THE ROLE OF COLOR IN DETERMINING VISUAL COMPLEXITY IN ABSTRACT IMAGES

A Ph.D. Dissertation

by

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The Graduate School of Economics and Social Sciences

of

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THE DEPARTMENT OF INTERIOR ARCHITECTURE AND ENVIRONMENTAL DESIGN

İHSAN DOĞRAMACI BİLKENT UNIVERSITY

ANKARA

September 2019

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

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ABSTRACT

THE ROLE OF COLOR IN DETERMINING VISUAL COMPLEXITY IN ABSTRACT IMAGES

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Colors are important elements of everyday environment as they effect every part of our daily life including our physiology, psychology, well- being, perception, cognition, and etc. Colors are experienced and encountered in everyday environment and they are never seen in isolation since the environment which surrounds us presents the colors together with other colors (Kocaoğlu & Olguntürk, 2018). The thesis searches the association between color, visual complexity and visual interest in abstract images without isolating colors from each other, as previous studies did. Thus, the aim of this thesis is to understand the role of color on visual complexity and visual interest in abstract images in order to develop a theoretical measure that merges both scientific and artistic approaches of color. This study is conducted to find the level of visual complexity which makes an image visually interesting and the role of color within this phenomenon by using Delta E (ΔE) values of colors in abstract images. As the results of the study indicated, there was an inverted U- curve relationship between average Delta E values and both visual interest and visual complexity in abstract images.

Keywords: Abstract Images, Color, Delta E, Visual Complexity, Visual Interest

ÖZET

RENGİN SOYUT İMAJLARDAKİ GÖRSEL KARMAŞIKLIK ÜZERİNDEKİ ROLÜ

Aslanoğlu, Rengin
Doktora, İç Mimarlık ve Çevre Tasarımı Bölümü
Tez Danışmanı: Doç. Dr. Nilgün Olguntürk

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Renkler, fizyoloji, psikoloji, refah, algı, biliş vb. olmak üzere günlük hayatımızın her bölümünü etkilediği için günlük çevrenin önemli unsurlarındandır. Her gün etrafımızı çevreleyen ortamlarda renklerle karşılaşmaktayız ve bu ortamlarda renkler bir bütün halindedir (Kocaoğlu & Olguntürk, 2018). Önceki çalışmalar, renkleri birbirinden ayırarak renk parçaları kullanmışlardır. Bu tez, önceki çalışmaların aksine renkleri birbirinden izole etmeden, soyut imajlarda renk, görsel karmaşıklık ve görsel ilgi arasındaki ilişkiyi araştırmaktadır. Bu nedenle, tez, rengin hem bilimsel hem de sanatsal yaklaşımlarını birleştirmek için teorik bir ölçü geliştirmek amacıyla, rengin görsel karmaşıklık ve görsel ilgiyi üzerindeki rolünü anlamayı amaçlamaktadır. Bu çalışma, imajları görsel olarak ilginç kılan görsel karmaşıklık düzeyini ve soyut imajlardaki renklerin Delta E (ΔE) değerlerini kullanarak bu görüngü içindeki rengin rolünü bulmak için yapılmıştır. Çalışmanın sonuçlarına göre, ortalama Delta E değerleri ile soyut imajlarda hem görsel ilgi hem de görsel karmaşıklık arasında ters U-eğrisi ilişkisi bulunmuştur.

Keywords: Delta E, Görsel İlgi, Görsel Karmaşıklık, Renk, Soyut İmajlar

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CHAPTER 1

INTRODUCTION

Colors are the important elements of everyday environment as they effect every part of our daily life including our physiology, psychology, well- being, perception, cognition, and etc., it is the indispensable part of human visual experience and aesthetic judgement (Moller & Hurlbert, 1997). Studies showed that people with normal trichromatic color vision have a strong color detection and discrimination abilities (Gegenfurtner & Rieger, 2000) and proved that color is what the eye sees best (Chaparro, Huang, Kronauer & Eskew, 1993). Thus, color is an important visual bond that constitutes emotional, physical and sensorial relations between people and their environment (Ulusoy & Olguntürk, 2016). Having an understanding of visual complexity, visual interest and color can help analyze and explain human perception system by clarifying the uncertainty of the role of color in visual complexity perception.

Every person with normal vision system experiences and encounters with color in their everyday environment and colors are never seen in isolation since the environment which surrounds us presents the colors together with other colors

(Kocaoğlu & Olguntürk, 2018). Most of the well-known color studies researching about the effects of color on human psychology, physiology, as well as examine the effects of emotion, mood, attention, and well-being used isolated color patches which might be lacking in reflecting the dominating factors such as the effect of different color compositions on human visual perception (Ladau, Smith & Place, 1988; Mahnke, 1996; Valdez & Mehrabian, 1994). There are limited number of studies examining color, visual complexity and visual interest together and this study attempted to bring a new understanding to the association between color, visual complexity and visual interest since the complexity of an image expresses many aspects of its content and is an important factor in visual interest (Kocaoğlu & Olguntürk, 2018).

Complexity studies' results differ a lot since they manipulated all of the complexity dimensions without considering the dimensions' appropriateness to the related factors (Nadal, Munar, Marty & Cela-conde, 2010). The first part of this study were framing the dimensions of visual complexity by focusing only on; intelligibility, organization, and variety of colors in abstract images. Abstract images were selected for evaluating the association between color, visual interest and visual complexity since a visual language is composed in those images by just using line, form, shape, and color which makes it universal and culture-independent. For the first part of this study, Piet Mondrian's two abstract paintings; Ocean 5 and Composition No. VII and Vasily Kandinsky's two abstract paintings; Composition 8 and Decisive Rose were selected. As the first part of the thesis result showed, the second part of the study found the dominating dimension of complexity and searched further about the role of color in visual complexity by using a generated abstract image. In order to have an in depth knowledge about the relationship between color, visual complexity and visual interest, an abstract image was generated and colored according to various color schemes; monochromatic, analogous, split-complementary, complementary, triadic and tetradic. Those color schemes are used by designers and artists and are mostly intuitive in their works and described qualitatively (Kocaoğlu Aslanoğlu & Olguntürk, 2019).

1.1. Aim of the Study

The aim of this study is to understand the association between color, visual complexity and visual interest in abstract images for developing a theoretical measure in order to merge both scientific and artistic approaches of color. By merging objective and subjective methods, a better understanding of visual complexity and visual interest can be obtained. With the aim of building a theoretical measure for the association between color, visual complexity and visual interest, two interconnected experiments were conducted.

The first part aimed to find the most effective visual complexity dimensions about color and the related research questions of the first experiment are:

RQ1.1. How do intelligibility of colors in abstract images effect visual complexity and visual interest?

RQ1.2. How do organization of colors in abstract images effect visual complexity and visual interest?

RQ1.3. How do variety of colors in abstract images effect visual complexity and visual interest?

Also, the first part of the experiment aimed to find the association between visual complexity and visual interest with the research question mentioned above:

RQ1.4. Is there a relationship between visual complexity and visual interest in abstract images?

Hypotheses for the first experiment are:

H1.1. As intelligibility of colors in an abstract image increase, visual complexity and visual interest will also increase until there is over unintelligibility where both will decrease.

H1.2. As difficulty in distinguishing the rules used in images increase, visual complexity and visual interest will also increase.

H1.3. As the variety of colors used in abstract images increase, visual complexity and visual interest will both increase.

The hypothesis for finding the association between visual complexity and visual interest:

H1.4. There is an inverted U- curve relationship between visual complexity and visual interest in abstract images.

The second part aimed to develop a theoretical measure for understanding the role of color in visual complexity and visual interest in abstract images by using perceived total color difference (Delta E) and the research questions of the second experiment are:

RQ2.1. How do the perceived total color difference (Delta E) values of colors used in an abstract image effect the perception of visual complexity?

RQ2.2. How do the perceived total color difference (Delta E) values of colors used in an abstract image effect the perception of visual interest?

Hypotheses for the second experiment are:

H.2.1. As the average perceived total color difference (Delta E) values of colors in an abstract image increases, visual complexity will increase until a threshold where visual complexity start to decrease.

H.2.2. As the average perceived total color difference (Delta E) values of colors in an abstract image increases, visual interest will increase until a threshold where visual interest start to decrease.

1.2. The General Structure of the Thesis

This thesis consists of seven chapters. The first chapter consists the aim, research questions and hypotheses of the thesis. Also, the first chapter is giving information about the general structure of the thesis by giving descriptions of every chapter.

The second chapter of the thesis is about visual complexity. It contains definition of complexity, its further details and how to measure visual complexity with a compilation of previous studies. In addition, this chapter presents dimensions of visual complexity with prior experimental studies and their various measurement methodologies.

The third chapter is about color. Basics of color and different color order systems; Munsell Colour System, NCS (Natural Color System), CIELAB and RGB Color Model are explained in detail. Then, the relationship between color and visual complexity is discussed referring to prior studies.

The forth chapter describes the experimental study with its aims, research questions, hypotheses, methodologies of Part 1 and Part 2, and related procedures such as evaluation of abstract images with K- Mean, preparing the questionnaires and related details. This chapter finishes with the expanded explanation of procedures of the experiments; Part 1 and Part 2.

The fifth chapter includes the results and their data analysis with Statistical Package for the Social Sciences (SPSS). Both the results and statistical analysis of Part 1 and Part 2 presented in tables and graphs in this chapter.

Discussion of the results of the experiments and their relation to previous studies are stated in the sixth chapter. This chapter describes the findings of the experiments in detail with referring to prior studies and puts forward novel explanations about the association between color, visual complexity and visual interest.

The last chapter is a conclusion of the thesis with a brief summary of the study and suggestions for further research. All visual and written documents and detailed statistical charts of the study are included in the appendices.

CHAPTER 2

VISUAL COMPLEXITY

> Complexity without order produces confusion. Order without complexity causes boredom. (Arnheim, 1966, p. 124)

People constantly and automatically recognize, recall, memorize, attribute and evaluate, in other words they always process information coming from their environment (Kocaoğlu & Aslanoğlu, 2018). The fluency of this processing is mainly determined by the extent the perceived stimuli are complex (Miniukovich & De Angeli, 2014). The scene that enters the visual field requires a certain amount of effort to process, and this processing can range from highly effortful to quite effortless (Alter & Oppenheimer, 2009). For example, while looking around in an interior space containing very few objects, it makes instinctive sense to think that seeing the interior will require considerably less effort than perceiving a cluttered interior space with many objects since it is visually complex (Orth & Wirtz, 2014). Hence visual complexity establishes an essential part of peoples' environment and is an inseparable part of information processing (Marin & Leder, 2016).

Visual complexity is not a uniform concept; its multidimensional nature has been acknowledged with regard to human vision and cognition system, high-level image understanding and recognition problems. Its multidimensionality consists content-based image retrieval, image clustering and classification, computer graphics, web pages, as well as aesthetic classification of natural scenes, abstract patterns, and artworks (Yu & Winkler, 2013). Visual complexity is described by factors such as the number and variety of elements (diversity of elements), their disorganization, as well as the degree of symmetry (Berlyne, Ogilvie & Parham, 1968; Chipman, 1977; Ichikawa, 1985; Nadal, Munar, Marty & Cela-conde, 2010). One of the dominating factors of visual complexity is the number and variety of elements (Berlyne, Ogilvie & Parham, 1968; Nadal, Munar, Marty & Cela-conde, 2010). While the abstract patterns, simple figures or faces are being explored, symmetry is often studied as an independent factor of complexity (Day, 1967; Eisenman, 1968; Gartus & Leder, 2013; Jacobsen & Höfel, 2002; Tinio, Gerger & Leder, 2013).

As Reber, Schwarz & Winkielman, (2004) pointed out; visual complexity depends on individual perceptual organization, previous experiences and knowledge. Berlyne (1971) clearly stated that the hedonic value of a stimulus was not directly determined by objective complexity (the amount or degree of complexity physically present in a stimulus) features, but by subjective complexity (the subject's perception of the complexity of the stimulus in a stimulus). Thus, every individual perceives complexity depending on the way he or she perceptually organizes the scene, i.e. it is about how each individual organizes the elements in a stimulus in order to form a coherent and clear scene (Hogeboom & van Leeuwen, 1997). As Berlyne (1974, p.19) mentioned;

> “The collative variables are actually subjective, in the sense that they depend on the relations between physical and statistical properties of stimulus objects and processes within the organism. A pattern can be more novel, complex, or ambiguous for one person than for another or, for the same person, at one time than at another. Nevertheless, many experiments, using rating scales and other techniques, have confirmed that collative properties and subjective informational variables tend, as one would expect, to vary concomitantly with the corresponding objective measures of classical information theory”.

As stated above, the collative variables compare the incoming information with the existing knowledge and experiences for detecting potentially interesting stimulus. Berlyne (1960) defined “interesting” with collative variables. Collative variables do not affect interest directly, however they control pleasure and arousal which are the necessities for having motivation to explore the incoming information. According to Berlyne’s theory (1960) either high or low arousal potential level does not maximize rewarding and explained as such; “moderate arousal potential will be maximally rewarding” (p. 201). On the other hand the mentioned moderate level also depends on different factors such as; ecological variables which are the variables that related to the significance and relations to environmental objects (Palmer, Schloss & Sammartino, 2013) and psychophysical variables which are related to perceptions evoked by the sensory dimensions of the stimulus.

