interesting. Moreover, emotional responses to these different complexity levels of fractal patterns were assessed. Whereas the second phase aimed to determine whether different CTs of natural light influenced the choice of three dimensional fractal pattern complexity. People's emotional response were also evaluated.

A previous study demonstrated that the most visually interesting fractal pattern complexity was mid-complexity D = 1.5 (Abboushi et al., 2019). In the literature, most of the findings supported the Fractal Fluency Theory, which support the concept that mid-complexity fractal patterns in nature allowed people to adapt more efficiently to an environment (Taylor et al., 2018; Taylor & Spehar, 2016). Moreover, this theory is associated with the ART and biophilia hypothesis (Abboushi et al., 2019). However, in the present study, the results of the first phase indicated that the most visually interesting pattern was high-complexity level D = 1.7. Furthermore, the findings demonstrated that as D value increased from D = 1.1 to D = 1.7, visual interest increased gradually, after that visual interest decreased for D = 1.9. Regarding emotional response, the findings of the first phase indicated that complexity level of fractal patterns had no significant effects on participants' *pleasure* state, however, complexity level had a significant positive influence on participants' *arousal* state.

The results of the second phase found that the most interesting fractal pattern for all CTs (noon – 4000K, overcast sky – 6500K, clear sky – 12000K) was for D = 1.7. Therefore, it may be concluded that CT of natural light does not affect the choice of fractal pattern complexity. Moreover, findings demonstrated that CT had a high significant influence on low-complexity fractal patterns, whereas it had no significant influence on mid- and high-complexity levels of fractal patterns. Regarding emotional response, CT had no significant influence on *pleasure*, since as the complexity of fractal pattern increased, the *pleasure* state also increased regardless of CT. Furthermore, CT had no significant influence on *arousal* state, because as the complexity level increased, the *arousal* state increased as well regardless of CT.

The present study contributed to the literature, as there are no previous research examining the effects of different CTs of projected fractal pattern on people's visual interest and emotional assessment in interior spaces. Moreover, it is worth to mention that the present study included the complexity level D = 1.9, which was not examined in previous studies. Therefore, the findings of the present research add to the previous literature, and guide future research, which may focus on the influence and implementation of projected fractal patterns with different CTs of natural light in interior spaces. These results also illustrate an example of transferring the benefits of biophilic design into creating high quality interior spaces improving users' visual interest. The results of the present study also guide interior architects and façade designers in implementing fractal patterns for creating more visually interesting interior spaces.

In the present study, renderings were generated using Autodesk 3ds Max software (version 2017) and the scenario were fictionalized as an interior space with a window through which natural light patterns penetrated and reflected on the walls and floor. One limitation is related with the spatial variables of projection, which include projection surfaces, view direction, material properties, and pattern size. In the present study, fractal patterns were projected on a two wall planes, divided-equally, and a floor surface. It is important as well to investigate whether other positions on projected surfaces would provoke different effects on visual interest (projection on one wall plane and floor - one wall plane and ceiling – two wall planes and ceiling etc.). Moreover, the view direction, material properties, and pattern size were kept under control in the present study. The findings of this research may be further developed by investigating these variables. Another limitation of this research was

not examining participants' behavioral intentions because of time restriction. Therefore, further studies may investigate the influence of projected fractal patterns with different natural light CTs on people's behavioral intentions.

For future studies, effects of spatial variables may be examined on visual interest and emotional response, since projection surfaces, view direction, material properties, and pattern size may influence people's visual interest and emotional response. Additionally, the effects of CTs, other than the ones used in this research may also be investigated in order to obtain a wider spectrum of natural light CT and validate the results of this study showing that CT had no significant influence on the visual interest of mid- and high-complexity fractal patterns. Furthermore, the scale of the projected fractal patterns in proportion of the space is another important factor to be considered. Thus, future studies may investigate the effect of projected fractal patterns' scale on people's visual interest and emotional response. Lastly, the variables of age, gender, culture, and educational background may be considered to observe whether these variables have an influence on the visual interest and emotional response. The findings of this study filled some gaps in the literature and enlightened the design of future natural light and façade structures in order to create visually interesting interior spaces.

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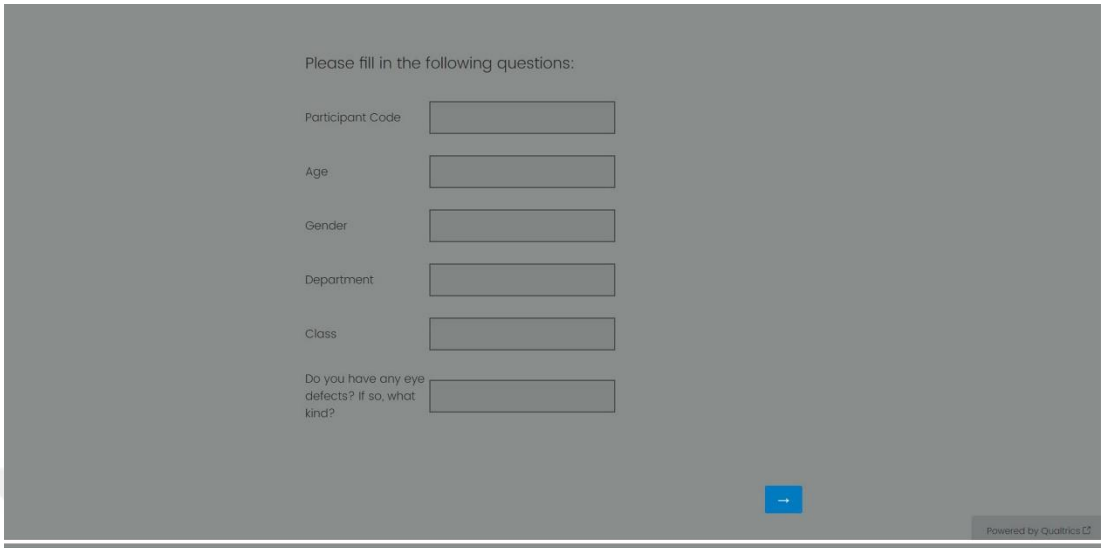
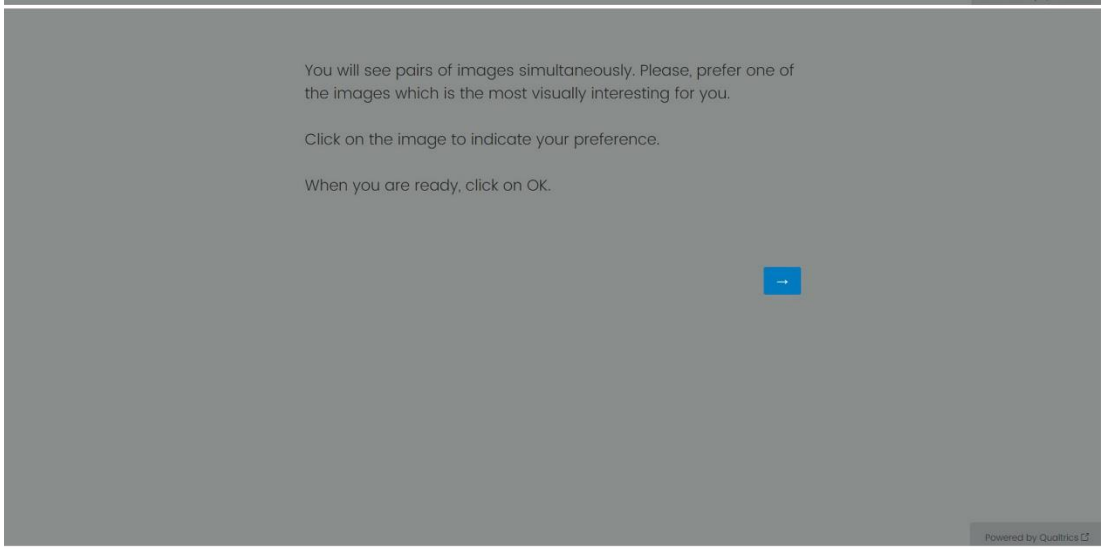
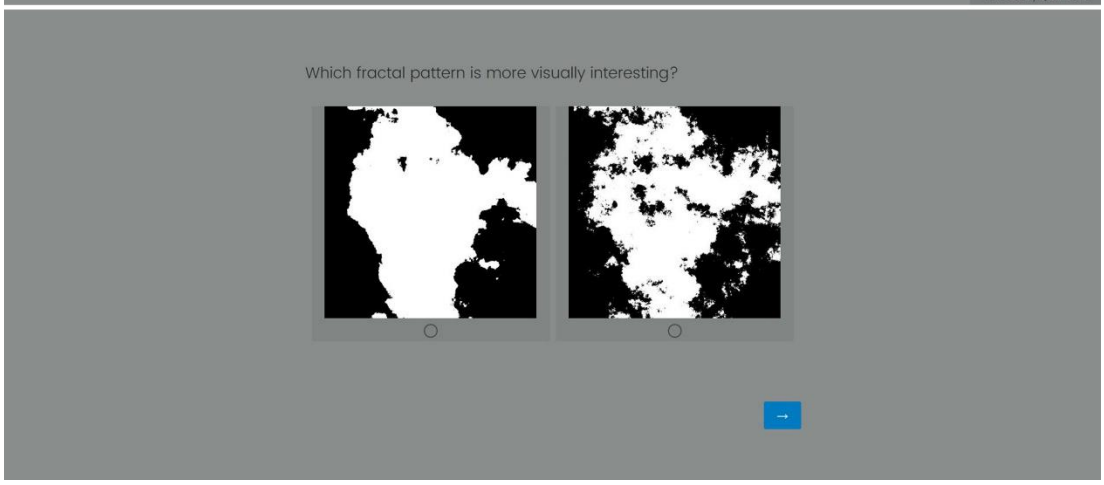
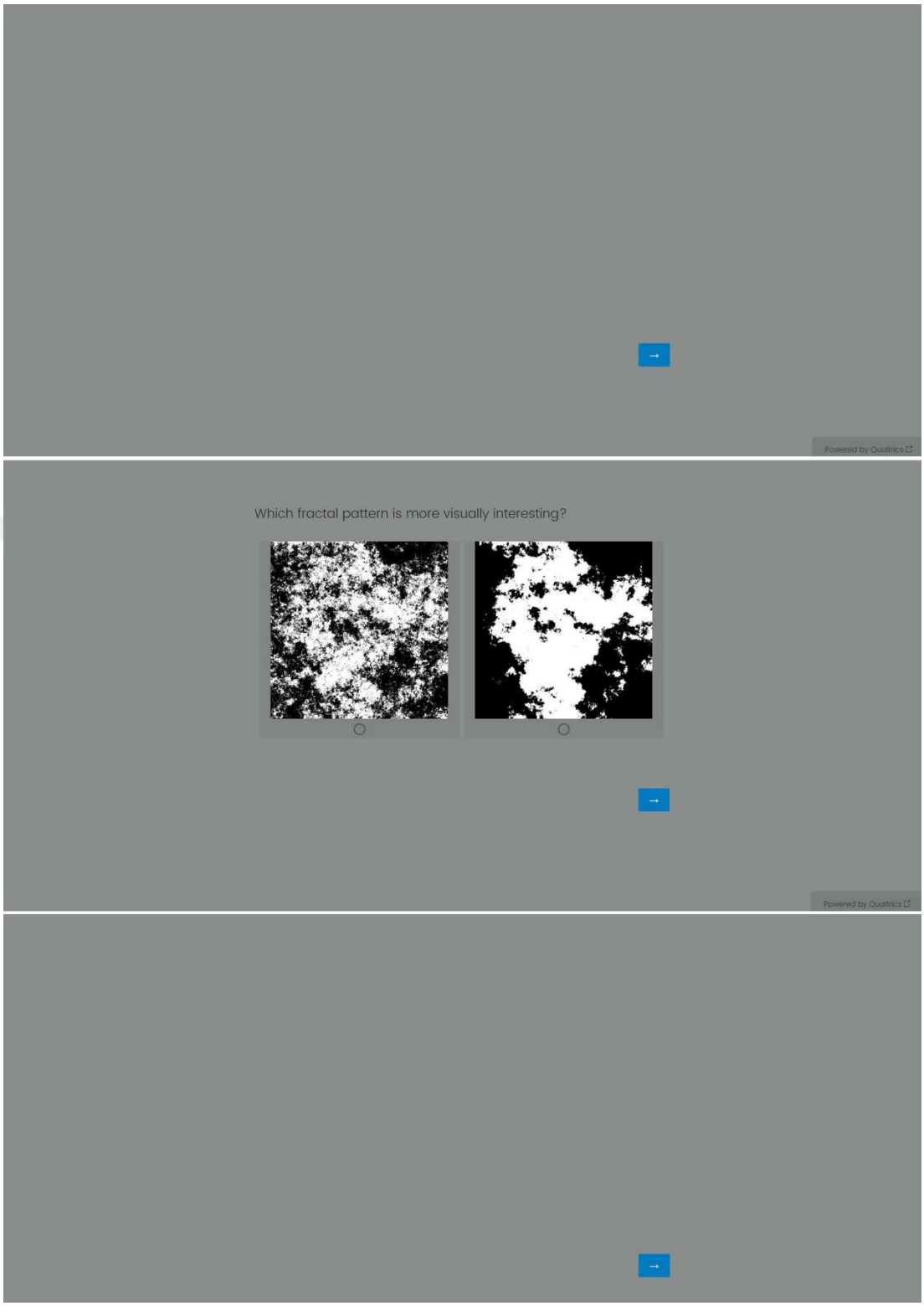
APPENDICES