Berylne (1960) introduced the principle of unity in diversity (organization of the incoming stimulus) while putting his theory about arousal. He relates diversity to the two factors that establish complexity which are heterogeneity (being uneven) and numerosity (having many parts) of elements, however argues that diversity can also cause novelty (the familiarity or unfamiliarity of the stimulus according to observer's previous experiences), ambiguity (uncertainty, having numerous alternatives), and surprise (existence of something unexpected in the stimulus). In contrast, the principle of unity is proposed to temperate or reduce arousal levels (Berlyne, 1960; Van Geert & Wagemans, 2019). Post, Blijlevens & Hekkert (2016) defined the principle of unity-in-variety as "the maximization of both unity and variety, in order to achieve a balance that offers the greatest aesthetic appreciation" (p. 142). They (2016) studied their theories about unity and variety of being the partial opposites while instantaneously contributing of aesthetic appreciation which is the valuing of a stimulus that has a perceptual paradigm (Lopes, 2014). As their results stated; "there is an asymmetrical relationship between unity and variety, in the sense that the appreciation of variety is dependent on the presence of unity, whereas unity can be appreciated independently of variety" (Van Geert & Wagemans, 2019). Thus, without unity, appreciation of variety cannot occur. Another study of Post, Nguyen & Hekkert (2017) about webpage aesthetics showed that aesthetic appreciation is influenced by both unity and variety. Unity and variety independently and positively have an impact on aesthetic appreciation which instantaneously maximizes unity. Also variety leads to an ideal stability where aesthetic appreciation is the highest. However, as a summary, when unity lacks disorder occurs and appreciation starts to decrease.

Visual complexity was explored and explained within various contexts such as ecological variables, psychophysical variables and aesthetic appreciation by many research studies. The next section continues with the definition of visual complexity and the methods for measuring visual complexity with literature review.

2.1. Definition of Complexity

The word complexity comes from the Latin word “complexus” which means “entwined, twisted together, embrace, and woven together” (Castiglioni, Mariotti, Brambilla & Campagna, 1966). Also there are various definitions of complexity coming from different fields including engineering, design and architecture and in all complexity is interpreted as the state of having countless parts which cause difficulty in understanding and interpreting the whole (Kocaoğlu & Olguntürk, 2018). Complexity is always associated with disorder and often called as the “edge of chaos” (Sala, 2000). Complexity is the “equilibrator among chaos and simplicity, so it is the transition space between order and disorder”. However this explanation is not enough to understand totally the concept of complexity (Kocaoğlu & Olguntürk, 2018). Some of the definitions and further explanations about complexity are below:

- Complexity is described as the degree to which a system or component has a design or implementation that is difficult to understand, describe, explain, record and verify (Ramanarayanan, Bala, Ferwerda & Walter, 2008).
- Complexity is called as having multiple interpretations in the way of grouping elements (von Meiss, 1989).
- Visual complexity of an object (e.g., a web page or an image) refers to the number of elements presented in the object and the level of information detail carried by these elements (Liqiong & Poole, 2010; van der Helm, 2000).

- Visual complexity is defined as the way in which the formal elements of line, direction, shape, size, color, tone, and texture were used to produce harmony, contrast, dominance, rhythm, and balance (Osborne & Farley, 1970).
- Complexity is mostly seen as a quality in need of control (von Meiss, 1989).
- The more complex the structure becomes, the greater the need for order (Arnheim, 1971).
- The complexity of a string is the length of the shortest possible description of the string in some fixed universal description language (Woodward, 2005). For example the below two strings include 32 lowercase letters and digits.

  <u>String 1:</u> cdcdcdcdcdcdcdcdcdcdcdcdcdcdcdcd

  <u>String 2:</u> shc6nd7fmc8slv9dnrlcng983grs304r

“The first string has a short English-language description, namely "cd 16 times", which consists of 11 characters with space included. The second one has no obvious simple description other than writing down the string itself, which has 32 characters. In other words, the complexity of a string is the minimal description of the string. It can be shown that the complexity of any string cannot be more than a few bytes larger than the length of the string itself. Strings like the “cdcd” example above, whose complexity is small relative to the string's size, are not considered to be complex” (Vitanyi & Li, 1997).

According to those definitions, complexity is sometimes perceived as a complicated and negative notion that needs to be corrected and often determined by factors such as the irregularity, detail, dissimilarity, and quantity of objects; the asymmetry and irregularity of their arrangements (Kent & Chris, 1994; Pieters, Wedel & Batra 2010); and the variations in color and contrast (Leder & Carbon 2005).

As a summary of all mentioned definitions, complexity is the “amount of detail or intricacy” in a composition (having numerosity and variety of elements); both complexity and simplicity are inseparable and parts of a whole since they are indicated by the level of order (Arnheim, 1971). For instance, a simple composition (with lower amount of detail) has minimum level of complexity (more simplicity) or a complex composition (with higher amount of detail) has maximum level of complexity (less simplicity). Similarly in design, complexity is diversity or variety so that a visual interest can be created. As Olguntük & Demirkan (2011) stated; “Simple compositions can result in monotony or boredom, whereas complex compositions are prone to produce chaos if a strong order fails to be established. Thus, a successful amount of complexity with a readable order is necessary in designing”. Daniel Berlyne (1960, 1971, 1974) indicates that people generally prefer stimuli of intermediate complexity to simple and highly complex ones under normal arousal conditions. Intermediate levels of complexity give rise to an optimal level of arousal, yielding the highest hedonic (having a pleasant sensation) value. According to Berlyne, “an increase in complexity leads to the activation of a primary reward system up to an optimum. An aversion system becomes active upon a further increase in complexity, yielding an inverted U-shaped function (See Figure 1) between complexity and hedonic value” (Marin and Leder, 2016). The theory predicts that by adjusting visual complexity to an optimal level, viewers’ pleasure of an object will increase (See Figure 1). Consequently, stimuli of a moderate degree of visual complexity will be considered pleasant, whereas both less and more complex stimuli will be considered unpleasant (Tuch et. al., 2012).

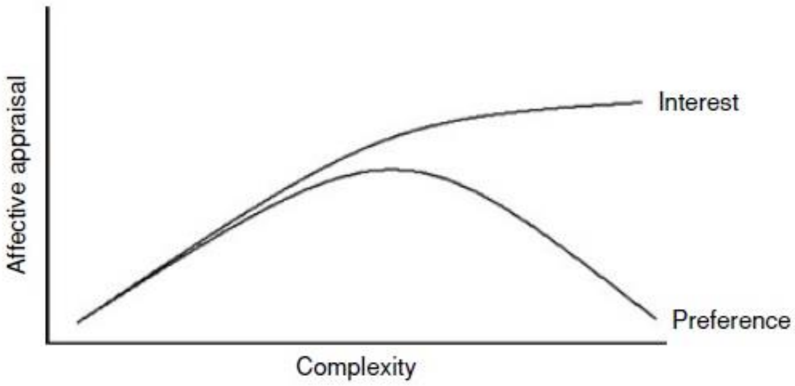


Figure 1. Graph showing the relationship between preference, interest and complexity level (Forsythe, Nadal, Sheehy, Cela-Conde & Sawey, 2011, p. 51)

Since complexity is the transition space between order and disorder, finding the right balance between simplicity and complexity is important to create interest in a composition (Kocaoğlu & Olguntürk, 2018). It is demonstrated that humans prefer a middle level of complexity, because simpler visual stimuli tend to be perceived as more aesthetically pleasing, probably due to more fluent mental processing of stimuli (Miniukovich & De Angeli, 2014). On the other hand, if it is too simple, humans are bored or else if it is too complex, they will be mixed up (Norman, 2010; Olguntük & Demirkan, 2011). In other words, everyone wants more capability, therefore they want more elements. Everyone wants ease of use, therefore they want simplicity. As Klinger & Salingaros (2000) stated; “people seek organized complexity, and become disinterested in, or repelled by, low or disorganized complexity”. The need for organized complexity is coming from the causal mechanism of human perceptual system which was explored by Vitz (1966). As Vitz argued, “the ease with which perceptual experience could be processed was inversely related to a stimuli’s complexity or uncertainty”. People were motivated to stimuli which are close to the maximum limit of human perceptual system when the organization of stimuli were reinforced (Vitz, 1966).

As well, the field of environmental psychology deals with visual complexity as a variable that has a significant impact on the human psychological response to the both natural and artificial environment (Mehrabian & Russell, 1974; Nasar, 1987; Nasar, 1997). Environmental complexity is defined as the visual richness, quantity, and variety of decoration of an environment and as the amount of information in an environment (Nasar, 1997) and for a landscape complexity is also refers to the diversity and riches of elements in landscape patterns (Ode, Tveit & Fry, 2008; Orzechowska-Szajda, 2015). Kaplan and Kaplan (1989) stress the fact that “complexity is the source of content and exploration opportunities and the abundance of landscape elements and the diversity of land cover are the two most important indicators of visual landscape character” (Tveit, Ode & Fry, 2006). Some studies give emphasis to the role of vegetation in landscape preferences, as well as “spatial diversity and complexity, water forms, the lay of the land, topography, the scope of visibility” (Bishop, 1996; Bishop & Hulse, 1994; Crawford, 1994). In the literature of the subject complexity is expressed as “the diversity of elements in the form of the number and types of objects, land cover and pattern variability – the variety of forms of land use, as well as size and shape diversity”. Hence, finding the right balance for visual complexity is a thorough decision for artists, designers and environmental psychologists.

2.2. Measuring Visual Complexity

Throughout the history of human vision and perception research, complexity is always a subject of interest and research. Various disciplines such as engineering, psychology, environmental psychology, design and architecture approach visual complexity from different points of view. Because of this distinction in defining visual complexity, there are varied methods for measuring visual complexity.

For understanding the role of color in visual complexity and visual interest, a brief information could be given about aesthetics and pleasure since an objective measure of visual complexity started with studies about aesthetics. Aesthetics is the philosophical study of beauty and taste. It is closely related to "the philosophy of art, which is concerned with the nature of art and the concepts in terms of which individual works of art are interpreted and evaluated" (https://www.britannica.com/topic/aesthetics). As a definition, it is "the study of human minds and emotions in relation to the sense of beauty" (Palmer, Schloss & Sammartino, 2013). At this particular point, beauty should be clarified too. Beauty is defined by Santayana (1896) as pleasure as the quality of a thing. Besides the general definition of beauty given previously, this notion depends on two aspects; one of this is order and the other one is complexity. It arises from the "balance or combination of order", unity or harmony and complexity, multiplicity or diversity (Boselie & Leeuwenberg, 1985; Eisenman, 1968; Roberts, 2007). For instance, "if the repertoire is given by a palette of colors with a probability distribution, the final product (a painting) is a selection (a realization) of this palette on a canvas. In general, in an artistic process, order is produced from disorder. The distribution of elements of an aesthetic state has a certain order, the repertoire shows a certain complexity and the final product has a certain beauty”.

Sense of beauty implies the notion aesthetics. There are several approaches to define aesthetics and one and the most suitable of those approaches was introduced by Immanuel Kant (1987) in the book The Critique of Judgment. This approach is a philosophical study of certain states of mind—responses, attitudes, emotions—that are held to be involved in aesthetic experience. Kant located “the distinctive features of the aesthetic in the faculty of judgment, whereby human take up a certain stance toward objects, separating them from their scientific interests and their practical concerns. The key to the aesthetic realm lies therefore in a certain disinterested attitude, which we may assume toward any object and which can be expressed in many contrasting ways” (https://www.britannica.com/topic/aesthetics). In other words aesthetic judgment can be defined as the assessment that someone does of the aesthetic or artistic value of a certain visual stimulus (Roberts, 2007).

As beauty depends on both order and complexity, before going into deep about complexity, order needs to be explained in detail. Order can be called as the organization of an information in a stimulus. As Birkhoff (1933) discussed order has formal and connotative elements. Formal elements are defined as the physical properties of the information or the stimulus; “repetition, similarity, contrast, symmetry, balance, sequence and equality”, whereas the connotative elements are the ones which remain outside. The formal elements of order; “repetition, similarity, contrast, symmetry, balance, sequence and equality” are linked with complexity. As such, a structure can be more or less systematic at any level of complexity. Thus, the level of ordered and systematic complexity is the level of order (Arnheim, 1971).

Since the human perception studies started, order and complexity are proposed as the most important indicators of aesthetic appreciation. As Perolini (2011) stated “aesthetics cannot be absent from the built forms and just like the importance of a defined space, aesthetic qualities of a space reinforce spatial experiences”. Visual complexity, which refers to the visual variety or information rate of visual stimuli, is an important variable that influences first impressions and emotions, also aesthetic preferences concerning the stimuli (Berlyne, 1971). The studies about measuring aesthetic appreciation initiated the research about visual complexity. In order to understand visual complexity, first aesthetic appreciation and its related studies should be presented well.

Aesthetic judgment can be defined as the assessment that someone makes of the aesthetic or artistic value of a certain visual stimulus” (Roberts, 2007). Art is like the other activity of the mind, is focusing on psychology, in order to build an accessible understanding (Arnheim, 1966) and the psychology of art aims to characterize the psychological mechanisms involved in the appreciation of art, such as grasping an artwork’s symbolism and identifying its compositional resources (Leder & Nadal, 2014). A model (see Figure 2) introduced by Leder, Belke, Oeberst & Augustin (2004) showing “the mental functioning while experiencing aesthetic stimuli, i.e. an artwork, which aims to provide an integrated description of the psychological processes involved in aesthetic appreciation. It also tries to explain the relation between art and aesthetics, showing the features that make an experience aesthetic, and the relation between contemporary art and more traditional forms of art. The model is designed to show the relation amongst perception, complexity, familiarity, knowledge, style, content and experiences (expertise) in the psychological mechanisms involved in the appreciation of art”. One of the indicatives for aesthetic appreciation is complexity, which effects aesthetic evaluation during the early perceptual analysis of objects of aesthetic (Berlyne, 1970; Berlyne, 1971; Gartus & Leder, 2017; Mayer & Landwehr, 2014).

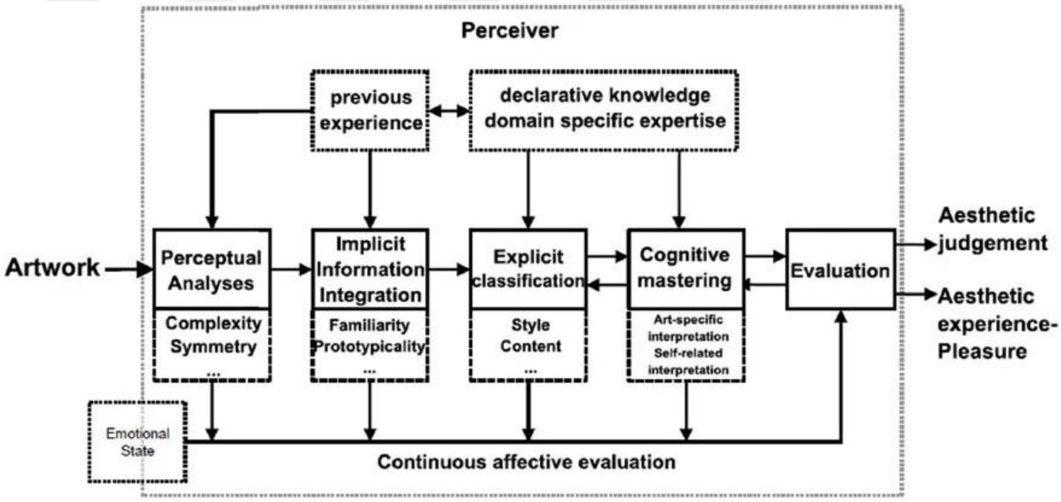


Figure 2. Model of aesthetic appreciation and aesthetic judgments (Leder & Nadal, 2004)

It is believed that the perceptual ability of people effect aesthetic preference of complex visual stimuli; “aesthetic pleasure would be caused by an easy functioning of perceptual processes, whereas displeasure would be caused by their difficult functioning” (Chevrier & Delorme, 1980). In a study, participants’ perceptual abilities were measured with Poppelreuter-Ghent's overlapping figures test (Sala, Laiacona, Trivelli, & Spinnler, 1995) and embedded figures test (Happé, 2013). Researchers created 6 transparent rectangles with various complexities and participants were asked to rate according to their aesthetic preferences. As the results showed, number of overlapping patterns were significantly influenced the difficulty of the task. However, direction and degree of rotation could not found as a significant influencer.

Nicki and Moss (1975) conducted a study exploring the effects of complexity measures, redundancy and subjective complexity on aesthetic preference which were rated by 7- point Likert Scale. Their results showed that there was a linear relationship between complexity measures, redundancy, subjective complexity and aesthetic preference. A similar study was conducted by Nicki and Gale (1977) by measuring the physiological activities of participants by electroencephalogram (EEG). Their results supported the previous results of Nicki and Moss (1975); there was an increasing linear graph between complexity and interest.

A significant study explored the dimensions of complexity; color, form, direction of dominant lines and texture (Wohlwill, 1968). The amount of voluntary exploration and ratings by the participants indicated the aesthetic preference which was the focal point of the study. The results showed that, participants’ preferences increased as complexity increases but up to a certain point, after that their preferences started to decrease. The reason behind this case might be the effort required to process the visual information. It might also reduce the interest which might decrease preference too (Wohlwill, 1968).

A study exploring the effect of the amount of information in artworks on aesthetic preference was conducted by Neperud and Marschalek (1988). Two early 20th century black and white artworks and their altered versions by removing some lines and shapes were shown to college students who did not have any art education. Participants were asked to select among adjective pairs; pleasing- annoying (hedonic value), beautiful- ugly (hedonic value), weak- strong (potency dimension), powerful- powerless (potency dimension), active- passive (activity dimension) and noisy- quiet (activity dimension). Also complex- simple, dense- disperse, cohesive- diffuse and pleasant- unpleasant adjective pairs were added. Their results showed that all variables were influenced by the amount of information in artworks (Neperud and Marschalek, 1988).

Besides having an innovative methodology to examine the dimensions of complexity, the alterations done in the artworks might cause semantic uncertainty. Another study including artworks was conducted by Krupinski and Locher (1988). Their aim was to find a relationship between complexity, arousal and aesthetic judgement through symmetry. They used well- known artworks of Vasarely, Rothko, Braque, Matisse, Mondrian and Kandinsky, also similar to those artworks chosen, some modifications were made on them. Those modifications were single symmetry and double symmetry transformations. Participants rated those artworks (both altered and unaltered ones) according to its composition, complexity and creativity. According to their findings, the artworks that applied single symmetry were rated higher than the double symmetry versions. A similar study was conducted by Messinger (1998) in order to determine the association between interest, pleasure and complexity in artworks. The artworks Messinger chose were varying in style, genre and era. Participants were asked to rate those chosen artworks according to interest, pleasure and visual complexity and the results indicated an inverse U- shaped relation among pleasure and interest. However, no relation could be found between pleasure and complexity.

One of the important metric approaches was introduced by an American mathematician George David Birkhoff. He transformed the relationship between aesthetic, order and complexity into a mathematical formula. Birkhoff reformulated the concept of beauty through aesthetic measure. It is the ratio between order and complexity and defined this ratio as “the complexity is roughly the number of elements that the image consists of and the order is a measure for the number of regularities found in the image”.

$$M = \frac{O}{C}$$

(M stands for aesthetic measure, O for Order and C for Complexity)

According to Birkhoff’s formula, complexity is the number of elements that the image consists of and the order is a measure for the number of regularities found in the image (Rigau, Feixas, & Sbert, 2007) and aesthetic experience is developed on three phases:

1. A preliminary effort of attention, which is necessary for the act of perception, and that increases proportionally to the complexity (C) of the object.

2. The feeling of value or aesthetic measure (M) that rewards this effort.

3. The verification that the object is characterized by certain harmony, symmetry or order (O), which seems to be necessary for the aesthetic effect.

As Rigau, Feixas, & Sbert (2007) stated, by the analysis of the aesthetic experience, Birkhoff suggested that “the aesthetic feelings stem from the harmonious interrelations inside the image and that the aesthetic measure is determined by the order relations in the aesthetic object”. Birkhoff used various items to explain his formula; polygons, vase contours, poetry or music melodies (Staudek, 1999).

The formula that Birkhoff introduced was used in various studies as a base. For example Aitken (1974) investigated the effects of the number of sides of random polygons on visual complexity. The number of sides of the polygons varied between 4 and 40. The results showed that, interest and pleasantness increased as complexity increased. Munsinger & Kessen (1964) studied preference of random shaped polygons with various complexities. According to their results people prefer intermediate visual complexity rather than high or low one. Day (1968) studied the effects of number of sides of random polygons, varied between 10 and 160 and found an inverse U-shaped distribution for pleasantness and interest. Eysenck and Castle (1970) revisited Birkhoff’s formula by using 90 polygons. 1100 participants, both art students and people without any art education, rated the shown polygons according to their preference. Results showed that art students preferred simple polygons, and the others preferred complex ones (Eysenck & Castle, 1970).

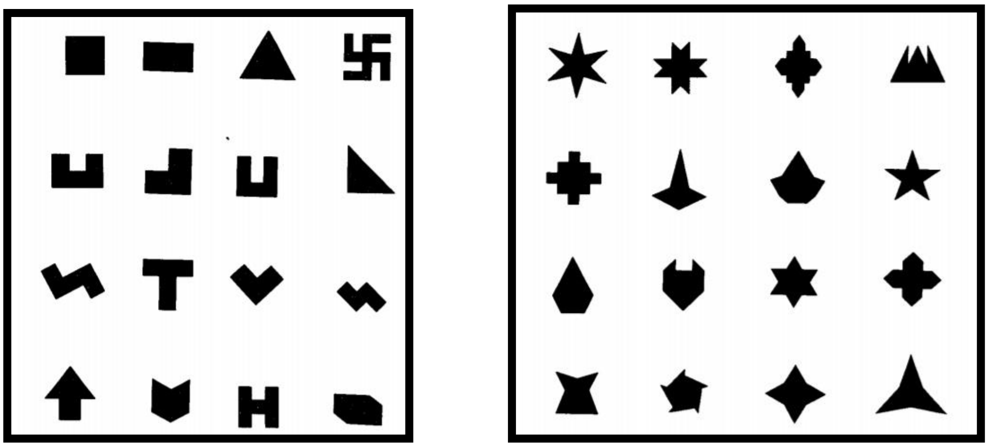


Figure 3. Polygons preferences of art students (Left) and polygons preferences of students without art education (Right) (Eysenck & Castle, 1970)

According to Berlyne (1963; 1970) interest and preference of an image is directly related to the visual complexity of that image. As Gombrich (1984 p. 9) stated, “We must ultimately be able to account for the most basic fact of aesthetic experience, the fact that delight lies somewhere between boredom and confusion”. In other words, people prefer intermediate level of arousal, rather than highly complex or very low complex ones (See Figure 1). Besides, visual complexity is related with the regularity of the pattern, amount of elements, heterogeneity, or irregularities of the form in that image. Those dimensions that Berlyne (1963) introduced, later was developed as intelligibility of the elements, organization, amount of elements, variety of elements, asymmetry, variety of colors, and three- dimensional appearance (Roberts, 2007).

On the grounds of Berlyne's studies, a series of experiments were conducted to understand the association between complexity and preference using random shaped polygons. Also researchers tried to set dimensions of visual complexity. The first and the most examined dimension was symmetry. It has been argued that human preference for symmetry systems from the applicability of symmetry as a biological function signing health and good genes (Gartus & Leder, 2017). On the other hand, symmetry preference was a mere by-product of visual processing (Enquist & Arak, 1994). There is also evidence that there is an automatic reaction to symmetry in the brain (Bertamini, Makin, Palumbo, Rampone & Wright, 2015). Symmetry has an important role in determining the visual complexity; according to studies symmetric shapes are perceived as less complex than asymmetric shapes with the same number of sides which can be attributed to the increase of idleness caused by symmetry (Friedenberg & Bertamini, 2015; Gartus & Leder, 2017). Symmetry facilitates image segmentation and plays an important role in object inquiry and representation (Li, Pizlo & Steinman, 2009; Machilsen, Pauwels & Wagemans, 2009). Another reason in preferring symmetry might be the fluency which was stated in the fluency hypothesis (Reber, Winkielman & Schwarz, 1998). According to this view, the stimulus which can be processed fluently creates positive hedonic feelings, so people might prefer symmetry just because they can process it easily. Symmetrical balance has a seemingly basic appeal (Berlyne, 1971; Lauer, 1979). Murdoch and Flurscheim (1983) add that "symmetry suggests a state of order, but that some asymmetry can often create a greater sense of interest. A touch of asymmetry can be appealing by adding an element of uniqueness" (Schmitt & Simonson, 1997). Several researchers mention that complete symmetry may be too monotonous and thereby uninteresting; a touch of asymmetry can be appealing by adding an element of distinctiveness, which may create a greater sense of interest (Murdoch & Flurscheim, 1983; Schmitt & Simonson, 1997). Uniqueness can be obtained by visual complexity. Symmetry is often mentioned as the simplest case of balance, Lauer (1979) describes balance as "equal visual weight at both sides of an axis, so that there is a sense of equilibrium. In symmetrical balance, shapes are repeated in the same position on either side of an axis. Asymmetrical balance is more subtle (Lauer, 1979), in that the visual weight and "eye" attraction of two sides are balanced but with different elements". As a summary, preferring symmetry for abstract patterns and for faces provides order and relieves tension (Berlyne, 1971; Jacobsen & Höfel, 2003; Lauer, 1979; Rentschler, Juttner, Unzicker & Landis, 1999; Rhodes, 2006; Schmitt and Simonson, 1997).

A major aspect of the structural factor of complexity is symmetry (Ichikawa, 1985) which is everywhere in the environment and it can be detected fast and efficiently by human vision (Bertamini, Friedenberg & Kubovy, 1997; Carmody, Nodine & Locher, 1977; Chipman, 1977; Locher & Nodine, 1987; Treder, 2010; Wagemans, 1997). Mathematical and geometrical components; the golden ratio, symmetry, the Fibonacci's sequence, and the Euclidean geometry, had their inspirations from nature as arts, design and architecture did. For many centuries, architecture found inspiration in mathematical and geometrical components, i.e. in nature which is, intrinsically, fractal, complex, but at the same time symmetric and already aesthetically appealing (Sala, 2000). It is argued that, having symmetry and less complexity increases the sense of order, therefore have a positive effect on perception quality (Mariëlle, Creusen, Veryzer & Schoormans, 2010). As a contrary to Mariëlle, Creusen, Veryzer & Schoormans (2010), as Norman (2010) argued having a higher complexity level can increase perception quality. Hence, several studies were conducted in order to test those contradicting phenomena.