APPENDIX A1. Sample Items from the Visual Interest Assessment Questionnaire – Phase 1

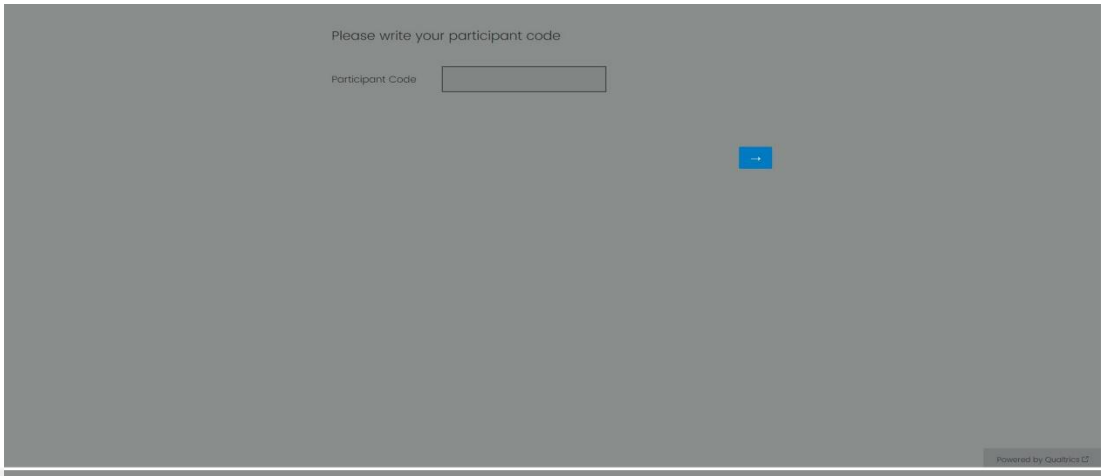


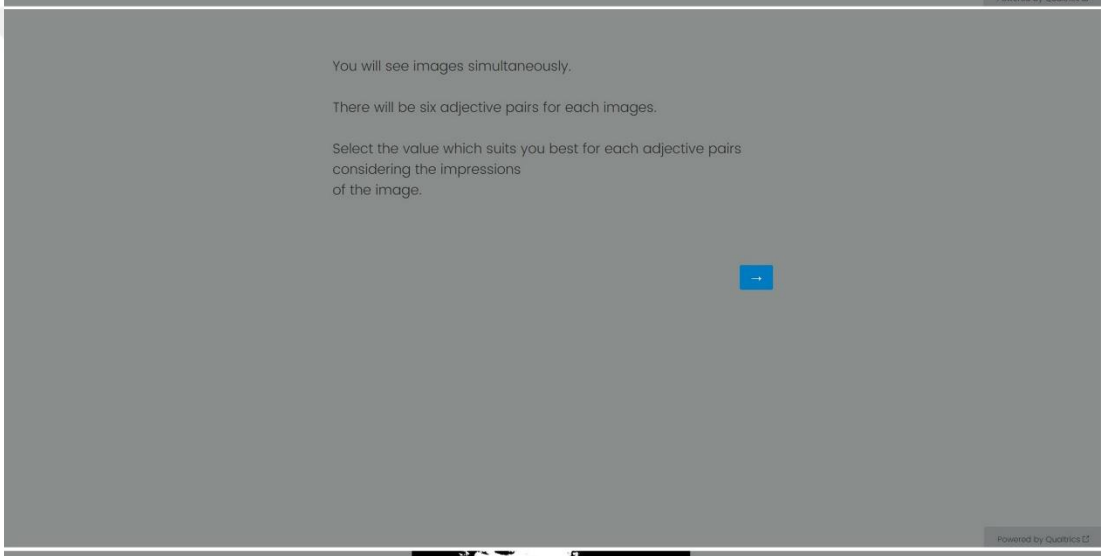


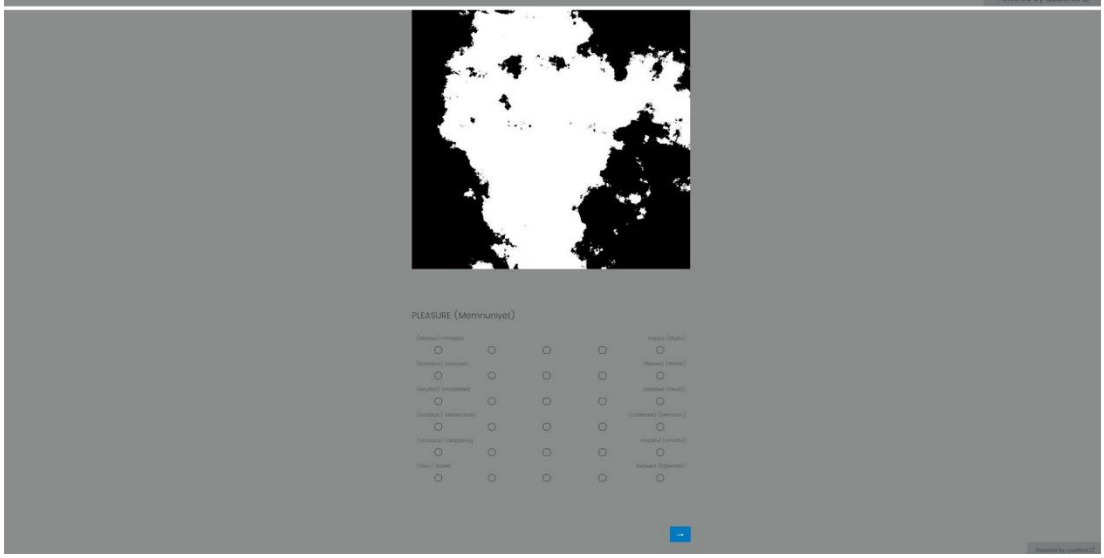


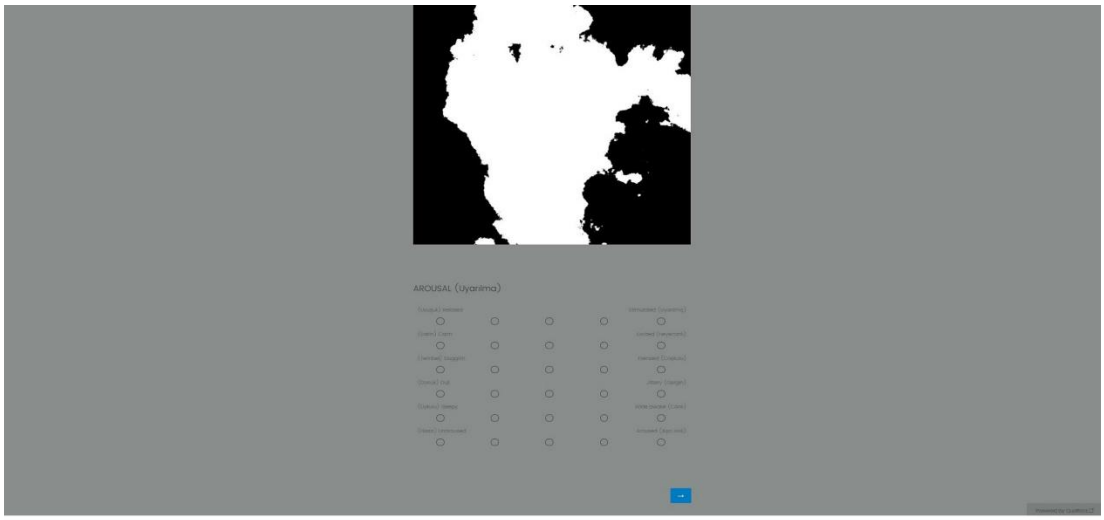

Powered by Qualtrics
Which fractal pattern is more visually interesting?
Powered by Qualtrics

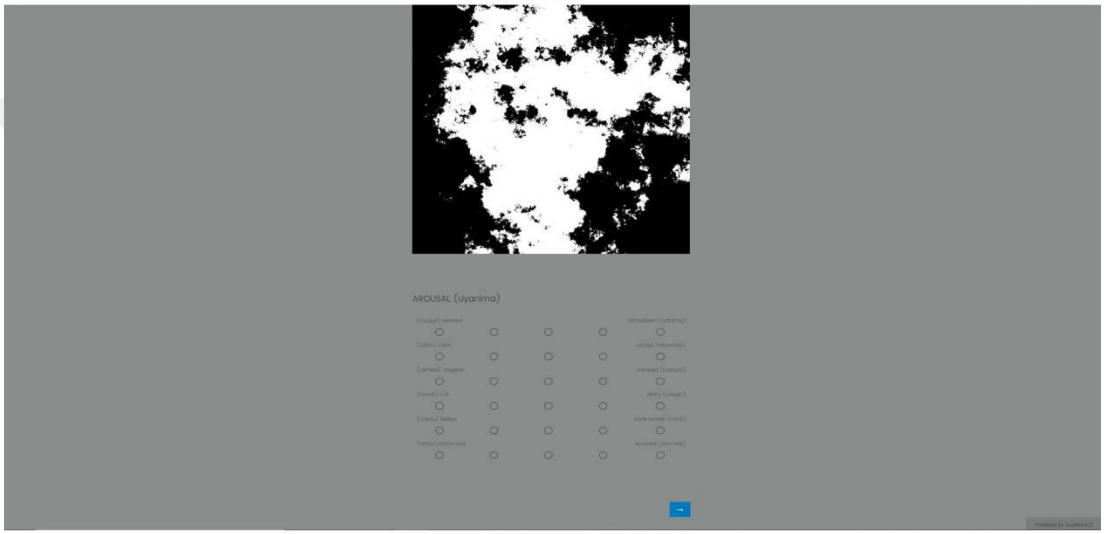
APPENDIX A2. Sample Items from the Emotional Response Assessment Questionnaire – Phase 1