Eisenman (1968) conducted a study for evaluating the association between complexity and symmetry. Twelve geometric shapes varying in complexity and symmetry were created, then participants were asked to select their most and least preferred ones. According to the results, participants preferred symmetric figures over asymmetric ones. Eisenman continued his experiment only by showing the asymmetric figures to participants. The results showed that, when participants needed to select their preferences among symmetric and asymmetric figures, they tended to select the symmetric ones, but when there were only asymmetric ones participants tended to select the simplest one and do not prefer the complex ones. So it could be concluded that people prefer simple and intermediately complex figures. Eisenman and Gillens (1968) did additional experiments with materials including various complexities and symmetries. Their results indicated that, people preferred the complex symmetric figures. As Eisenman and Gillens (1968) concluded, symmetry had acted by reducing the complexity introduced by the number of vertices of the figures.

Finding a measure for the mathematical and psychological complexity of an image has gain importance (Attneave & Arnoult, 1956; Chipman, 1977; Garcia, Badre & Stasko, 1994; Hochberg & Brooks, 1960). The measures that have been developed inclined to be founded on a counting system whereby elements (lines and angles) and the regularity, irregularity, and heterogeneity of those elements additively contribute to a mathematical calculation of visual complexity (Birkhoff, 1933; Eysenck, 1941; Eysenck, 1968; Eysenck & Castle, 1970; Jacobsen & Höfel, 2003). Many attempts (Arnheim, 1971; Birkoff, 1933; Salingaros, 1997; Stiny & Gips, 1978) have been made to formulate a general approach to visual complexity based on some principle that would be universally applicable across all domains. These attempts have generally failed because the results were not consistent (Gero & Kazakov, 2003).

An important attempt for quantifying visual complexity of patterns is the parameter named fractal dimension (D). This parameter describes "how the patterns occurring at different magnifications combine to build the resulting fractal shape (Mandelbrot, 1977). For Euclidean shapes, dimension is described by familiar integer values - for a smooth line (containing no fractal structure) D has a value of one, whilst for a completely filled area, (again containing no fractal structure) its value is two. For the repeating patterns of a fractal line, D lies between 1 and 2 and, as the complexity and richness of the repeating structure increases, its value moves closer to two (Mandelbrot, 1977). For fractals described by a low D value, the patterns observed at different magnifications repeat in a way that builds a very smooth, sparse shape. However, for fractals with a D value closer to two, the repeating patterns build a shape full of intricate, detailed structure and visually complex" (Taylor et. al., 2005). As previous research showed, people preferred intermediate levels of fractal dimension which lies between 1,3 and 1,5. (Street et. al., 2016). Fractional dimension also provides a way to measure the roughness or convolution of fractal curves. The dimension of a line, a square, and a cube is easy to calculate (one, two, and three, respectively). Roughness can be thought of as an increase in dimension: a rough curve has a dimension between 1 and 2, and a rough surface has a dimension somewhere between 2 and 3. There are various methods for measuring fractal dimension, D, and all are based on a power law that generates scale-invariant properties (Taylor & Sprott, 2008). The fractal dimension D may be any real number between 1 and 2 and is defined by:

$$D = \log(L2/L1)$$

$$D = \log(S2/S1)$$

(L1, L2 are the measured lengths of the curves (in units), and S1, S2 are the sizes of the units (i.e., the scales) used in the measurements)

Taylor & Sprott (2008) described fractal dimension D as;

> "D describes how the patterns occurring at different magnifications combine to build the resulting fractal shape. For Euclidean shapes, dimension is described by familiar integer values − for a smooth line (containing no fractal structure) D has a value of one, while for a completely filled area (again containing no fractal structure) its value is two. For the repeating patterns of a fractal line, D lies between one and two, and, as the complexity and richness of the repeating structure increases, its value moves closer to two. A traditional method for measuring D is the box-counting method, in which the pattern is covered with a computer-generated mesh of identical squares (or boxes). The number of squares, N(L), that contain part of the pattern are counted, and this count is repeated as the size, L, of the squares in the mesh is reduced. N(L) gives a measure of the space coverage of the pattern, and reducing the square size is equivalent to looking at this coverage at finer

magnifications. For fractal behavior, N(L) scales according to the power law relationship $N(L) \sim L^{-D}$, where $1 < D < 2$ (Gouyet, 1996)".

After Mandelbrot (1977) introduced the concept of fractal geometry, it is speculated that fractal and Euclidean shapes might be processed in different regions of the brain due to their differing visual qualities (Clark & Lesmoir-Smith, 1994). The reason for this is hypothesized as, the human perception system has evolved over millions of years in a natural fractal environment. Only recently, by evolutionary time scales people found their selves in a primarily Euclidean environment of straight lines and few spatial scales (Rogowitz & Voss, 1990).

Throughout the evolution process people got used to perceive and live in a Euclidean environment (i.e. among straight lines). The evolved perception system is mostly explained by the phenomenon Gestalt principles for grouping visual stimuli. Gestalt principles describes the way how human perception system works during reducing complex scenes and/ or shapes into simpler ones. According to the principles, the overall organization of the scene (visual stimuli) cannot be reduced into its parts (Roberts, 2007). The scene can be grouped according to some principles of perceptual organization; proximity, similarity, common density, orientation, continuity, closure, common region and connectivity. Another principle that Gestalt psychologists introduced is figural goodness, which is: "Out of all possible organizations for a given stimulus, the simplest will be perceived, that which minimizes its complexity" (Roberts, 2007).

The intrinsically multidimensional problem of evaluating the complexity of an image is of certain significance in both computer science and cognitive psychology (Cardaci, Di Gesu, Petrou & Tabacchi, 2005). In broader contexts the general problem of visual complexity measurement is ill-defined. The evaluation of visual complexity is useful in understanding relations among different levels of the recognition process. It is also of interest to real applications such as image compression and information theory (Kocaoğlu & Olguntürk, 2018).

According to image compression applications, a compressed image consists of a string of numbers that represent the organization of that picture. This string is a measure of information content and the compressed file size of a bitmap image is associated with its subjective image complexity (Donderi, 2006a). When the image contains few elements or is more homogeneous in design, there are few meaning options and as such the file string encompasses mostly numbers to be repeated. A more complex picture will have more image elements and these elements will be less expectable. So, the file string will be longer and contain an increasing number of alternatives. The results of the studies about visual complexity and file size showed that the simplest objective clue of the visual complexity of a digital image is the compressed file size; JPEG compressed file size (Donderi & McFadden, 2005; Donderi, 2006b) and GIF file size (Forsythe et. al., 2011) have been found to correlate with human perceptions of visual complexity.

Like in the image compression applications, the length of strings or file size can give a measure for complexity wise, a similar method can be applied in visual-based design the notions (Gero & Kazakov, 2003). There is a need for measure in visual complexity since it is often described with subjective methods. Therefore, the number of lines and the level of detail in a drawing can obtain an objective measurement for visual complexity in various disciplines including built environment and design.

One of the earlier attempts to develop a measure for visual complexity in built environment was done by Heath, Smith, and Lim (2000). They conducted a study about the relationship between visual complexity of façade articulation, preference, arousal, pleasure, and urban skyline silhouette. Their results were; the strongest effect on preference, arousal, and pleasure was the degree of silhouette complexity, with higher silhouette complexity associated with higher levels of perceived complexity and preference and higher arousal and pleasure. The results of their study still was not enough to develop an objective measurement.

The pioneers in this field are the psychologists Snodgrass and Vanderwart (1980) who established a classification of the complexity of a set of black and white line art drawings. This grouping was based on subjective observers’ rankings. Later, in order to obtain a more objective measure of complexity, “more algorithmic measures” were presented (number of line segments, lines crossings, etc.). But, these were not calculated computationally.

The studies about visual complexity are valuable in gaining information about how to measure it but still lacks some points. This study aims to fill this gap with measuring visual complexity by examining the dimensions of it which are going to be discussed in the next sub chapter.

2.3. Dimensions of Visual Complexity

The previously mentioned studies examined visual complexity only from a single dimension such as handling it through symmetry or number of edges of polygons or color. Some of those studies could find the effects of those dimensions on visual complexity and some of them could not (See Table 2). The dimensions could be interrelated somehow and those studies were missing the chance to examine them since they were only testing one or two dimensions with omitting the rest.

Rump (1968) was trying to find a general factor of preference for complexity, even if he could not relate the dimensions (asymmetry, multiplicity and heterogeneity) of visual complexity and suggested that a specific dimension should be used in visual complexity studies. He also concluded that people's assessment of the complexity of an image may differ depending on the feature they focus primarily.

The association between dimensions of complexity and aesthetic preference was examined by recording the time spent while perceiving those images and their preferences by Kreitler, Zigler and Kreitler (1974). However, there were no significant results showing the association between dimensions of complexity and preference. Another study was conducted by Francès (1976) using the dimensions of complexity. In this study, two groups of participants coming from different education levels were compared; university students and manual workers. Numerous materials were shown to them to rate preference and interest according to their complexities. According to the results, both groups showed interest in most complex ones. The difference between university students and manual workers was, students tended to prefer complex ones, whereas workers preferred simple ones. Another study about the dimensions of complexity was done by Jacobsen and Höfel (2003). They tested the effect of symmetry on aesthetic preference and found that symmetry had a direct effect on aesthetic preference. The relationship between aesthetic preference, complexity levels (low, medium, high) and gender, education, personal traits were examined by Osborne and Farley (1970). As results indicated, high complex visual stimuli had the highest preference scores which showed a linear relation between complexity and aesthetic preference.

Another study sought to determine the validity of complexity and mystery as predictors of interior preferences by using grayscale images and to identify design attributes related to their perception in interiors (Scott, 1993). Complexity and mystery were positively related to preference and also to each other. Design features underlying perceptions of complexity included the number and variety of elements present, the composition of scene elements, and the scene's spatial geometry. The recent visual complexity research defines complexity as the overall visual diversity or the amount of information which is contained in a scene. In terms of interior spaces visual complexity is specially linked to design elements such as walls, floors, ceilings, furniture and fixtures, density and layout (Orth & Wirtz, 2014; Orth, Wirtz & McKinney, 2016). Jang, Baek, Yoon and Choo (2018) studied the effect of visual complexity on consumer responses in store design. In their experimental phase, they designed a store virtually and controlled the level of visual complexity, which was manipulated by the presence of decorative patterns, layout type; grid or free-form, and the quantity of fixtures and other objects. Their results showed that “high-visual complexity in a fashion store has a negative effect on pleasure when consumers’ involvement level is low, but such negative effect of visual complexity diminished in consumers with high fashion involvement”. Regardless of consumers’ involvement levels, it was found that higher arousal was significantly related with higher visual complexity. The visual complexity of a store environment draws the attention of consumers and affects their emotional and behavioral response (Gilboa & Rafaeli, 2003; Orth & Wirtz, 2014; Orth, Wirtz & McKinney, 2016, Jang, Baek, Yoon & Choo, 2018).

Kreitler, Zigler, and Kreitler (1974) argued that visual complexity was best conceived as a multidimensional concept. In order to begin characterizing the structure of this concept, they designed a study which they used the five complexity dimensions; heterogeneity of elements, irregularity of the disposition of the elements, the amount of elements, irregularity of the shape, and incongruence of the juxtaposition of the elements (Roberts, 2007). As their results showed, a stimulus which facilitates the organization of its meaning and its forms into an overall organization could be rated as simpler than a stimulus with fewer elements, or more homogeneous, but which were harder to integrate or organize into a coherent whole. These findings introduced the view that there could be a multidimensional nature of complexity.

Based on the literature review on visual complexity, it is seen that examining visual complexity is not enough to have a full understanding of its effects and reasons. Accordingly, seven main dimensions were derived; intelligibility of colors, disorganization of colors, amount of elements, variety of elements, asymmetry, variety of colors, and three- dimensional appearance (See Table 1).

Table 1 Dimensions of visual complexity (Roberts, 2007)

Dimension 1 ***Intelligibility of colors***	How difficult it is to identify the colors in the image. **Sub-dimension:** Understandability
Dimension 2 ***Disorganization of colors***	How difficult it is to organize the colors into a coherent scene. **Sub-dimension:** Regularity
Dimension 3 ***Amount of elements***	Numerousness of the elements in the image. **Sub-dimension:** Density
Dimension 4 ***Variety of elements***	Heterogeneity of the elements in the image
Dimension 5 ***Asymmetry***	How unbalanced is the image.
Dimension 6 ***Variety of colors***	Heterogeneity of the colors present in the image. **Sub-dimension:** Number of colors **Sub-dimension:** Number of combinations of colors having hue difference **Sub-dimension:** Number of combinations with value difference **Sub-dimension:** Number of combinations with chroma difference
Dimension 7 ***Three-dimensional appearance***	How three-dimensional does the image look. **Sub-dimension:** Roughness **Sub-dimension:** Directionality

A study conducted by Roberts (2007) attempted to gather the dimensions of visual complexity. As a result of this study, intelligibility of the elements, disorganization, amount of elements, variety of elements, asymmetry, variety of colors and three-dimensional appearance could have an effect on visual complexity. Among all those dimensions; intelligibility, disorganization and variety of colors were chosen since there is a gap in the literature review which studied the effects of color on visual complexity and visual interest. Thus, in this study's first part the selected three dimensions of visual complexity were examined and defined within the context of color of stimuli (See Figure 4). Intelligibility is the difficulty in identifying colors in a stimulus i.e. differentiation of colors. The second dimension for visual complexity is disorganization. It is the difficulty in organizing colors in the stimulus into a coherent scene. It is about the rule in the usage of colors; in terms of the location of colors in the stimulus (symmetrical, radial, diagonal, grid etc.) and in terms of harmoniousness of colors (monochromatic, analogous, complementary contrast, split-complementary contrast), visual complexity of that stimulus (Kocaoğlu & Olguntürk, 2018). The last dimension is variety of colors (hue, value and chroma) in a stimulus.