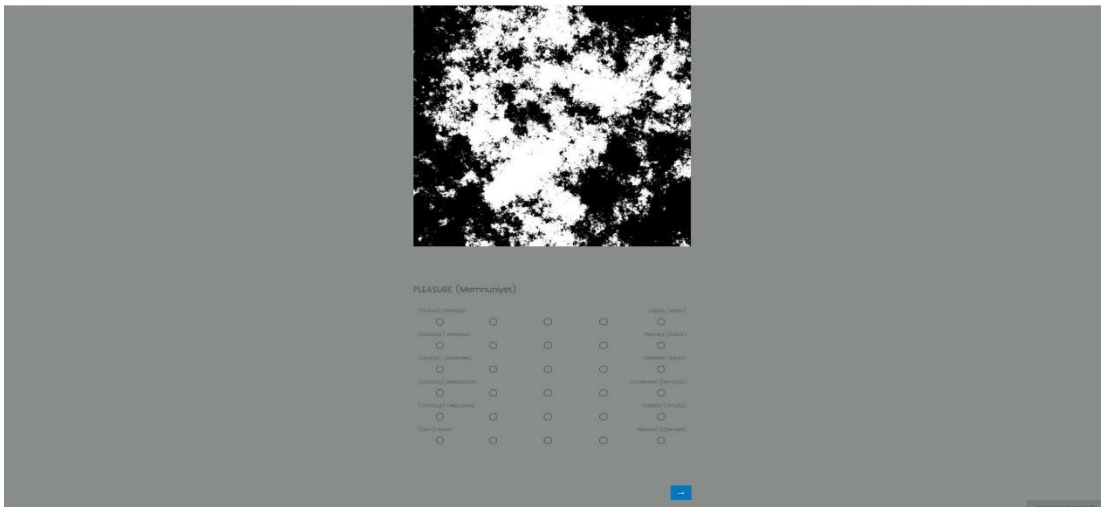




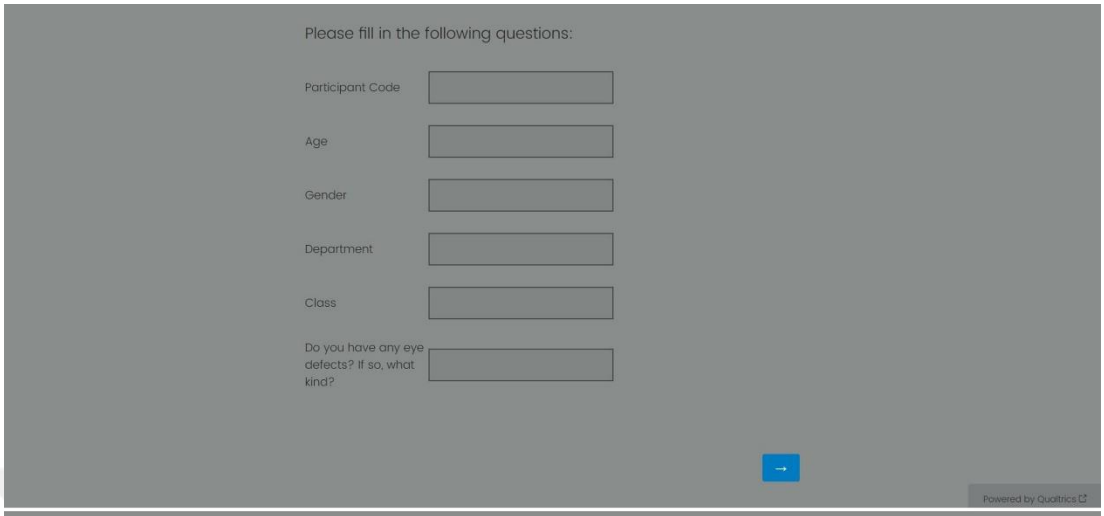


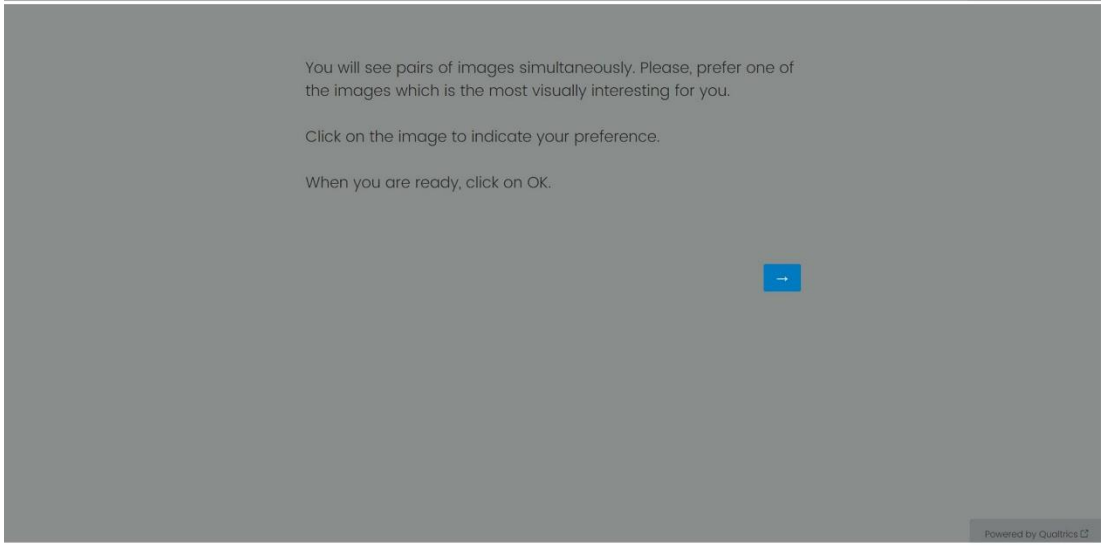

AROUSAL (Uyarılma)

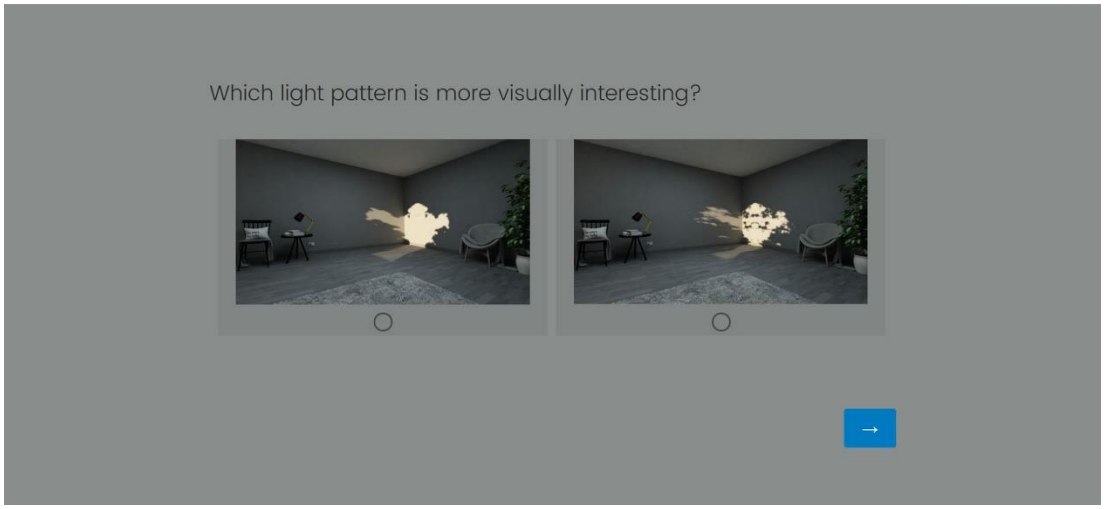

AROUSAL (Uyarılma)

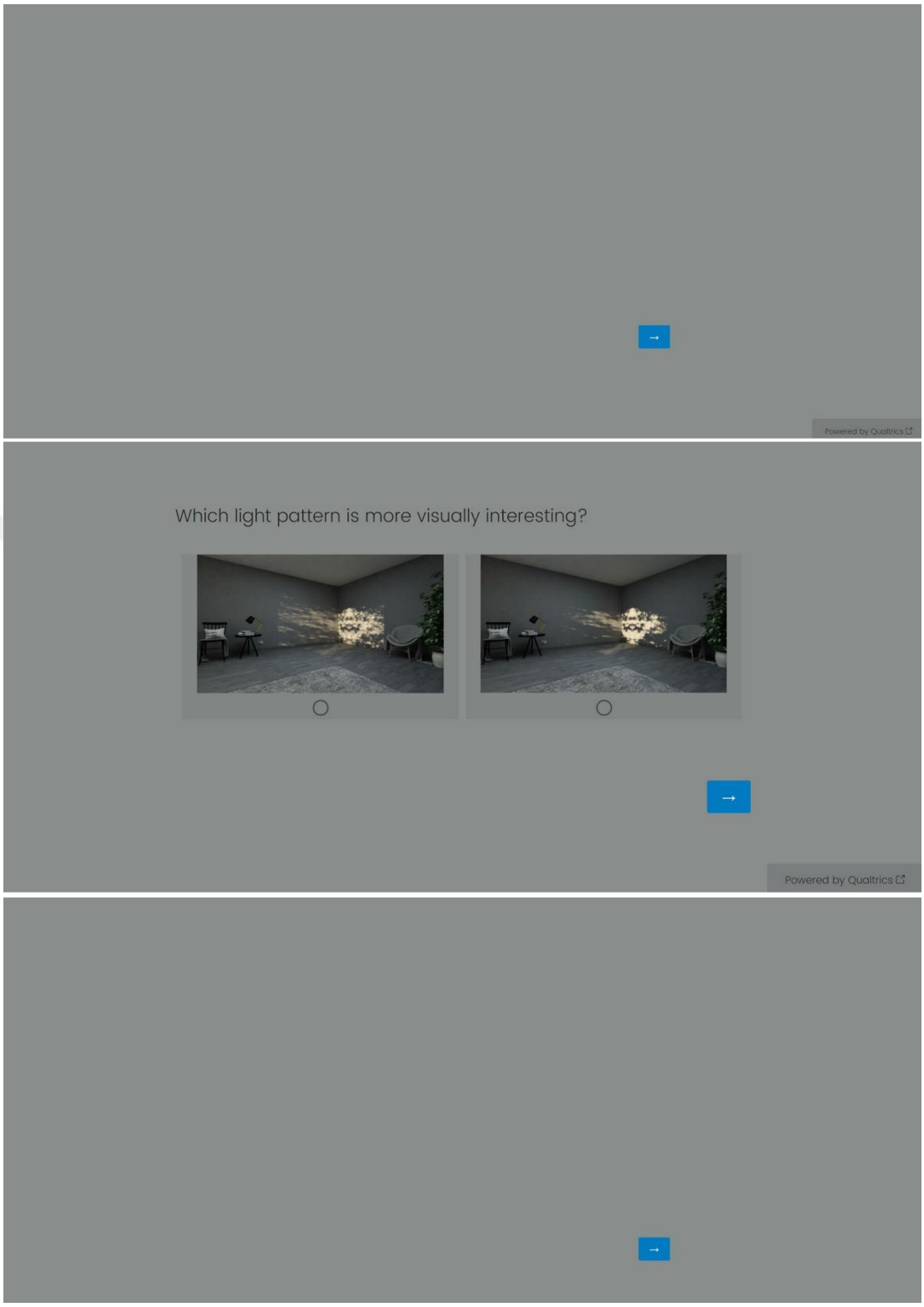

PLEASURE (Memnuniyet)

APPENDIX B1. Sample Items from the Visual Interest Assessment Questionnaire (4000K) – Phase 2