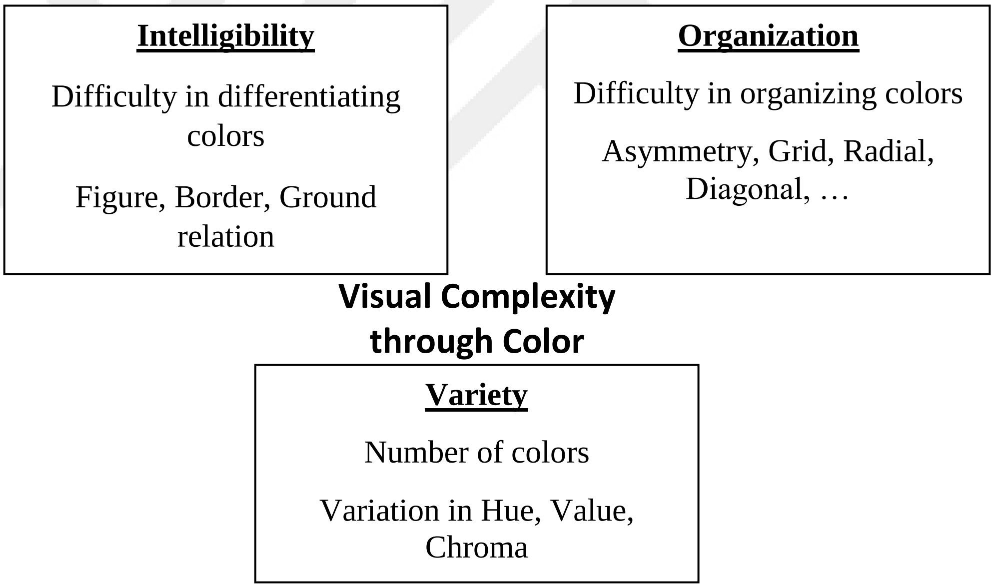


Figure 4. Dimensions of visual complexity (illustrated by Rengin Aslanoğlu)

Table 2 Fundamental studies about visual complexity (Table created by Rengin Aslanoğlu)

	Researcher and date	**Aim**	**Method**	**Results**
1	Brighouse, 1939	studied Birkoff's formula	Tested the association between order and complexity	when a stimulus is too complicated, it is perceived as chaotic, disorganized and unpleasant; if it is too simple, it is perceived as insipid, flat and uninteresting
2	Munsinger and Kessen, 1964	association between complexity and preference	random shaped polygons	participants preferred intermediate visual complexity
3	Day, 1968	association between complexity and interest, preference	random shaped polygons (varied btw. 10-160)	inverse U- shaped distribution for pleasantness and interest
4	Eisenman and Gillens, 1968	association between complexity and symmetry	materials including various complexities and symmetries	participants preferred the complex symmetric figures
5	Eisenman, 1968	association between complexity and symmetry	12 geometric shapes	participants preferred symmetric figures over asymmetric ones
6	Wohlwill, 1968	effects of dimensions of complexity; color, form, direction of dominant lines, texture and natural-artificial on aesthetic preference	images varying in complexity dimensions	participants' preferences increased as complexity increases but up to a certain point, after that their preferences started to decrease
7	Eysenck and Castle, 1970	revisited Birkhoff's formula	1100 participants, both art students and people without any art education, rated the shown 90 polygons according to their preference	art students preferred simple polygons, and the others preferred complex ones

Table 2 (cont'd)

8	Nicki, 1972	association between complexity and EEG desynchronizations	10 low, 10 medium and 10 highly complex images	EEG desynchronizations reached its peak point at medium level of complexity, whereas it was decreasing at low and high complex images
9	Aitken, 1974	association between complexity and interest, pleasantness	random shaped polygons (varied btw. 4-40)	interest and pleasantness increases as complexity increases
10	Nicki and Moss, 1975	effects of complexity measures, redundancy and subjective complexity on aesthetic preference	non-representational art	found a linear relationship between complexity measures, redundancy, subjective complexity and aesthetic preference
11	Francès, 1976	Differences between university students and manual workers preferences through dimensions of complexity	materials including various complexities	both groups showed interest in most complex ones, students tended to prefer complex ones, whereas workers preferred simple ones
12	Nicki and Gale, 1977	effects of complexity measures on interest	physiological activities of participants by EEG to images	found an increasing linear graph between complexity and interest. Also the results of EEG showed a decreasing graph with the complexity of the images
13	Snodgrass and Vanderwart, 1980	classification of the complexity	a set of black and white line art drawings	a classification based on subjective observers ranking was obtained
14	Krupinski and Locher, 1988	association between complexity, arousal and aesthetic judgement through symmetry	used well-known artworks & the altered versions	the artworks that applied single symmetry were rated higher than the double symmetry versions
15	Messinger, 1998	association between interest, pleasure and complexity in artworks	artworks varying in style, genre and era	found an inverse U-shaped relation among pleasure and interest. No relation could be found btw. pleasure and complexity

Table 2 (cont'd)

16	Neperud and Marschalek, 1988	effect of the amount of information in artworks on aesthetic preference	Two early 20th century black and white artworks and their altered versions (removing some lines and shapes)	results showed that all variables were influenced by the amount of information in artworks
17	Scott, 1993	aimed to determine the validity of complexity and mystery as predictors of interior preferences	used grayscale images	complexity and mystery were positively related to preference and also to each other
18	Heaps and Handel, 1996	tried to find the effects of complexity, connectedness, depth, orientation, repetitiveness, structure on texture perception	rank texture images along several perceptual dimensions by using grayscale textures	textures with repetitive and uniform oriented patterns were judged less complex than disorganized patterns in grayscale textures
19	Heath, Smith, and Lim, 2000	relationship between visual complexity of façade articulation, preference, arousal, pleasure, and urban skyline silhouette	greyscale urban skyline silhouette	the strongest influence on preference, arousal, and pleasure was the degree of silhouette complexity, with higher silhouette complexity associated with higher levels of perceived complexity and preference and higher arousal and pleasure
20	Jacobsen and Höfel, 2002	effect of symmetry (as a dimension of complexity) on aesthetic preference	graphic patterns	symmetry had a direct effect on aesthetic preference
21	Oliva, Mack, Shrestha and Peeper, 2004	finding the dimensions of complexity in interior scenes	interior scenes	found a multi-dimensional representation of visual complexity with; quantity of objects, clutter, openness, symmetry, organization, variety of colors

Table 2 (cont'd)

22	Guo, Asano, Asano, Kurita and Li, 2012	tried to identify texture characteristics that effect visual complexity	Used grayscale textures	found that regularity, roughness, directionality, density, and understandability have effect
23	Ciocca, Corchs, Gasparini, Bricolo and Tebano, 2015	effect of color in the perception of real world images' complexity	color and greyscale versions of real world images	no significant difference between the effects of color or grayscale on perception of image complexity

As the outcomes of literature review about visual complexity showed (See Table 2), this study aimed to examine the role of visual complexity dimensions; intelligibility, disorganization and variety of colors in abstract images. The next chapter is going to present color basics, color systems, and role of color in visual complexity.

CHAPTER 3

COLOR

Color is a specific visual sensation produced by visible radiation. The color stimulus happens when light from a natural or artificial source is interrupted by an object or a dust particle (Boff, Kaufman & Thomas, 1986; Meervein, Rodeck, & Mahnke, 2007). According to the Commission International de l'Éclairage (CIE), color is defined as an "attribute of visual perception consisting of any combination of chromatic or achromatic content" (Fairchild, 2005, p. 84) which can be named by chromatic colors as red, yellow, orange, green, and etc. or achromatic colors as white, gray, black.

People use colors to choice qualified or tastier foods, sense danger, identify changes and select their partners (Ulusoy & Olguntürk, 2016). Besides nature, in artificial environments, people use color for building themselves habitable atmospheres. Color is an inherent property of materials and an inseparable component in design. It covers all of our physical environment including materials and surfaces that influence our perception and emotion with its aesthetic and functional aspects. Color enhances life quality; hue or saturation variation in color has a positive effect on mood and behavior (Kwallek, 1996). Color improves ambience and quality of experience; it reduces stress and creates safe environments since color eases navigation, wayfinding and communication of information with color coding in our environment (Ulusoy & Olguntürk, 2016).

The entire range of human color perception is done with "the operation of three types of photosensitive retinal cone cells and the neural mechanisms responsible for interpreting their signals" (Weber & Changizi, 2014). The cone cells; short wavelength (S), medium-wavelength (M) and long wavelength (L) contain photosensitive pigments which absorb different wavelength levels of light. The short wavelength (S) pigment has peak absorption of light at about 430 nm, roughly corresponding to blue light; the medium wavelength (M) pigment has peak absorption at about 530 nm, corresponding to green light; and the long wavelength (L) pigment has peak absorption at about 560 nm, corresponding to red light (Weber & Changizi, 2014). Even if the color perception seems like mere physical, color perception is also related with all human senses.

> "Talking about color is the act of naming, explaining and interpreting what belongs to the field of individual and visual perception. Color perception is associated with and related to the senses of touch, hearing, taste and smell. In addition, color perception is complemented by memory and knowledge of color, and by the practice of receiving and transmitting information, as well as conceiving and reproducing images." (Cler, 2011, p. 181)

This chapter consists of definition of color in order to understand its basics; hue, saturation and brightness and various systems; Munsell Color System, Natural Color System (NCS), CIELAB and RGB Color Model. Color as an indicator of visual complexity is also discussed within this section.

3.1. Basics of Color

There are 3 fundamentals of color; hue, brightness i.e. lightness or value and saturation i.e. chroma or purity. Hue is the name of the color such as red, blue, green, yellow, etc which contains chroma. White, gray and black as being achromatic colors are considered to be colors without hue (Raskin, 1986). The second fundamental of color is brightness which is also known as lightness or value. Brightness represents a colors' lightness or darkness (Fehrman & Fehrman, 2000). By adding black to a pure hue, a darker shade of it can be obtained and by adding white to the same hue makes a lighter tint. By adding grey to the pure hue, different tones of it can be obtained. Saturation is known as chroma and colourimetric purity which represents the amount of pigment in a color (Fehrman & Fehrman, 2000). Saturation is the strength and vividness of a hue which is related with the intensity of color.

These fundamentals of color can be independently measured (Munsell, 1988; Fehrman & Fehrman, 2000). Without altering any of the other dimensions, it is possible to alter one quality and obtain several colors. For example, without altering the brightness and hue rate, a color may be strengthened or weakened in saturation;

without changing the brightness or saturation, the hue may be modified; without manipulating the hue or saturation, the brightness may be changed (Munsell, 1988).

3.2. Color Schemes

Color schemes are basically mean using colors together. The main aim of color schemes is to use colors together to make them look appealing. Color schemes are described by using the different combinations of colors on the color wheel. The color wheel (invented by Isaac Newton) is the basis of color theory, mapping the color spectrum onto a circle. By using various combinations of colors, many color schemes can be obtained according to the purpose, need, aesthetic and practical reasons. While creating a color scheme, one color and its shades can be used (i.e. monochromatic color scheme), as well as using many colors can also create a color scheme (i.e. tetradic color scheme) which all described in detail below;

Achromatic Color Scheme: Achromatic color scheme is a scheme with using white, black and gray without any color (hue). An achromatic color scheme contains various shades and tints of whites, blacks and grays (See Figure 5).

Figure 5. Achromatic Color Scheme

(http://www.deanenettles.com/webexamples/colorexamples/achromatic.gif)

Monochromatic Color Scheme: In monochromatic color scheme, different tones (adding gray to a pure color), shades (adding black to a pure color) and tints (adding white to a pure color) of a single color is used (See Figure 6).

Figure 6. Monochromatic Color Scheme

(https://www.researchgate.net/publication/317442984_Analyzing_Users%27_Preferred_Color_On_Websites_Based_On_Demographic_Features/figures?lo=1)

Analogous Color Scheme: An analogous color scheme uses colors that are next to each other on the color wheel. Analogous color schemes are also called neighboring colors (See Figure 7 and 8).

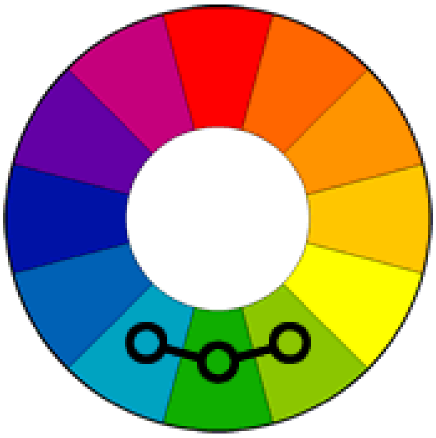


Figure 7. Analogous Color Scheme

(https://www.tigercolor.com/color-lab/color-theory/color-theory-intro.htm)

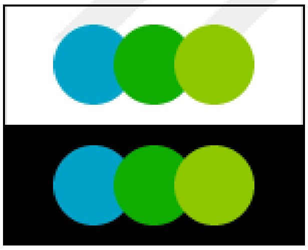


Figure 8. An example of Analogous Color Scheme

(https://www.tigercolor.com/color-lab/color-theory/color-theory-intro.htm)

Complementary Color Scheme: Complementary color scheme uses any two colors, which are located opposite on the color wheel (See Figure 9 and 10).

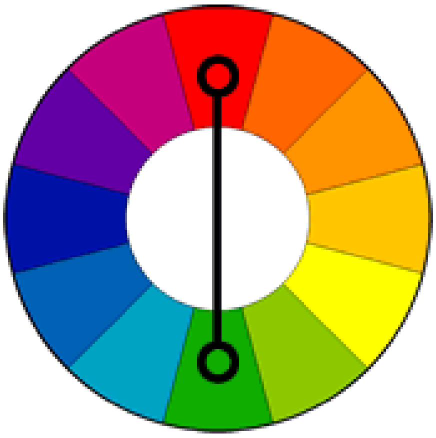


Figure 9. Complementary Color Scheme

(https://www.tigercolor.com/color-lab/color-theory/color-theory-intro.htm)

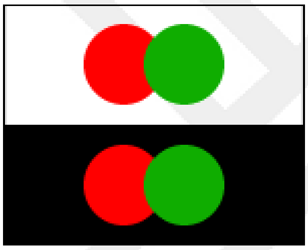


Figure 10. An example of Complementary Color Scheme

(https://www.tigercolor.com/color-lab/color-theory/color-theory-intro.htm)

Split- Complementary Color Scheme: Split-complementary color scheme can be called as a variation of the complementary color scheme; in the split- complementary color scheme two adjacent colors are used in addition to one opposite color in the color wheel (See Figure 11 and 12).

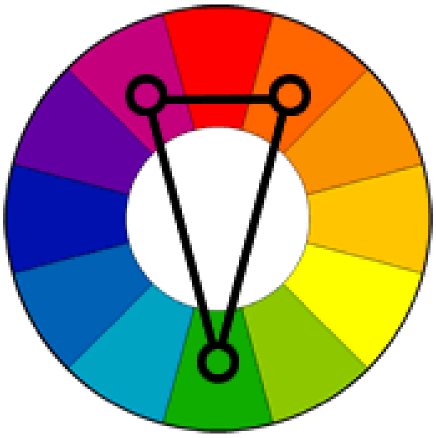


Figure 11. Split- Complementary Color Scheme

(https://www.tigercolor.com/color-lab/color-theory/color-theory-intro.htm)

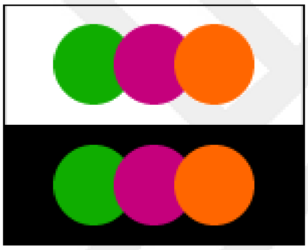


Figure 12. An example of Split- Complementary Color Scheme

(https://www.tigercolor.com/color-lab/color-theory/color-theory-intro.htm)

Triadic Color Scheme: Triadic color scheme uses any three colors which are equally distanced around the color wheel (See Figure 13 and 14).

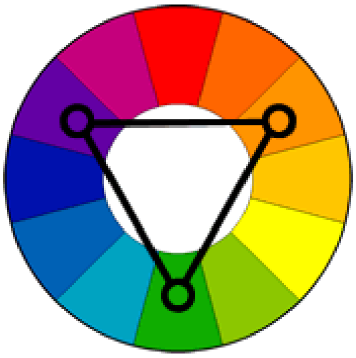


Figure 13. Triadic Color Scheme

(https://www.tigercolor.com/color-lab/color-theory/color-theory-intro.htm)

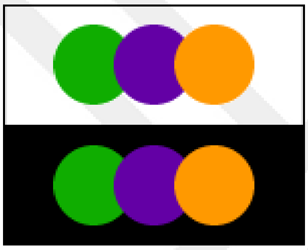


Figure 14. An example of Triadic Color Scheme

(https://www.tigercolor.com/color-lab/color-theory/color-theory-intro.htm)

Tetradic Color Scheme: Tetradic color scheme uses four colors arranged into two complementary pairs (See Figure 15 and 16).

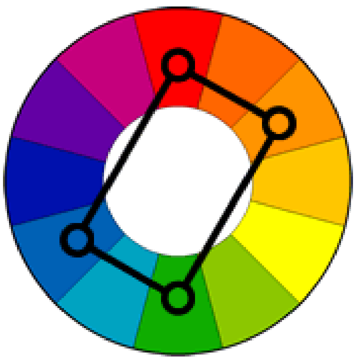


Figure 15. Tetradic Color Scheme

(https://www.tigercolor.com/color-lab/color-theory/color-theory-intro.htm)

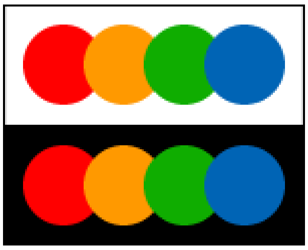


Figure 16. An example of Tetradic Color Scheme

(https://www.tigercolor.com/color-lab/color-theory/color-theory-intro.htm)

3.3. Color Systems

Human vision is said to be able to distinguish between 2 million and 10 million different colors (Gouras, 1991; Pointer & Attridge, 1998) and while differentiating those colors from each other, a universal color language is needed for communicating easily. Among numerous color order systems, Munsell Colour System, NCS, CIELAB and RGB Color Model are the most widely used systems in different research and industry areas such as design, architecture, graphic design, fashion and marketing.

3.3.1. Munsell Color System

The Munsell Color System is one of the most widely used color system which is founded by Albert H. Munsell in 1905 (https://munsell.com/about-munsell-color/). The Munsell Color System orders colors with its three attributes; hue, value and chroma (Fehrman & Fehrman, 2000). Today, color theory and mathematical color system is mostly based on Munsell's theory of color. For a long time until Albert H.

Munsell founded Munsell Color System, scientists had studied the mechanics of color going as far back as Newton’s early color wheel. Munsell combined the art and science of color into a single color theory. As an artist and an educator, Munsell developed his color theory to bring clarity to color communication by establishing an orderly system for accurately identifying every color that exists (https://munsell.com/about-munsell-color/). Munsell based this system on *perceived equidistance* which is identical with the human visual system’s perception of color.

Figure 17. Munsell Hue Designation Circle

(https://munsell.com/about-munsell-color/how-color-notation-works/munsell-hue/)

In Munsell Hue Designation Circle (See Figure 17) there are ten major hues, which are in clockwise order. Among all 10 major hues, 5 of them are the principle hues; red (5R), yellow (5Y), green (5G), blue (5B), and purple (5P). The other 5 hues are the intermediate hues which are; yellow-red (5YR), green-yellow (5GY), blue-green

(5BG), purple-blue (5PB), and red-purple (5RP) (https://munsell.com/about-munsell-color/how-color-notation-works/munsell-hue/).

In Munsell Hue Designation Circle the neutral colors are placed along a vertical line which is called the neutral axis. In this neutral axis black is placed at the bottom, white is at the top, and all grays are in between. The different hues are displayed at various angles around the neutral axis. The chroma scale is perpendicular to the axis, increasing outward. This three-dimensional arrangement of colors is called the Munsell Color Space. The hue designation circle is divided by a scale including 100 equal spaces. A hue range (for example R) consists of eleven hue radii; 0-10. For each hue range, there is a major hue that is located at the middle of each hue range, along hue radius 5. The numbering of radii works clockwise from 0 to 10 in each range (Helvacıoğlu, 2011). The divisions between 5R and 5YR are designated as; 6R, 7R, 8R, 9R, 10R, YR, 2YR, 3YR and 4YR with similar designations between other hues. Other divisions are represented by using decimals; 2.5 YR is intended to be perceptually midway between samples having hues of 2YR and 3YR (Helvacıoğlu, 2011).

All colors lie within a detailed region of Munsell Color Space. This region is called Munsell Color Solid (See Figure 18). Hue is restricted to one turn round the circle which is limited on the lower end by pure black, which is as dark as a color can be, and on the top by pure white, which is as light as a color can be (https://munsell.com/about-munsell-color/how-color-notation-works/munsell-color-space-and-solid/). As seen in Figure 18 the highest chroma yellow colors have high values, while the highest chroma blue colors have lower values.

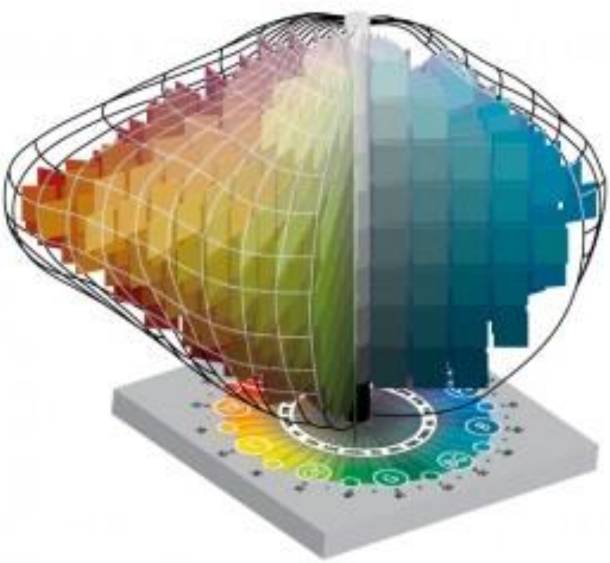


Figure 18. Munsell Color Solid

(https://munsell.com/about-munsell-color/how-color-notation-works/munsell-color-space-and-solid/)

The scale of value ranges from 0 for pure black to 10 for pure white. Black, white and the grays (See Figure 19) between them are called neutral colors which have no hue in it. Value is showing the lightness or darkness of a color; 0 is absolute black, 10 is absolute white and greys are from 1 to 9. For instance, 5/ is representing the middle grey. The Munsell value of a sample in between other samples is designated by using decimals. For instance, a value of 7.5 would be intended to be perceptually midway in lightness from samples having values of 7 and 8 (Helvacıoğlu, 2011).

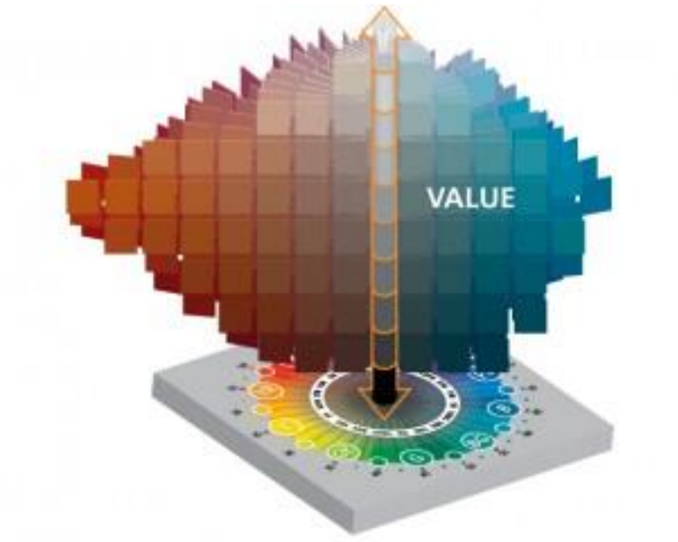


Figure 19. Munsell Value

(https://munsell.com/about-munsell-color/how-color-notation-works/munsell-value/)

Chroma is the degree of a color. For example colors of low chroma are called weak or dull whereas colors with high chroma are called highly saturated, strong and vivid. Adding blue chroma to grey until a vivid and strong blue is obtained or adding grey to blue until a weak and dull blue is obtained are about the chroma degree of a color (See Figure 20).

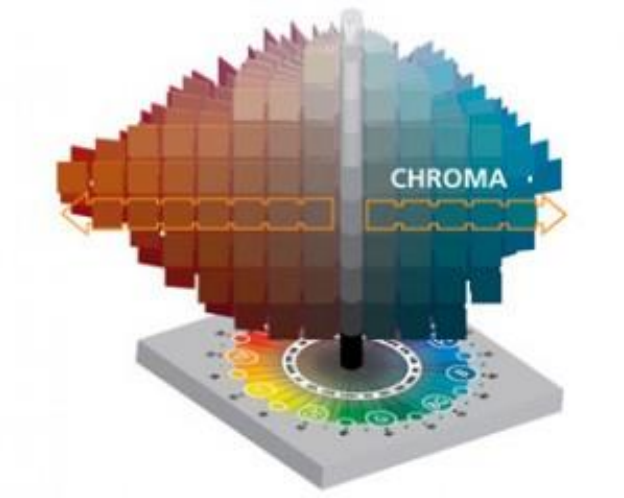


Figure 20. Munsell Chroma

(https://munsell.com/about-munsell-color/how-color-notation-works/munsell-chroma/)

Hues are positioned on vertical axis showing values from light to dark (Helvacıoğlu, 2011). The Munsell notation for a chromatic color is given in the order of H/V/C. For example, the first color in red highlighted square is 7.5PB 9/4, the below color is 7.5 PB 8/4, the color at the third row is 7.5 PB 7/12, at the forth row 7.5 PB 6/16 and the last 2 colors are 7.5 PB 1/14 and 7.5 PB 1/16 respectively (See Figure 21).