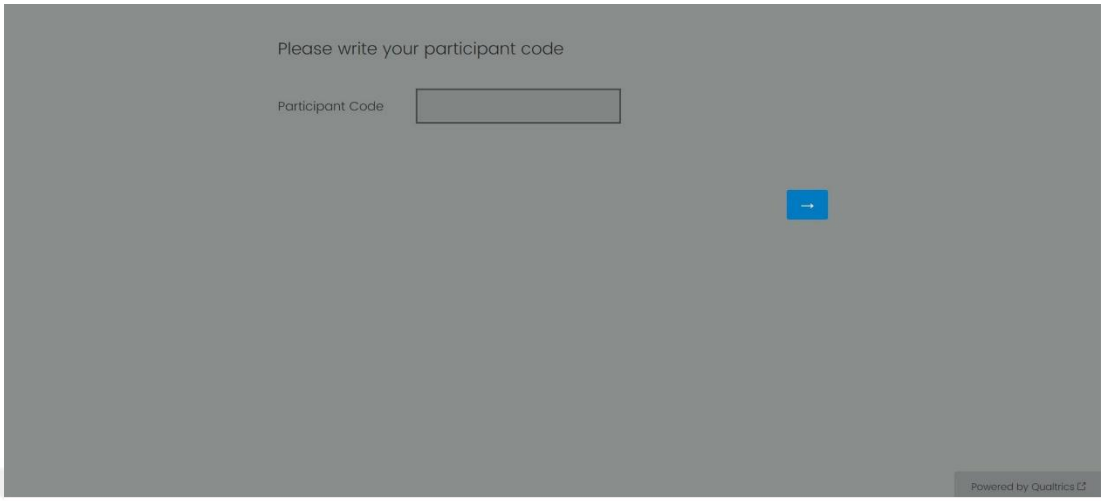


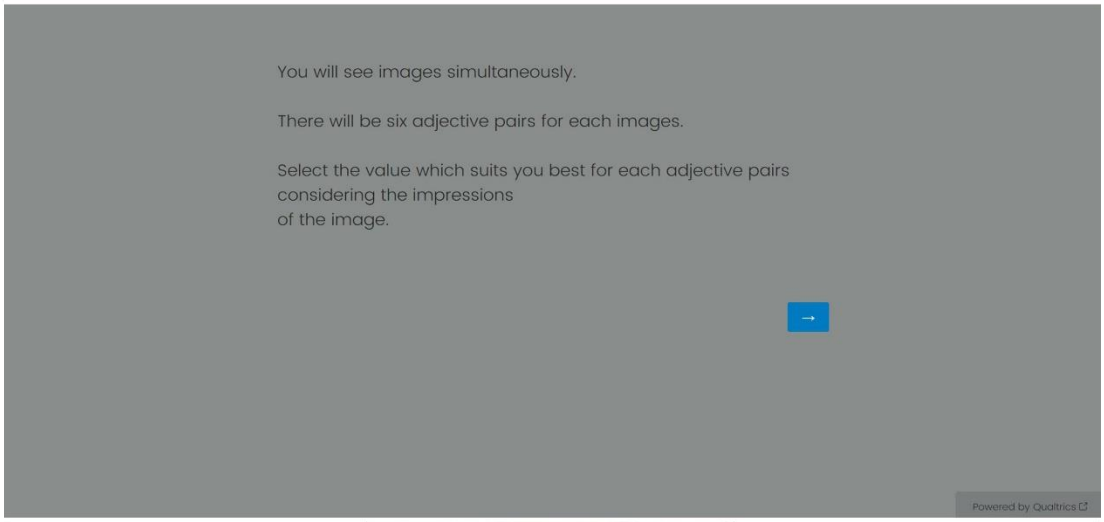


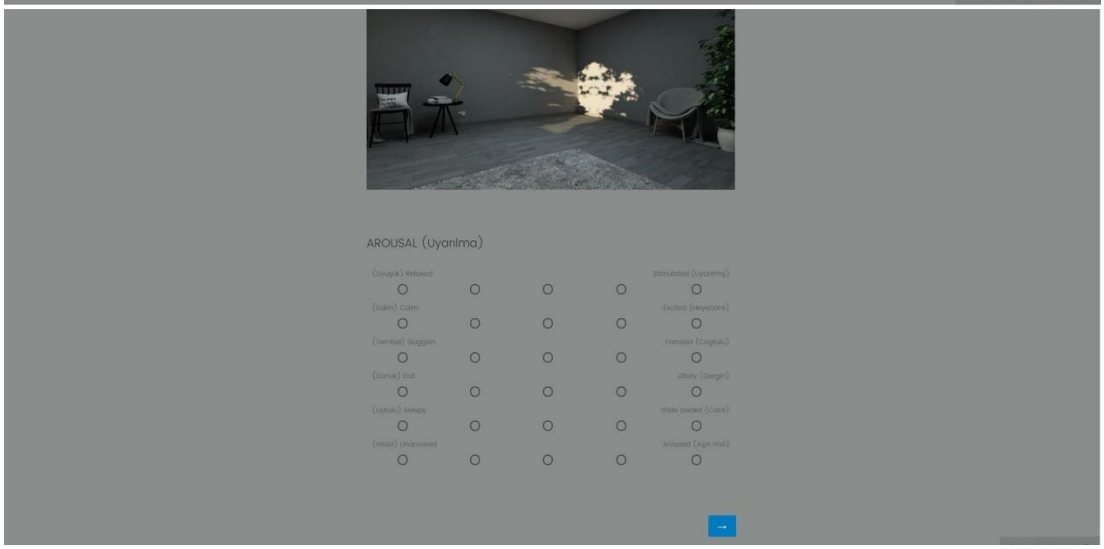


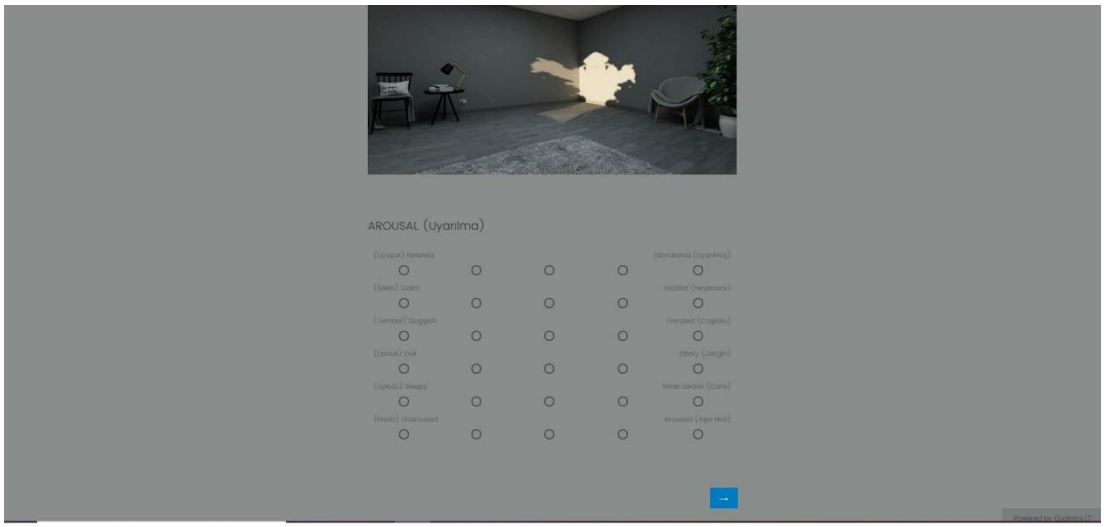

Powered by Qualtrics
Which light pattern is more visually interesting?
Powered by Qualtrics

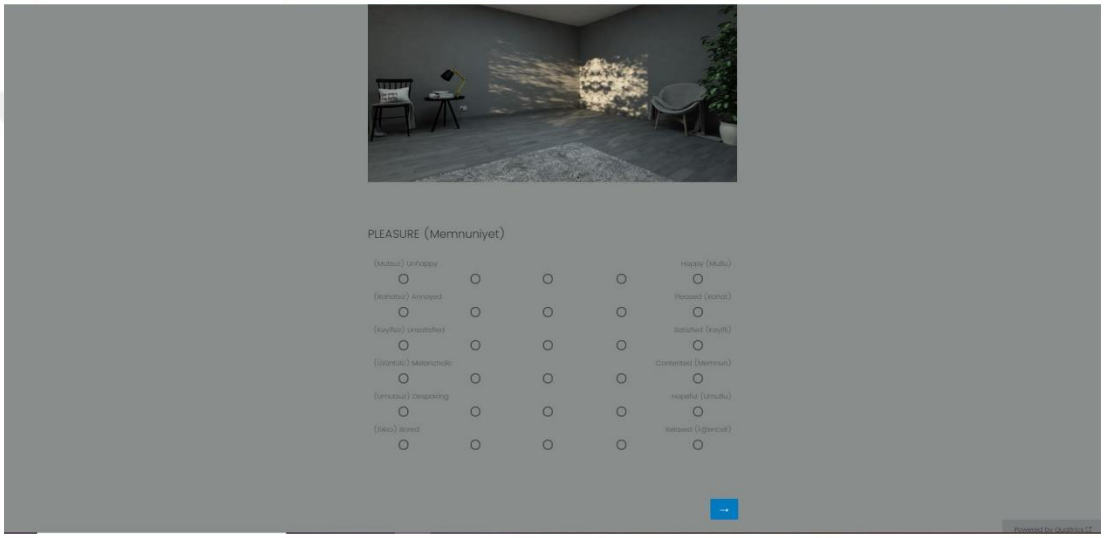
APPENDIX B2. Sample Items from the Emotional Response Assessment Questionnaire (4000K) – Phase 2

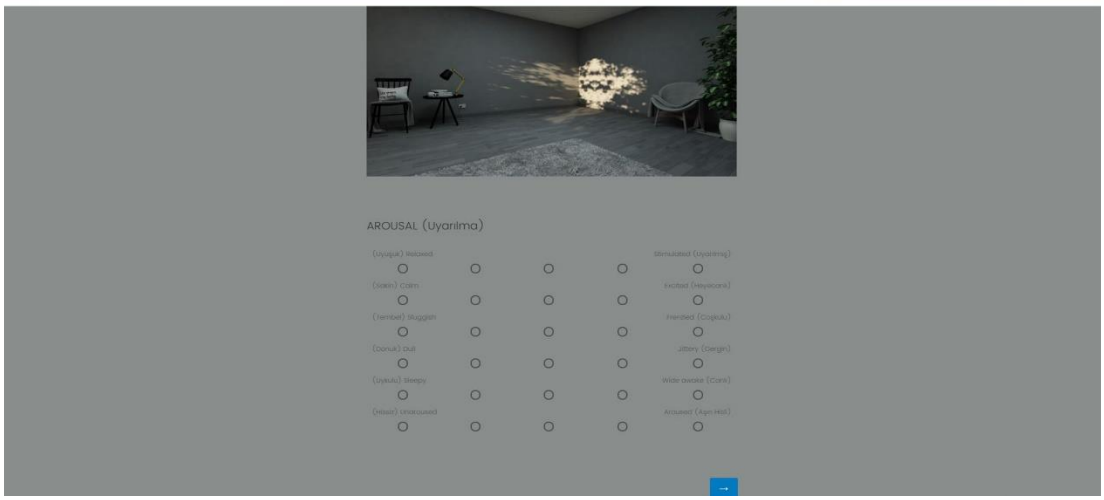







AROUSAL (Uyarılma)
(Uyuşuk) Relaxed
Stimulated (Uyarılmış)
(Sakin) Calm
Excited (Heyecanlı)
(Tembel) Sluggish
Frenzied (Coşkulu)
(Donuk) Dull
Jittery (Gergin)
(Uykulu) Sleepy
Wide awake (Canlı)
(Hissiz) Unaroused
Aroused (Aşırı Hisli)


PLEASURE (Memnuniyet)
(Mutsuz) Unhappy
Happy (Mutlu)
(Rahatsız) Annoyed
Pleased (Rahat)
(Keyfsiz) Unsatisfied
Satisfied (Keyifli)
(Üzüntülü) Melancholic
Contented (Memnun)
(Umutsuz) Despairing
Hopeful (Umutlu)
(Sıkıcı) Bored
Relaxed (Eğlenceli)


AROUSAL (Uyarılma)
(Uyuşuk) Relaxed
Stimulated (Uyarılmış)
(Sakin) Calm
Excited (Heyecanlı)
(Tembel) Sluggish
Frenzied (Coşkulu)
(Donuk) Dull
Jittery (Gergin)
(Uykulu) Sleepy
Wide awake (Canlı)
(Hissiz) Unaroused
Aroused (Aşırı Hisli)

APPENDIX C: Statistical Analysis

Table 37. Tests of normality for visual interest – Phase 1

Item	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
1	0.503	30	0.0001	0.452	30	0.0001
2	0.457	30	0.0001	0.554	30	0.0001
3	0.473	30	0.0001	0.526	30	0.0001
4	0.503	30	0.0001	0.552	30	0.0001
5	0.473	30	0.0001	0.526	30	0.0001
6	0.457	30	0.0001	0.654	30	0.0001
7	0.440	30	0.0001	0.577	30	0.0001
8	0.389	30	0.0001	0.624	30	0.0001
9	0.503	30	0.0001	0.452	30	0.0001
10	0.488	30	0.0001	0.492	30	0.0001
11	0.473	30	0.0001	0.526	30	0.0001
12	0.457	30	0.0001	0.554	30	0.0001
13	0.406	30	0.0001	0.612	30	0.0001
14	0.389	30	0.0001	0.624	30	0.0001
15	0.372	30	0.0001	0.632	30	0.0001
16	0.389	30	0.0001	0.624	30	0.0001
17	0.503	30	0.0001	0.452	30	0.0001
18	0.517	30	0.0001	0.404	30	0.0001
19	0.488	30	0.0001	0.492	30	0.0001
20	0.478	30	0.0001	0.518	30	0.0001
21	0.389	30	0.0001	0.624	30	0.0001
22	0.337	30	0.0001	0.638	30	0.0001
23	0.372	30	0.0001	0.632	30	0.0001
24	0.337	30	0.0001	0.638	30	0.0001
25	0.457	30	0.0001	0.554	30	0.0001

Cont'd **(Table 37)**

Item	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistics	df	Sig.	Statistics	df	Sig.
26	0.488	30	0.0001	0.492	30	0.0001
27	0.473	30	0.0001	0.526	30	0.0001
28	0.423	30	0.0001	0.597	30	0.0001
29	0.389	30	0.0001	0.624	30	0.0001
30	0.406	30	0.0001	0.612	30	0.0001
31	0.372	30	0.0001	0.632	30	0.0001
32	0.423	30	0.0001	0.597	30	0.0001
33	0.354	30	0.0001	0.637	30	0.0001
34	0.354	30	0.0001	0.637	30	0.0001
35	0.372	30	0.0001	0.632	30	0.0001
36	0.337	30	0.0001	0.638	30	0.0001
37	0.337	30	0.0001	0.638	30	0.0001
38	0.337	30	0.0001	0.638	30	0.0001
39	0.406	30	0.0001	0.612	30	0.0001
40	0.423	30	0.0001	0.597	30	0.0001

a. Lilliefors Significance Correction

Table 38. Pleasure state's means for D = 1.1 – Phase 1

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			3.00			Happy
Annoyed			3.13			Pleased
Unsatisfied			2.97			Satisfied
Melancholic			3.27			Contented
Despairing			3.10			Hopeful
Bored			2.83			Relaxed

Table 39. Pleasure state's means for D = 1.3 – Phase 1

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			3.07			Happy
Annoyed			3.23			Pleased
Unsatisfied			3.03			Satisfied
Melancholic			3.37			Contented
Despairing			3.27			Hopeful
Bored			2.93			Relaxed

Table 40. Pleasure state's means for D = 1.5 – Phase 1

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			3.03			Happy
Annoyed			3.07			Pleased
Unsatisfied			3.27			Satisfied
Melancholic			3.17			Contented
Despairing			2.97			Hopeful
Bored			2.03			Relaxed

Table 41. Pleasure state's means for D = 1.7 – Phase 1

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			3.07			Happy
Annoyed			3.00			Pleased
Unsatisfied			3.03			Satisfied
Melancholic			3.30			Contented
Despairing			2.87			Hopeful
Bored			3.37			Relaxed

Table 42. Pleasure state's means for D = 1.9 – Phase 1

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			3.17			Happy
Annoyed			3.03			Pleased
Unsatisfied			3.30			Satisfied
Melancholic			3.27			Contented
Despairing			3.03			Hopeful
Bored			3.47			Relaxed

Table 43. Arousal state's means for D = 1.1 – Phase 1

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed		2.47				Stimulated
Calm		2.33				Excited
Sluggish		2.17				Frenzied
Dull		2.37				Jittery
Sleepy			2.83			Wide Awake
Unaroused		2.40				Aroused

Table 44. Arousal state's means for D = 1.3 – Phase 1

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed			2.97			Stimulated
Calm			2.77			Excited
Sluggish			2.87			Frenzied
Dull			2.73			Jittery
Sleepy			2.90			Wide Awake
Unaroused			2.90			Aroused

Table 45. Arousal state's means for D = 1.5 – Phase 1

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed			3.23			Stimulated
Calm			2.97			Excited
Sluggish			3.03			Frenzied
Dull			2.93			Jittery
Sleepy			3.27			Wide Awake
Unaroused			3.20			Aroused

Table 46. Arousal state's means for D = 1.7 – Phase 1

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed				3.73		Stimulated
Calm			3.33			Excited
Sluggish			3.50			Frenzied
Dull			3.43			Jittery
Sleepy			3.63			Wide Awake
Unaroused				3.80		Aroused

Table 47. Arousal state's means for D = 1.9 – Phase 1

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed				3.77		Stimulated
Calm				3.87		Excited
Sluggish				3.80		Frenzied
Dull			3.33			Jittery
Sleepy				3.93		Wide Awake
Unaroused				3.87		Aroused

Table 48. Test of normality for emotional response – Phase 1

Item	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
1	0.167	30	0.033	0.918	30	0.024
2	0.218	30	0.001	0.902	30	0.009
3	0.244	30	0.000	0.874	30	0.002
4	0.203	30	0.003	0.912	30	0.016
5	0.197	30	0.004	0.906	30	0.012
6	0.224	30	0.000	0.908	30	0.013
7	0.276	30	0.000	0.861	30	0.001
8	0.211	30	0.002	0.879	30	0.003
9	0.230	30	0.000	0.869	30	0.002
10	0.203	30	0.003	0.837	30	0.000
11	0.184	30	0.011	0.907	30	0.012
12	0.226	30	0.000	0.867	30	0.001
13	0.229	30	0.000	0.860	30	0.001
14	0.211	30	0.001	0.911	30	0.016
15	0.179	30	0.015	0.920	30	0.028
16	0.211	30	0.001	0.904	30	0.010
17	0.215	30	0.001	0.901	30	0.009
18	0.198	30	0.004	0.893	30	0.006
19	0.172	30	0.024	0.909	30	0.014
20	0.147	30	0.095	0.899	30	0.008
21	0.188	30	0.008	0.918	30	0.024
22	0.154	30	0.066	0.898	30	0.007
23	0.231	30	0.000	0.885	30	0.004
24	0.165	30	0.035	0.916	30	0.021
25	0.214	30	0.001	0.854	30	0.001
26	0.204	30	0.003	0.898	30	0.008
27	0.198	30	0.004	0.913	30	0.018
28	0.239	30	0.000	0.901	30	0.009
29	0.252	30	0.000	0.893	30	0.006

Cont'd **(Table 48)**

30	0.233	30	0.000	0.909	30	0.014
31	0.189	30	0.008	0.865	30	0.001
32	0.253	30	0.000	0.823	30	0.000
33	0.218	30	0.001	0.899	30	0.008
34	0.155	30	0.062	0.921	30	0.029
35	0.244	30	0.000	0.899	30	0.008
36	0.327	30	0.000	0.825	30	0.000
37	0.191	30	0.007	0.921	30	0.029
38	0.202	30	0.003	0.893	30	0.006
39	0.214	30	0.001	0.873	30	0.002
40	0.170	30	0.027	0.917	30	0.023
41	0.184	30	0.011	0.907	30	0.013
42	0.201	30	0.003	0.912	30	0.017
43	0.328	30	0.000	0.824	30	0.000
44	0.223	30	0.001	0.908	30	0.013
45	0.219	30	0.001	0.856	30	0.001
46	0.224	30	0.001	0.901	30	0.009
47	0.210	30	0.002	0.890	30	0.005
48	0.260	30	0.000	0.868	30	0.001
49	0.249	30	0.000	0.862	30	0.001
50	0.146	30	0.103	0.885	30	0.004
51	0.159	30	0.051	0.889	30	0.005
52	0.147	30	0.096	0.903	30	0.010
53	0.165	30	0.037	0.922	30	0.030
54	0.243	30	0.000	0.873	30	0.002
55	0.242	30	0.000	0.852	30	0.001
56	0.308	30	0.000	0.780	30	0.000
57	0.286	30	0.000	0.845	30	0.000
58	0.220	30	0.001	0.898	30	0.008
59	0.225	30	0.000	0.847	30	0.001
60	0.223	30	0.001	0.842	30	0.000

Table 49. Test of normality for visual interest – Phase 2 (continued)

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
AB	,440	30	,000	,577	30	,000
AB-2	,503	30	,000	,452	30	,000
AC	,517	30	,000	,404	30	,000
AC-2	,517	30	,000	,404	30	,000
AD	,473	30	,000	,526	30	,000
AD-2	,517	30	,000	,404	30	,000
AE	,517	30	,000	,404	30	,000
AE-2	,503	30	,000	,452	30	,000
BA	,457	30	,000	,554	30	,000
BA-2	,517	30	,000	,404	30	,000
BC	,517	30	,000	,404	30	,000
BC-2	,517	30	,000	,404	30	,000
BD	,488	30	,000	,492	30	,000
BD-2	,528	30	,000	,347	30	,000
BE	,503	30	,000	,452	30	,000
BE-2	,488	30	,000	,492	30	,000
CA	,503	30	,000	,452	30	,000
CA-2	,517	30	,000	,404	30	,000
CB	,517	30	,000	,404	30	,000
CB-2	,457	30	,000	,554	30	,000
CD	,488	30	,000	,492	30	,000
CD-2	,406	30	,000	,612	30	,000
CE	,473	30	,000	,526	30	,000
CE-2	,440	30	,000	,577	30	,000
DA	,503	30	,000	,452	30	,000
DA-2	,517	30	,000	,404	30	,000
DB	,517	30	,000	,404	30	,000
DB-2	,517	30	,000	,404	30	,000
DC	,503	30	,000	,452	30	,000
DC-2	,440	30	,000	,577	30	,000
DE	,354	30	,000	,637	30	,000
DE-2	,372	30	,000	,632	30	,000
EA	,517	30	,000	,404	30	,000
EA-2	,528	30	,000	,347	30	,000
EB	,473	30	,000	,526	30	,000
EB-2	,488	30	,000	,492	30	,000
EC	,423	30	,000	,597	30	,000

Cont'd **(Table 49)**

EC-2	,389	30	,000	,624	30	,000
ED	,337	30	,000	,638	30	,000
ED-2	,337	30	,000	,638	30	,000
AB	,488	30	,000	,492	30	,000
AB-2	,503	30	,000	,452	30	,000
AC	,488	30	,000	,492	30	,000
AC-2	,457	30	,000	,554	30	,000
AD	,503	30	,000	,452	30	,000
AD-2	,488	30	,000	,492	30	,000
AE	,473	30	,000	,526	30	,000
AE-2	,457	30	,000	,554	30	,000
BA	,488	30	,000	,492	30	,000
BA-2	,473	30	,000	,526	30	,000
BC	,488	30	,000	,492	30	,000
BC-2	,457	30	,000	,554	30	,000
BD	,488	30	,000	,492	30	,000
BD-2	,457	30	,000	,554	30	,000
BE	,423	30	,000	,597	30	,000
BE-2	,406	30	,000	,612	30	,000
CA	,457	30	,000	,554	30	,000
CA-2	,440	30	,000	,577	30	,000
CB	,473	30	,000	,526	30	,000
CB-2	,423	30	,000	,597	30	,000
CD	,423	30	,000	,597	30	,000
CD-2	,457	30	,000	,554	30	,000
CE	,372	30	,000	,632	30	,000
CE-2	,354	30	,000	,637	30	,000
DA	,457	30	,000	,554	30	,000
DA-2	,457	30	,000	,554	30	,000
DB	,406	30	,000	,612	30	,000
DB-2	,457	30	,000	,554	30	,000
DC	,389	30	,000	,624	30	,000
DC-2	,423	30	,000	,597	30	,000
DE	,372	30	,000	,632	30	,000
DE-2	,406	30	,000	,612	30	,000
EA	,423	30	,000	,597	30	,000
EA-2	,457	30	,000	,554	30	,000
EB	,440	30	,000	,577	30	,000
EB-2	,423	30	,000	,597	30	,000
EC	,406	30	,000	,612	30	,000
EC-2	,389	30	,000	,624	30	,000
ED	,337	30	,000	,638	30	,000