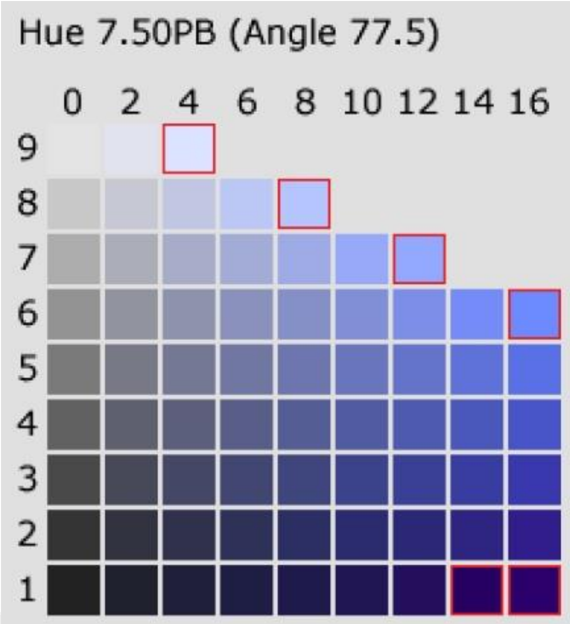


Figure 21. Examples of Munsell Color System

(Figure captured by Rengin Aslanoğlu)

The Atlas of the Munsell Color System (See Figure 22) contains the physical samples (color chips) which are arranged in slots on the hue charts; “each hue chart is printed with a V/C grid and labelled with its hue notation and the hue chips are arranged on a square grid to show variations of Munsell value vertically and Munsell chroma horizontally” (Helvacıoğlu, 2011).

Figure 22. Atlas of the Munsell Color System dated 1915

(Photo taken by Rengin Aslanoğlu)

The Munsell Color System is widely used since it has a simple usage. Various disciplines from different industries are using Munsell Color System because it creates a universal communication system throughout the world. It is easy to read and select color samples from Munsell Color System since it is reliable and organizes color the way the human eye sees color.

3.3.2. Natural Color System

The Natural Color System (NCS) is based on the views of German physiologist Ewald Hering. NCS is a proprietary perceptual color model and it is based on the color opponency hypothesis of color vision. The current version of the NCS was developed by the Swedish Color Centre Foundation since 1964 (http://www.wiki-zero.co/index.php?q=aHR0cHM6Ly9lbi53aWtpcGVkaWEub3JnL3dpa2kvTmF0dXJhbF9Db2xvcl9TeXN0ZW0jY2l0ZV9ub3RlLTE; Sivik, 1997). The NCS is based on human perception of color.

The idea behind NCS is the Hering Color System developed in Sweden. Red, yellow, green and blue are the elementary hues in Hering Color System. Those hues are called as elementary or unique hues since they cannot be described with other colors' combinations. For example, orange can be described with reddish yellow or yellowish red. But an elementary hue cannot be described as such. As Hård and Sivik (1981) stated, "elementary colors are defined in visual terms as a yellow that is neither greenish nor reddish, a red that is neither yellowish nor bluish, a blue that is nether reddish nor greenish, and a green that is neither bluish nor yellowish". Also, according to Hering Color System, yellow and blue, and red and green are opponents which form pairs and cannot form a combination (e.g. reddish green).

In Hering Color System, like other systems, black and white are accepted as basic colors. Thus, with four elementary hues and with black and white there are six basic colors. Black and white can form combinations so they can be pairs. By combining black and white, various greys are obtained like whitish black and blackish white.

Based on Hering Color System, NCS is mostly used for determining surface colors similar to human color perception with six basic colors; yellow, red, blue, green, white and black. In NCS color space (See Figure 23 and Figure 24) Y (Yellow), R (Red), B (Blue) and G (Green) are presented as binary compositions which is divided into four sections. Those equally divided quadrants; Y/R, R/B, G/Y and B/G are used in hue designations.

Colors in the NCS are defined by the relative amounts of the basic colors that are perceived presented by percentages (Hunt, 1987). For example, a pure color such as blue has a blueness of 100% and similarly red has a redness of 100%. As another example, R50B in the NCS color circle means an equal (50%- 50%) mixture of pure red and pure blue. Also greys can be presented with percentages. For instance, a medium grey can be defined as a mixture of 50% black and 50% white.

Hue ranges are separated by dashed lines; for example the hues between G50Y and Y50R are the yellows; the hues between Y50R and R50B are the reds, continuing in the same manner around the circle (Helvacıoğlu, 2011). In this terminology with yellowish reds and bluish reds, common hue terms such as orange and purple are excluded (Agoston, 1987). This criticism for the NCS system is summarized by Luo (2016).

“It has been criticized for not having the degree of difference between neighboring colors the same all-round the circle. Although the colors are shown in a continuous circle, the four elementary colors are to be understood as the beginnings and ends of four separate hue sequences. The colors between red and blue are equally spaced visually as are the colors between blue and green, but there is a greater degree of visual difference in the red to blue sequence than in the blue to green.” (Luo, 2016, p. 266).

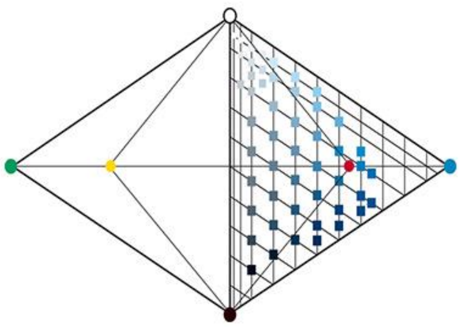


Figure 23. NCS Color Space

(https://ncscolour.com/about-us/how-the-ncs-system-works/)

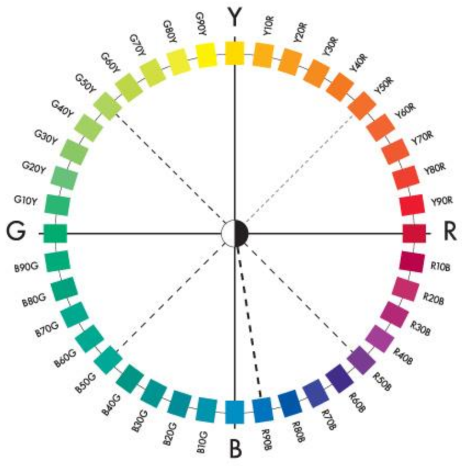


Figure 24. NCS Color Circle

(https://ncscolour.com/about-us/how-the-ncs-system-works/)

For presenting a hue, percentages are not enough; two unitary hues and the quadrant of the circle in which the hue is located needs to be identified with C (chromaticness), W (whiteness) and S (blackness) (Hunt, 1987). In the hue triangle (see Figure 25) the amounts of C, W, and S are presented. For instance, S1050-R90B means 10% of blackness, 50% chromaticness, 90% blue and 10% red (see Figure 26).

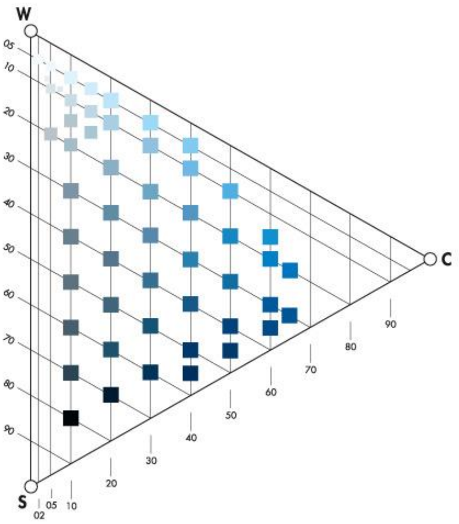


Figure 25. NCS Color Triangle

(https://ncscolour.com/about-us/how-the-ncs-system-works/)

Figure 26. NCS Color Sample

(https://ncscolour.com/about-us/how-the-ncs-system-works/)

The NCS Color Atlas has 40 color triangles which has one page for every hue. It is useful and easy to find colors in the atlas since colors are arranged and presented according to the notation system of NCS. It is possible to compare colors based on blackness, whiteness and chromaticness and also gives lightness values and light reflectance values of colors.

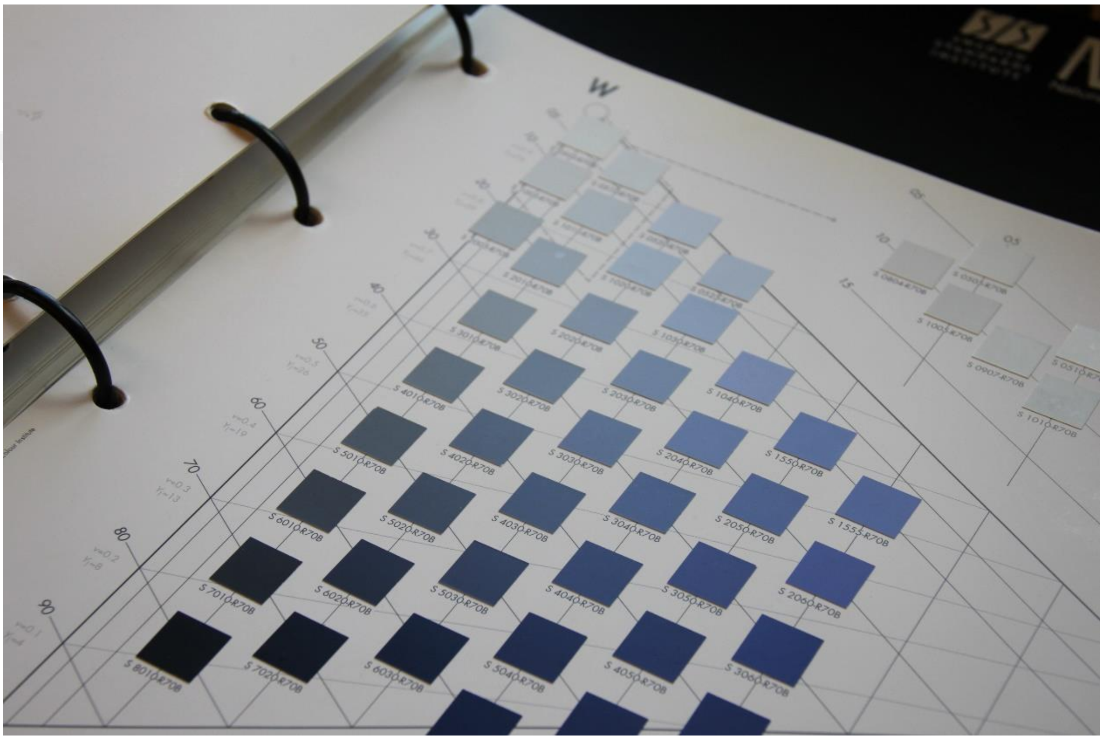


Figure 27. NCS Color Atlas

(https://ncscolour.com/wp-content/uploads/2016/04/NAT_2.jpg)

The NCS is creating a universal color language which can be easily used by both professionals and non-professionals. It is a cross-industry color system used around the world for color communication between designers and manufacturers, retailers and customers (https://ncscolour.com/about-us/how-the-ncs-system-works/). NCS offers both a useful catalogue (color atlas, See Figure 27) and a portable color measuring instrument which is compact and reliable. It describes the formal basic elements of the color language and it provides the ability to identify characteristic similarities and relations between colors (Hård and Sivik, 2001). Since the NCS system is based on how people visually perceive colors, it is also widely used by psychologists. It is important to note that the NCS was designed just as a means of describing colors and showing how they are related as a visual phenomenon (Luo, 2016). With its simple notations, both colorists, manufacturers and non-professionals can define colors and communicate easily.

3.3.3. RGB Color Model

RGB color model is creating colors by mixing them in various proportions of colored light which is called "additive color mixture". With mixing three basic colors; red, blue and green white light is obtained. The mixture of red, blue and green light creates a colorless white light and by playing with the intensities of colors, different colors are also obtained which can be seen in Figure 28. In other words, by reducing or increasing the intensities of three primary colors; red, blue and green, the different tints of white can be obtained. By mixing two primary colors, secondary colors are obtained; cyan, magenta and yellow and orange. Yellow-green, cyan-green, cyan-blue, blue-magenta and red magenta are the tertiary colors in RBG color model.

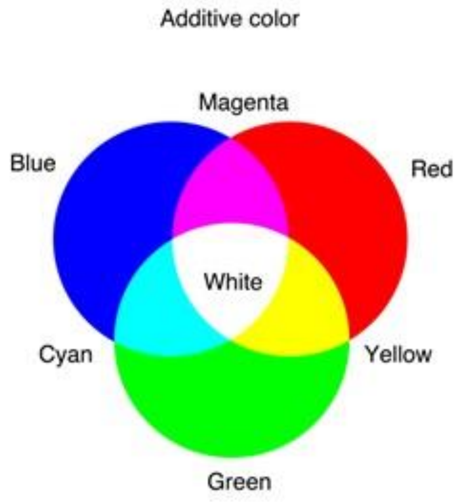


Figure 28. The additive colors

(https://marketingaccesspass.com/what-colors-make-red-what-two-colors-make-red/)

As Figure 28 shows, by adding primary colors; red, blue and green white is obtained and by the same logic the mixture of blue and green makes cyan, by adding blue to red, magenta is obtained and by adding red to green, yellow is obtained. There is also subtractive colors which need to be mentioned. In subtractive colors, the secondary colors; cyan, magenta and yellow are overlapped with equal amounts and as a result of this mixture black is obtained.