Cont'd **(Table 49)**

ED-2	,337	30	,000	,638	30	,000
AB	,440	30	,000	,577	30	,000
AB-2	,457	30	,000	,554	30	,000
AC	,457	30	,000	,554	30	,000
AC-2	,423	30	,000	,597	30	,000
AD	,440	30	,000	,577	30	,000
AD-2	,457	30	,000	,554	30	,000
AE	,423	30	,000	,597	30	,000
AE-2	,440	30	,000	,577	30	,000
BA	,457	30	,000	,554	30	,000
BA-2	,440	30	,000	,577	30	,000
BC	,440	30	,000	,577	30	,000
BC-2	,406	30	,000	,612	30	,000
BD	,440	30	,000	,577	30	,000
BD-2	,440	30	,000	,577	30	,000
BE	,440	30	,000	,577	30	,000
BE-2	,406	30	,000	,612	30	,000
CA	,440	30	,000	,577	30	,000
CA-2	,457	30	,000	,554	30	,000
CB	,473	30	,000	,526	30	,000
CB-2	,406	30	,000	,612	30	,000
CD	,372	30	,000	,632	30	,000
CD-2	,389	30	,000	,624	30	,000
CE	,354	30	,000	,637	30	,000
CE-2	,354	30	,000	,637	30	,000
DA	,440	30	,000	,577	30	,000
DA-2	,423	30	,000	,597	30	,000
DB	,457	30	,000	,554	30	,000
DB-2	,440	30	,000	,577	30	,000
DC	,440	30	,000	,577	30	,000
DC-2	,440	30	,000	,577	30	,000
DE	,372	30	,000	,632	30	,000
DE-2	,389	30	,000	,624	30	,000
EA	,406	30	,000	,612	30	,000
EA-2	,423	30	,000	,597	30	,000
EB	,406	30	,000	,612	30	,000
EB-2	,440	30	,000	,577	30	,000
EC	,354	30	,000	,637	30	,000
EC-2	,372	30	,000	,632	30	,000
ED	,372	30	,000	,632	30	,000
ED-2	,372	30	,000	,632	30	,000

a. Lilliefors Significance Correction

Table 50. Pleasure state's means for D = 1.1 (4000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			3.13			Happy
Annoyed			3.17			Pleased
Unsatisfied			3.03			Satisfied
Melancholic			3.33			Contented
Despairing			3.27			Hopeful
Bored			3.20			Relaxed

Table 51. Pleasure state's means for D = 1.3 (4000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			2.93			Happy
Annoyed			2.97			Pleased
Unsatisfied			2.97			Satisfied
Melancholic			3.07			Contented
Despairing			2.93			Hopeful
Bored			2.80			Relaxed

Table 52. Pleasure state's means for D = 1.5 (4000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			2.93			Happy
Annoyed			3.00			Pleased
Unsatisfied			3.00			Satisfied
Melancholic			3.07			Contented
Despairing			2.93			Hopeful
Bored			3.40			Relaxed

Table 53. Pleasure state's means for D = 1.7 (4000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			3.43			Happy
Annoyed			3.43			Pleased
Unsatisfied			3.47			Satisfied
Melancholic			3.13			Contented
Despairing			3.33			Hopeful
Bored			3.27			Relaxed

Table 54. Pleasure state's means for D = 1.9 (4000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			3.47			Happy
Annoyed				3.57		Pleased
Unsatisfied				3.53		Satisfied
Melancholic			3.37			Contented
Despairing			3.20			Hopeful
Bored				3.50		Relaxed

Table 55. Arousal state's means for D = 1.1 (4000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed			2.93			Stimulated
Calm			2.80			Excited
Sluggish			2.87			Frenzied
Dull			2.73			Jittery
Sleepy			2.87			Wide-Awake
Aroused			2.67			Unaroused

Table 56. Arousal state's means for D = 1.3 (4000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed				3.50		Stimulated
Calm			3.47			Excited
Sluggish			3.27			Frenzied
Dull			3.10			Jittery
Sleepy			3.23			Wide-Awake
Aroused			3.17			Unaroused

Table 57. Arousal state's means for D = 1.5 (4000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed				3.60		Stimulated
Calm			3.33			Excited
Sluggish			3.43			Frenzied
Dull			3.40			Jittery
Sleepy				3.77		Wide-Awake
Aroused				3.80		Unaroused

Table 58. Arousal state's means for D = 1.7 (4000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed			3.30			Stimulated
Calm			3.20			Excited
Sluggish				3.50		Frenzied
Dull				3.50		Jittery
Sleepy				3.53		Wide-Awake
Aroused				3.50		Unaroused

Table 59. Arousal state's means for D = 1.9 (4000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed				3.53		Stimulated
Calm			3.27			Excited
Sluggish				3.57		Frenzied
Dull			3.37			Jittery
Sleepy				3.57		Wide-Awake
Aroused				3.83		Unaroused

Table 60. Pleasure state's means for D = 1.1 (6500K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			2.87			Happy
Annoyed			3.07			Pleased
Unsatisfied			2.83			Satisfied
Melancholic			3.03			Contented
Despairing			2.90			Hopeful
Bored			2.77			Relaxed

Table 61. Pleasure state's means for D = 1.3 (6500K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			3.07			Happy
Annoyed			3.10			Pleased
Unsatisfied			2.97			Satisfied
Melancholic			3.03			Contented
Despairing			2.97			Hopeful
Bored			3.17			Relaxed

Table 62. Pleasure state's means for D = 1.5 (6500K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			3.13			Happy
Annoyed			3.13			Pleased
Unsatisfied			3.10			Satisfied
Melancholic			3.10			Contented
Despairing			2.93			Hopeful
Bored			3.17			Relaxed

Table 63. Pleasure state's means for D = 1.7 (6500K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy				3.60		Happy
Annoyed			3.30			Pleased
Unsatisfied			3.40			Satisfied
Melancholic			3.47			Contented
Despairing			3.33			Hopeful
Bored				3.63		Relaxed

Table 64. Pleasure state's means for D = 1.9 (6500K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy				3.73		Happy
Annoyed				3.57		Pleased
Unsatisfied				3.57		Satisfied
Melancholic				3.57		Contented
Despairing			3.37			Hopeful
Bored				3.57		Relaxed

Table 65. Arousal state's means for D = 1.1 (6500K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed			2.87			Stimulated
Calm			2.90			Excited
Sluggish			2.93			Frenzied
Dull			2.87			Jittery
Sleepy			3.23			Wide Awake
Unaroused			2.80			Aroused

Table 66. Arousal state's means for D = 1.3 (6500K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed				3.57		Stimulated
Calm			3.33			Excited
Sluggish			3.20			Frenzied
Dull			3.00			Jittery
Sleepy			3.40			Wide Awake
Unaroused			3.13			Aroused

Table 67. Arousal state's means for D = 1.5 (6500K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed			3.43			Stimulated
Calm				3.57		Excited
Sluggish				3.70		Frenzied
Dull			3.43			Jittery
Sleepy				3.77		Wide Awake
Unaroused				3.60		Aroused

Table 68. Arousal state's means for D = 1.7 (6500K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed				3.87		Stimulated
Calm				3.73		Excited
Sluggish				3.73		Frenzied
Dull			3.30			Jittery
Sleepy				3.93		Wide Awake
Unaroused				3.77		Aroused

Table 69. Arousal state's means for D = 1.9 (6500K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed				3.73		Stimulated
Calm				3.50		Excited
Sluggish				3.70		Frenzied
Dull				3.50		Jittery
Sleepy				3.67		Wide Awake
Unaroused				3.97		Aroused

Table 70. Pleasure state's means for D = 1.1 (12000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			3.13			Happy
Annoyed			3.17			Pleased
Unsatisfied			3.03			Satisfied
Melancholic			3.07			Contented
Despairing			2.93			Hopeful
Bored			2.97			Relaxed

Table 71. Pleasure state's means for D = 1.3 (12000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			2.97			Happy
Annoyed			3.00			Pleased
Unsatisfied			3.17			Satisfied
Melancholic			3.47			Contented
Despairing			3.07			Hopeful
Bored			3.27			Relaxed

Table 72. Pleasure state's means for D = 1.5 (12000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			3.23			Happy
Annoyed			3.10			Pleased
Unsatisfied			3.27			Satisfied
Melancholic			3.23			Contented
Despairing			3.17			Hopeful
Bored				3.63		Relaxed

Table 73. Pleasure state's means for D = 1.7 (12000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy			3.43			Happy
Annoyed			3.47			Pleased
Unsatisfied			3.43			Satisfied
Melancholic			3.47			Contented
Despairing			3.37			Hopeful
Bored			3.43			Relaxed

Table 74. Pleasure state's means for D = 1.9 (12000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Unhappy				3.70		Happy
Annoyed				3.57		Pleased
Unsatisfied				3.60		Satisfied
Melancholic				3.80		Contented
Despairing				3.67		Hopeful
Bored				3.67		Relaxed

Table 75. Arousal state's means for D = 1.1 (12000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed			3.13			Stimulated
Calm			3.00			Excited
Sluggish			2.87			Frenzied
Dull			2.63			Jittery
Sleepy			2.87			Wide Awake
Unaroused			2.60			Aroused

Table 76. Arousal state's means for D = 1.3 (12000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed			3.47			Stimulated
Calm			3.23			Excited
Sluggish			3.27			Frenzied
Dull			3.10			Jittery
Sleepy			3.40			Wide Awake
Unaroused			3.27			Aroused

Table 77. Arousal state's means for D = 1.5 (12000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed				3.77		Stimulated
Calm				3.57		Excited
Sluggish				3.67		Frenzied
Dull			3.17			Jittery
Sleepy				3.80		Wide Awake
Unaroused				3.73		Aroused

Table 78. Arousal state's means for D = 1.7 (12000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed				3.73		Stimulated
Calm			3.33			Excited
Sluggish				3.60		Frenzied
Dull			3.47			Jittery
Sleepy				3.63		Wide Awake
Unaroused				3.70		Aroused

Table 79. Arousal state's means for D = 1.9 (12000K) – Phase 2

	Extremely Negative	Negative	Neutral	Positive	Extremely Positive	
Relaxed				3.57		Stimulated
Calm			3.43			Excited
Sluggish				3.73		Frenzied
Dull			3.17			Jittery
Sleepy			3.40			Wide Awake
Unaroused				3.93		Aroused

Table 80. Test of normality for emotional response for all Kelvins (4000K, 6500K, 12000K) – Phase 2

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
1.1/Pleasure/Unhappy-Happy	,191	30	,007	,908	30	,013
1.1/Pleasure/Annoyed-Pleased	,185	30	,010	,901	30	,009
1.1/Pleased/Unsatisfied-Satisfied	,200	30	,003	,902	30	,009
1.1/Pleased/Melancholic-Contented	,208	30	,002	,900	30	,008
1.1/Pleased/Despairing-Hopeful	,192	30	,006	,916	30	,021
1.1/Pleased/Bored-Relaxed	,235	30	,000	,889	30	,004
1.1/Arousal/Relaxed-Sstimulated	,180	30	,014	,893	30	,006
1.1/Arousal/Calm-Excited	,177	30	,017	,876	30	,002
1.1/Arousal/Sluggish-Frenzied	,198	30	,004	,861	30	,001
1.1/Arousal/Dull-Jittery	,189	30	,008	,881	30	,003
1.1/Arousal/Sleepy-Wide Awake	,164	30	,038	,868	30	,002
1.1/Arousal/Unaroused-Aroused	,177	30	,017	,851	30	,001
1.3/Pleasure/Unhappy-Happy	,191	30	,007	,900	30	,008
1.3/Pleasure/Annoyed-Pleased	,199	30	,004	,885	30	,004
1.3/Pleased/Unsatisfied-Satisfied	,158	30	,053	,883	30	,003
1.3/Pleased/Melancholic-Contented	,189	30	,008	,919	30	,025
1.3/Pleased/Despairing-Hopeful	,223	30	,001	,907	30	,013
1.3/Pleased/Bored-Relaxed	,178	30	,016	,910	30	,015
1.3/Arousal/Relaxed-Sstimulated	,277	30	,000	,850	30	,001
1.3/Arousal/Calm-Excited	,228	30	,000	,886	30	,004
1.3/Arousal/Sluggish-Frenzied	,229	30	,000	,901	30	,009
1.3/Arousal/Dull-Jittery	,202	30	,003	,899	30	,008
1.3/Arousal/Sleepy-Wide Awake	,211	30	,002	,886	30	,004

Cont'd **(Table 80)**

1.3/Arousal/Unaroused-Aroused	,186	30	,010	,881	30	,003
1.5/Pleasure/Unhappy-Happy	,148	30	,093	,893	30	,006
1.5/Pleasure/Annoyed-Pleased	,186	30	,009	,881	30	,003
1.5/Pleased/Unsatisfied-Satisfied	,213	30	,001	,865	30	,001
1.5/Pleased/Melancholic-Contented	,165	30	,035	,873	30	,002
1.5/Pleased/Despairing-Hopeful	,141	30	,135	,885	30	,004
1.5/Pleased/Bored-Relaxed	,186	30	,010	,863	30	,001
1.5/Arousal/Relaxed-Stimulated	,171	30	,025	,896	30	,007
1.5/Arousal/Calm-Excited	,223	30	,001	,908	30	,013
1.5/Arousal/Sluggish-Frenzied	,186	30	,010	,909	30	,014
1.5/Arousal/Dull-Jittery	,255	30	,000	,888	30	,004
1.5/Arousal/Sleepy-Wide Awake	,228	30	,000	,870	30	,002
1.5/Arousal/Unaroused-Aroused	,286	30	,000	,845	30	,000
1.7/Pleasure/Unhappy-Happy	,190	30	,007	,872	30	,002
1.7/Pleasure/Annoyed-Pleased	,172	30	,024	,887	30	,004
1.7/Pleased/Unsatisfied-Satisfied	,172	30	,023	,904	30	,010
1.7/Pleased/Melancholic-Contented	,242	30	,000	,882	30	,003
1.7/Pleased/Despairing-Hopeful	,213	30	,001	,909	30	,014
1.7/Pleased/Bored-Relaxed	,229	30	,000	,901	30	,009
1.7/Arousal/Relaxed-Stimulated	,200	30	,003	,875	30	,002
1.7/Arousal/Calm-Excited	,194	30	,005	,897	30	,007
1.7/Arousal/Sluggish-Frenzied	,192	30	,006	,892	30	,005
1.7/Arousal/Dull-Jittery	,195	30	,005	,889	30	,004
1.7/Arousal/Sleepy-Wide Awake	,237	30	,000	,857	30	,001
1.7/Arousal/Unaroused-Aroused	,201	30	,003	,872	30	,002
1.9/Pleasure/Unhappy-Happy	,198	30	,004	,891	30	,005
1.9/Pleasure/Annoyed-Pleased	,223	30	,001	,856	30	,001
1.9/Pleased/Unsatisfied-Satisfied	,204	30	,003	,875	30	,002

Cont'd **(Table 80)**

1.9/Pleased/Melancholic-Contented	,174	30	,021	,871	30	,002
1.9/Pleased/Despairing-Hopeful	,176	30	,018	,878	30	,002
1.9/Pleased/Bored-Relaxed	,262	30	,000	,883	30	,003
1.9/Arousal/Relaxed-Stimulated	,201	30	,003	,859	30	,001
1.9/Arousal/Calm-Excited	,195	30	,005	,875	30	,002
1.9/Arousal/Sluggish-Frenzied	,205	30	,002	,890	30	,005
1.9/Arousal/Dull-Jittery	,185	30	,010	,913	30	,017
1.9/Arousal/Sleepy-Wide Awake	,174	30	,021	,886	30	,004
1.9/Arousal/Unaroused-Aroused	,261	30	,000	,858	30	,001
1.1/Pleasure/Unhappy-Happy	,179	30	,015	,860	30	,001
1.1/Pleasure/Annoyed-Pleased	,211	30	,001	,824	30	,000
1.1/Pleased/Unsatisfied-Satisfied	,181	30	,014	,855	30	,001
1.1/Pleased/Melancholic-Contented	,157	30	,058	,908	30	,014
1.1/Pleased/Despairing-Hopeful	,170	30	,026	,899	30	,008
1.1/Pleased/Bored-Relaxed	,170	30	,026	,888	30	,004
1.1/Arousal/Relaxed-Sstimulated	,205	30	,002	,855	30	,001
1.1/Arousal/Calm-Excited	,203	30	,003	,867	30	,001
1.1/Arousal/Sluggish-Frenzied	,152	30	,074	,891	30	,005
1.1/Arousal/Dull-Jittery	,142	30	,124	,908	30	,013
1.1/Arousal/Sleepy-Wide Awake	,171	30	,026	,873	30	,002
1.1/Arousal/Unaroused-Aroused	,201	30	,003	,864	30	,001
1.3/Pleasure/Unhappy-Happy	,230	30	,000	,876	30	,002
1.3/Pleasure/Annoyed-Pleased	,203	30	,003	,895	30	,006
1.3/Pleased/Unsatisfied-Satisfied	,225	30	,000	,894	30	,006
1.3/Pleased/Melancholic-Contented	,179	30	,015	,920	30	,028
1.3/Pleased/Despairing-Hopeful	,189	30	,008	,915	30	,020
1.3/Pleased/Bored-Relaxed	,233	30	,000	,899	30	,008

Cont'd **(Table 80)**

1.3/Arousal/Relaxed-Sstimulated	,282	30	,000	,869	30	,002
1.3/Arousal/Calm-Excited	,185	30	,010	,915	30	,020
1.3/Arousal/Sluggish-Frenzied	,213	30	,001	,913	30	,018
1.3/Arousal/Dull-Jittery	,200	30	,004	,918	30	,024
1.3/Arousal/Sleepy-Wide Awake	,240	30	,000	,897	30	,007
1.3/Arousal/Unaroused-Aroused	,184	30	,011	,912	30	,016
1.5/Pleasure/Unhappy-Happy	,280	30	,000	,851	30	,001
1.5/Pleasure/Annoyed-Pleased	,268	30	,000	,857	30	,001
1.5/Pleased/Unsatisfied-Satisfied	,231	30	,000	,880	30	,003
1.5/Pleased/Melancholic-Contented	,244	30	,000	,871	30	,002
1.5/Pleased/Despairing-Hopeful	,155	30	,062	,921	30	,029
1.5/Pleased/Bored-Relaxed	,179	30	,015	,913	30	,018
1.5/Arousal/Relaxed-Stimulated	,196	30	,005	,864	30	,001
1.5/Arousal/Calm-Excited	,308	30	,000	,850	30	,001
1.5/Arousal/Sluggish-Frenzied	,257	30	,000	,871	30	,002
1.5/Arousal/Dull-Jittery	,226	30	,000	,878	30	,003
1.5/Arousal/Sleepy-Wide Awake	,325	30	,000	,831	30	,000
1.5/Arousal/Unaroused-Aroused	,322	30	,000	,845	30	,000
1.7/Pleasure/Unhappy-Happy	,256	30	,000	,840	30	,000
1.7/Pleasure/Annoyed-Pleased	,220	30	,001	,867	30	,001
1.7/Pleased/Unsatisfied-Satisfied	,208	30	,002	,875	30	,002
1.7/Pleased/Melancholic-Contented	,202	30	,003	,901	30	,009
1.7/Pleased/Despairing-Hopeful	,173	30	,023	,905	30	,011
1.7/Pleased/Bored-Relaxed	,194	30	,005	,894	30	,006
1.7/Arousal/Relaxed-Stimulated	,280	30	,000	,833	30	,000
1.7/Arousal/Calm-Excited	,257	30	,000	,860	30	,001
1.7/Arousal/Sluggish-Frenzied	,261	30	,000	,870	30	,002
1.7/Arousal/Dull-Jittery	,191	30	,007	,913	30	,017

Cont'd **(Table 80)**

1.7/Arousal/Sleepy-Wide Awake	,255	30	,000	,810	30	,000
1.7/Arousal/Unaroused-Aroused	,258	30	,000	,871	30	,002
1.9/Pleasure/Unhappy-Happy	,244	30	,000	,800	30	,000
1.9/Pleasure/Annoyed-Pleased	,254	30	,000	,838	30	,000
1.9/Pleased/Unsatisfied-Satisfied	,223	30	,001	,856	30	,001
1.9/Pleased/Melancholic-Contented	,230	30	,000	,868	30	,002
1.9/Pleased/Despairing-Hopeful	,162	30	,042	,892	30	,005
1.9/Pleased/Bored-Relaxed	,233	30	,000	,872	30	,002
1.9/Arousal/Relaxed-Stimulated	,262	30	,000	,813	30	,000
1.9/Arousal/Calm-Excited	,194	30	,005	,869	30	,002
1.9/Arousal/Sluggish-Frenzied	,203	30	,003	,883	30	,003
1.9/Arousal/Dull-Jittery	,208	30	,002	,899	30	,008
1.9/Arousal/Sleepy-Wide Awake	,192	30	,006	,872	30	,002
1.9/Arousal/Unaroused-Aroused	,216	30	,001	,842	30	,000
1.1/Pleasure/Unhappy-Happy	,186	30	,009	,858	30	,001
1.1/Pleasure/Annoyed-Pleased	,181	30	,014	,855	30	,001
1.1/Pleased/Unsatisfied-Satisfied	,172	30	,023	,871	30	,002
1.1/Pleased/Melancholic-Contented	,148	30	,093	,893	30	,006
1.1/Pleased/Despairing-Hopeful	,141	30	,135	,885	30	,004
1.1/Pleased/Bored-Relaxed	,157	30	,057	,893	30	,006
1.1/Arousal/Relaxed-Sstimulated	,161	30	,046	,890	30	,005
1.1/Arousal/Calm-Excited	,190	30	,007	,882	30	,003
1.1/Arousal/Sluggish-Frenzied	,193	30	,006	,892	30	,006
1.1/Arousal/Dull-Jittery	,177	30	,017	,886	30	,004
1.1/Arousal/Sleepy-Wide Awake	,161	30	,046	,900	30	,008
1.1/Arousal/Unaroused-Aroused	,220	30	,001	,841	30	,000
1.3/Pleasure/Unhappy-Happy	,207	30	,002	,891	30	,005
1.3/Pleasure/Annoyed-Pleased	,223	30	,001	,875	30	,002

Cont'd **(Table 80)**

1.3/Pleased/Unsatisfied-Satisfied	,181	30	,014	,855	30	,001
1.3/Pleased/Melancholic-Contented	,183	30	,011	,871	30	,002
1.3/Pleased/Despairing-Hopeful	,152	30	,076	,884	30	,004
1.3/Pleased/Bored-Relaxed	,153	30	,069	,911	30	,016
1.3/Arousal/Relaxed-Sstimulated	,217	30	,001	,868	30	,002
1.3/Arousal/Calm-Excited	,214	30	,001	,893	30	,006
1.3/Arousal/Sluggish-Frenzied	,212	30	,001	,897	30	,007
1.3/Arousal/Dull-Jittery	,162	30	,042	,894	30	,006
1.3/Arousal/Sleepy-Wide Awake	,181	30	,013	,899	30	,008
1.3/Arousal/Unaroused-Aroused	,167	30	,031	,918	30	,024
1.5/Pleasure/Unhappy-Happy	,193	30	,006	,854	30	,001
1.5/Pleasure/Annoyed-Pleased	,176	30	,018	,885	30	,004
1.5/Pleased/Unsatisfied-Satisfied	,225	30	,000	,824	30	,000
1.5/Pleased/Melancholic-Contented	,210	30	,002	,855	30	,001
1.5/Pleased/Despairing-Hopeful	,183	30	,012	,896	30	,007
1.5/Pleased/Bored-Relaxed	,213	30	,001	,863	30	,001
1.5/Arousal/Relaxed-Stimulated	,248	30	,000	,867	30	,001
1.5/Arousal/Calm-Excited	,266	30	,000	,861	30	,001
1.5/Arousal/Sluggish-Frenzied	,253	30	,000	,883	30	,003
1.5/Arousal/Dull-Jittery	,188	30	,008	,914	30	,019
1.5/Arousal/Sleepy-Wide Awake	,272	30	,000	,836	30	,000
1.5/Arousal/Unaroused-Aroused	,237	30	,000	,881	30	,003
1.7/Pleasure/Unhappy-Happy	,215	30	,001	,841	30	,000
1.7/Pleasure/Annoyed-Pleased	,261	30	,000	,782	30	,000
1.7/Pleased/Unsatisfied-Satisfied	,239	30	,000	,811	30	,000
1.7/Pleased/Melancholic-Contented	,210	30	,002	,853	30	,001
1.7/Pleased/Despairing-Hopeful	,178	30	,016	,879	30	,003

Cont'd **(Table 80)**

1.7/Pleased/Bored-Relaxed	,262	30	,000	,863	30	,001
1.7/Arousal/Relaxed-Stimulated	,278	30	,000	,813	30	,000
1.7/Arousal/Calm-Excited	,280	30	,000	,847	30	,001
1.7/Arousal/Sluggish-Frenzied	,256	30	,000	,860	30	,001
1.7/Arousal/Dull-Jittery	,194	30	,006	,867	30	,001
1.7/Arousal/Sleepy-Wide Awake	,276	30	,000	,842	30	,000
1.7/Arousal/Unaroused-Aroused	,261	30	,000	,841	30	,000
1.9/Pleasure/Unhappy-Happy	,282	30	,000	,785	30	,000
1.9/Pleasure/Annoyed-Pleased	,275	30	,000	,784	30	,000
1.9/Pleased/Unsatisfied-Satisfied	,271	30	,000	,766	30	,000
1.9/Pleased/Melancholic-Contented	,280	30	,000	,813	30	,000
1.9/Pleased/Despairing-Hopeful	,239	30	,000	,845	30	,000
1.9/Pleased/Bored-Relaxed	,205	30	,002	,849	30	,001
1.9/Arousal/Relaxed-Stimulated	,246	30	,000	,780	30	,000
1.9/Arousal/Calm-Excited	,264	30	,000	,764	30	,000
1.9/Arousal/Sluggish-Frenzied	,244	30	,000	,805	30	,000
1.9/Arousal/Dull-Jittery	,213	30	,001	,899	30	,008
1.9/Arousal/Sleepy-Wide Awake	,249	30	,000	,821	30	,000
1.9/Arousal/Unaroused-Aroused	,235	30	,000	,785	30	,000

a. Lilliefors Significance Correction

Table 81. Findings of the itemized analysis for D = 1.1 between 4000K & 6500K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 0.382
annoyed-pleased		p = 0.893
unsatisfied-satisfied		p = 0.424
melancholic-contented		p = 0.222
despairing - hopeful		p = 0.125
bored-relaxed		p = 0.127

Table 82. Findings of the itemized analysis for D = 1.1 between 4000K & 12000K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 0.876
annoyed-pleased		p = 0.767
unsatisfied-satisfied		p = 0.607
melancholic-contented		p = 0.273
despairing - hopeful		p = 0.216
bored-relaxed		p = 0.365

Table 83. Findings of the itemized analysis for D = 1.1 between 6500K & 12000K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 0.054
annoyed-pleased		p = 0.448
unsatisfied-satisfied		p = 0.225
melancholic-contented		p = 0.776
despairing - hopeful		p = 0.755
bored-relaxed		p = 0.350

Table 84. Findings of the itemized analysis for D = 1.3 between 4000K & 6500K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 0.543
annoyed-pleased		p = 0.599
unsatisfied-satisfied		p = 0.881
melancholic-contented		p = 0.851
despairing - hopeful		p = 0.635
bored-relaxed		p = 0.101

Table 85. Findings of the itemized analysis for D = 1.3 between 4000K & 12000K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 0.726
annoyed-pleased		p = 1.000
unsatisfied-satisfied		p = 0.695
melancholic-contented		p = 0.108
despairing - hopeful		p = 0.717
bored-relaxed		p = 0.134

Table 86. Findings of the itemized analysis for D = 1.3 between 6500K & 12000K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 0.660
annoyed-pleased		p = 0.625
unsatisfied-satisfied		p = 0.423
melancholic-contented		p = 0.051
despairing - hopeful		p = 0.732
bored-relaxed		p = 0.752

Table 87. Findings of the itemized analysis for D = 1.5 between 4000K & 6500K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 0.516
annoyed-pleased		p = 0.506
unsatisfied-satisfied		p = 0.623
melancholic-contented		p = 0.935
despairing - hopeful		p = 0.905
bored-relaxed		p = 0.311

Table 88. Findings of the itemized analysis for D = 1.5 between 4000K & 12000K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 0.151
annoyed-pleased		p = 0.479
unsatisfied-satisfied		p = 0.179
melancholic-contented		p = 0.348
despairing - hopeful		p = 0.191
bored-relaxed		p = 0.218

Table 89. Findings of the itemized analysis for D = 1.5 between 6500K & 12000K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 0.536
annoyed-pleased		p = 0.858
unsatisfied-satisfied		p = 0.446
melancholic-contented		p = 0.466
despairing - hopeful		p = 0.175
bored-relaxed	p = 0.048	

Table 90. Findings of the itemized analysis for D = 1.7 between 4000K & 6500K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 0.648
annoyed-pleased		p = 0.479
unsatisfied-satisfied		p = 0.660
melancholic-contented		p = 0.113
despairing - hopeful		p = 0.951
bored-relaxed		p = 0.084

Table 91. Findings of the itemized analysis for D = 1.7 between 4000K & 12000K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 0.837
annoyed-pleased		p = 0.767
unsatisfied-satisfied		p = 0.923
melancholic-contented		p = 0.088
despairing - hopeful		p = 0.666
bored-relaxed		p = 0.489

Table 92. Findings of the itemized analysis for D = 1.7 between 6500K & 12000K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 0.380
annoyed-pleased		p = 0.458
unsatisfied-satisfied		p = 0.816
melancholic-contented		p = 0.793
despairing - hopeful		p = 0.951
bored-relaxed		P = 0.299

Table 93. Findings of the itemized analysis for D = 1.9 between 4000K & 6500K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 0.295
annoyed-pleased		p = 0.740
unsatisfied-satisfied		p = 0.869
melancholic-contented		p = 0.361
despairing - hopeful		p = 0.512
bored-relaxed		p = 0.973

Table 94. Findings of the itemized analysis for D = 1.9 between 4000K & 12000K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 0.298
annoyed-pleased		p = 1.000
unsatisfied-satisfied		p = 0.933
melancholic-contented		p = 0.066
despairing - hopeful	p = 0.037	
bored-relaxed		p = 0.512

Table 95. Findings of the itemized analysis for D = 1.9 between 6500K & 12000K (pleasure dimension) – Phase 2

Items	Significant difference	No significant difference
unhappy-happy		p = 1.000
annoyed-pleased		p = 0.768
unsatisfied-satisfied		p = 0.948
melancholic-contented		p = 0.284
despairing - hopeful		p = 0.164
bored-relaxed		P = 0.475

Table 96. Findings of the itemized analysis for D = 1.1 between 4000K & 6500K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated		p = 0.977
calm-excited		p = 0.643
sluggish-frenzied		p = 0.896
dull-jittery		p = 0.502
sleepy-wide awake		p = 0.106
unaroused-aroused		p = 0.733

Table 97. Findings of the itemized analysis for D = 1.1 between 4000K & 12000K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated		p = 0.357
calm-excited		p = 0.441
sluggish-frenzied		p = 0.953
dull-jittery		p = 0.593
sleepy-wide awake		p = 1.000
unaroused-aroused		p = 0.617

Table 98. Findings of the itemized analysis for D = 1.1 between 6500K & 12000K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated		p = 0.085
calm-excited		p = 0.855
sluggish-frenzied		p = 0.637
dull-jittery		p = 0.299
sleepy-wide awake	p = 0.013	
unaroused-aroused		p = 0.299

Table 99. Findings of the itemized analysis for D = 1.3 between 4000K & 6500K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated		p = 0.808
calm-excited		p = 0.485
sluggish-frenzied		p = 0.583
dull-jittery		p = 0.654
sleepy-wide awake		p = 0.590
unaroused-aroused		p = 0.603

Table 100. Findings of the itemized analysis for D = 1.3 between 4000K & 12000K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated		p = 0.961
calm-excited		p = 0.372
sluggish-frenzied		p = 0.747
dull-jittery		p = 0.827
sleepy-wide awake		p = 0.577
unaroused-aroused		p = 0.979

Table 101. Findings of the itemized analysis for D = 1.3 between 6500K & 12000K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated		p = 0.734
calm-excited		p = 0.865
sluggish-frenzied		p = 0.537
dull-jittery		p = 0.713
sleepy-wide awake		p = 1.000
unaroused-aroused		p = 0.467

Table 102. Findings of the itemized analysis for D = 1.5 between 4000K & 6500K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated		p = 0.320
calm-excited		p = 0.348
sluggish-frenzied		p = 0.336
dull-jittery		p = 0.864
sleepy-wide awake		p = 1.000
unaroused-aroused		p = 0.287

Table 103. Findings of the itemized analysis for D = 1.5 between 4000K & 12000K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated		p = 0.604
calm-excited		p = 0.559
sluggish-frenzied		p = 0.477
dull-jittery		p = 0.261
sleepy-wide awake		p = 0.684
unaroused-aroused		p = 0.588

Table 104. Findings of the itemized analysis for D = 1.5 between 6500K & 12000K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated		p = 0.110
calm-excited		p = 0.915
sluggish-frenzied		p = 0.820
dull-jittery		p = 0.230
sleepy-wide awake		p = 0.796
unaroused-aroused		p = 0.670

Table 105. Findings of the itemized analysis for D = 1.7 between 4000K & 6500K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated	p = 0.032	
calm-excited		p = 0.144
sluggish-frenzied		p = 0.545
dull-jittery		p = 0.419
sleepy-wide awake		p = 0.150
unaroused-aroused		p = 0.333

Table 106. Findings of the itemized analysis for D = 1.7 between 4000K & 12000K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated		p = 0.085
calm-excited		p = 0.861
sluggish-frenzied		p = 0.673
dull-jittery		p = 0.885
sleepy-wide awake		p = 0.884
unaroused-aroused		p = 0.507

Table 107. Findings of the itemized analysis for D = 1.7 between 6500K & 12000K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated		p = 0.600
calm-excited		p = 0.138
sluggish-frenzied		p = 0.674
dull-jittery		p = 0.607
sleepy-wide awake		p = 0.101
unaroused-aroused		p = 0.629

Table 108. Findings of the itemized analysis for D = 1.9 between 4000K & 6500K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated		p = 0.240
calm-excited		p = 0.413
sluggish-frenzied		p = 0.668
dull-jittery		p = 0.501
sleepy-wide awake		p = 0.712
unaroused-aroused		p = 0.470

Table 109. Findings of the itemized analysis for D = 1.9 between 4000K & 12000K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated		p = 0.788
calm-excited		p = 0.543
sluggish-frenzied		p = 0.480
dull-jittery		p = 0.398
sleepy-wide awake		p = 0.490
unaroused-aroused		p = 0.572

Table 110. Findings of the itemized analysis for D = 1.9 between 6500K & 12000K (arousal dimension) – Phase 2

Items	Significant difference	No significant difference
relaxed-stimulated		p = 0.314
calm-excited		p = 0.632
sluggish-frenzied		p = 0.829
dull-jittery	p = 0.048	
sleepy-wide awake		p = 0.231
unaroused-aroused		p = 0.782