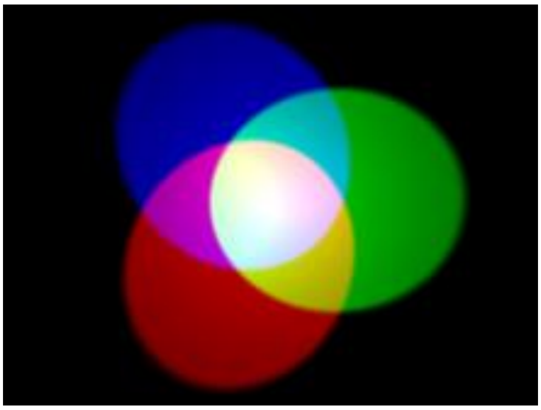


Figure 29. RGB lights together

(https://en.wikipedia.org/wiki/Color_mixing)

When RGB lights are projected on a white surface overlap partially, this partially overlapping area is brighter than the primary colored light beams and the beams' intensities are equally balanced. Here, the secondary colors; cyan, magenta and yellow are obtained clearly (See Figure 29). For example, by projecting blue and green lighted beams equally on a white surface, they overlap and form a brighter cyan than blue and green. A brighter cyan is obtained since all the intensities of two primary colors are equal, but if, for instance blue colored beam's intensity is higher than the green one a bluish green appears rather than a clear cyan. Thus by changing the intensities of colored light beams, different hues can be obtained.

The RGB Color Wheel represents all colors by assigning those colors to a specific angle (See Figure 30). The degrees around the RGB color wheel begins with 0˚ which represents red. Then the angles start to increase with adding 60˚ (60˚ represents yellow, 120˚ represents green, 180˚ represents cyan, 240˚ represents blue and 300˚ represents magenta).

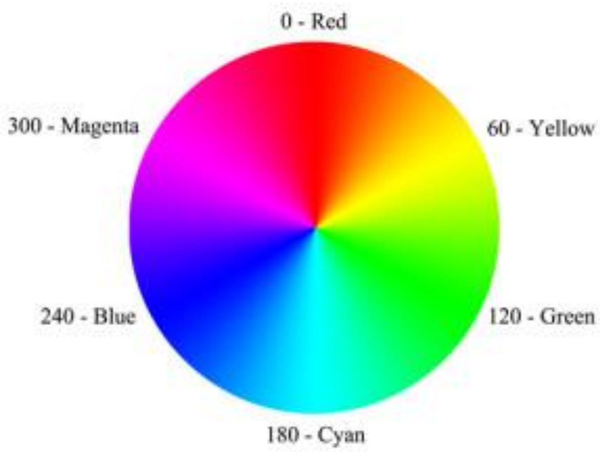


Figure 30. RGB color wheel

(https://guymanningphotography.wordpress.com/tag/diad/)

Also, there are other values to specify colors in RGB Color Model by using values between 0 and 255. For instance, pure red is represented with 255-0-0 (See Figure 31) which means there are no other colors in that particular red.

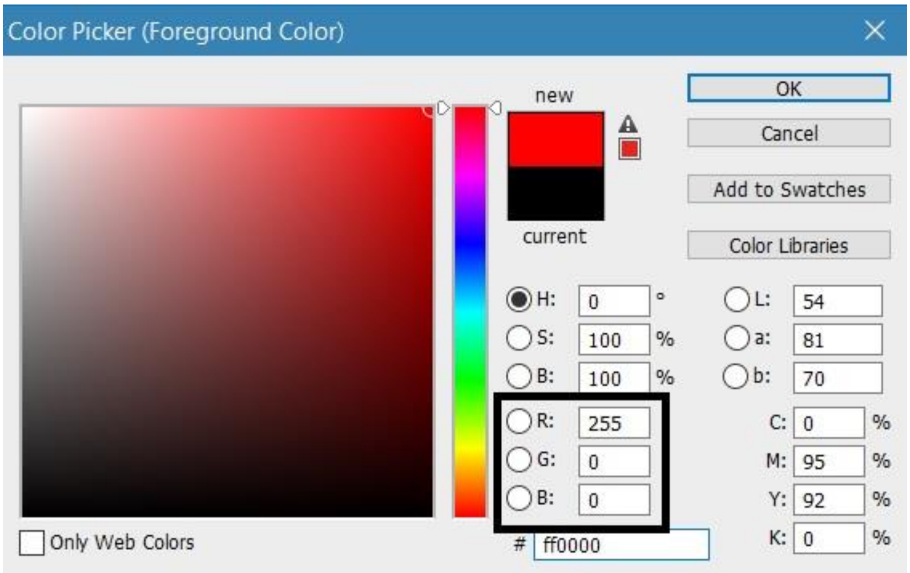


Figure 31. Value of pure red according to RGB Color Model

(Figure captured by Rengin Aslanoğlu)

As mentioned above, by changing the intensities of colored lights, different colored lights can be obtained. The intensities of colored lights are the wavelengths of those colors and can be changed by color matching functions. Each function shows the amount of primary colors' wavelengths which is needed in creating a desired color (700nm, 546.1nm and 435.8nm are the primaries of the 1931 RGB color matching functions: r(λ), g(λ), b(λ) which can be seen in Figure 32 and Figure 33).

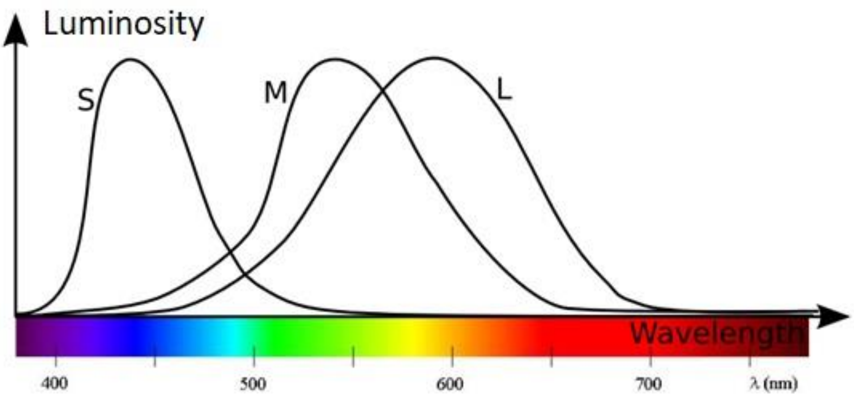


Figure 32. Wavelengths of red, blue and green (in nm)

(http://www.science4all.org/article/colors/)

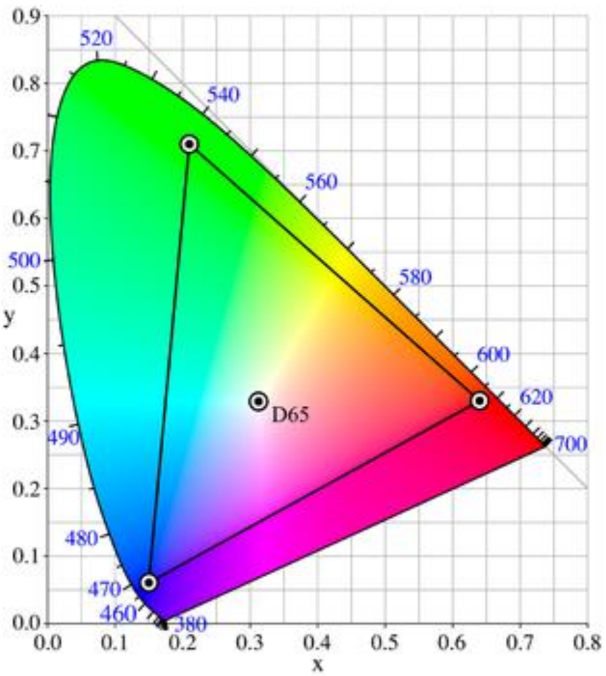


Figure 33. RGB chromaticity chart showing wavelengths of red, blue and green colors

(https://en.wikipedia.org/wiki/Adobe_RGB_color_space)

By equally scaling or changing the wavelengths of colored lights, millions of colors can be obtained. For example, by mixing 546nm (green) and 700 nm (red) together, an orange perceived as if it is 610nm can be obtained (See Figure 34).

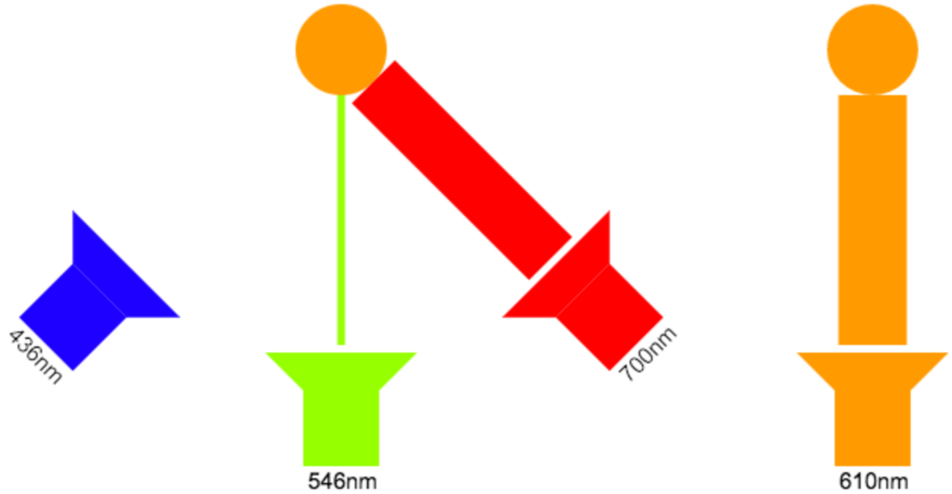


Figure 34. An example for the mixture of green and red

(https://medium.com/hipster-color-science/a-beginners-guide-to-colorimetry-401f1830b65a)

3.3.4. CIELAB

The International Commission on Illumination (CIE- Commission Internationale de I'Eclairage) presented CIELAB Color Space in 1976. CIELAB Color Space defines colors with three numerical values; L for the lightness, a and b for the green–red and blue–yellow color components which make it the most scientific color system since it allows to locate every color according to their purity, chromaticity and saturation. Likewise other color systems, CIELAB is also created by considering human color vision and perception i.e. in the way how people sees color and also taking into consideration of light.

The CIE uses X, Y and Z axis for indicating red, green and blue (See Figure 35 and Figure 36). The CIE triangle locates the position of each color from the mixture of two or more colors within the space. In the center of all colors, there is white.

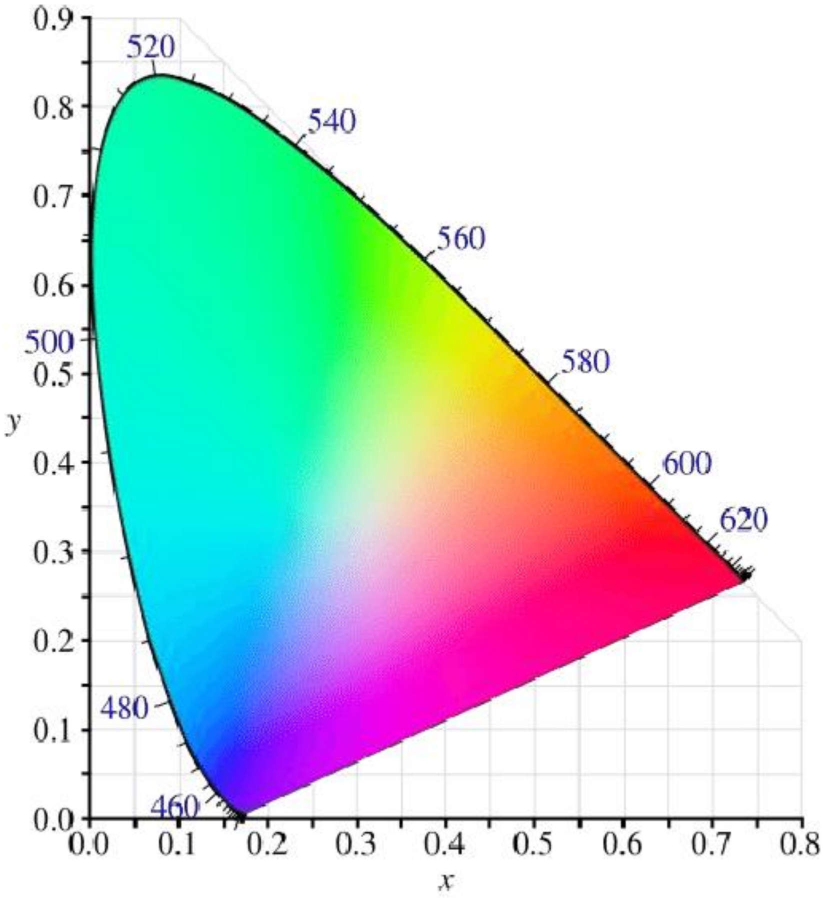


Figure 35. CIE chromaticity chart

(https://www.researchgate.net/figure/CIE-1931-color-space-chromaticity-diagram_fig1_319502286)

The CIELAB Color Space (See Figure 35 and Figure 36) is used for introducing the three-dimensions of x, y and Y graphically and to plot the points that has two-dimensional chromaticity diagrams in which one is placed above another (Helvacıoğlu, 2011). Each point in the diagram shows colors of a single luminance (Y), for example Y=0 represents only one color which is Black.

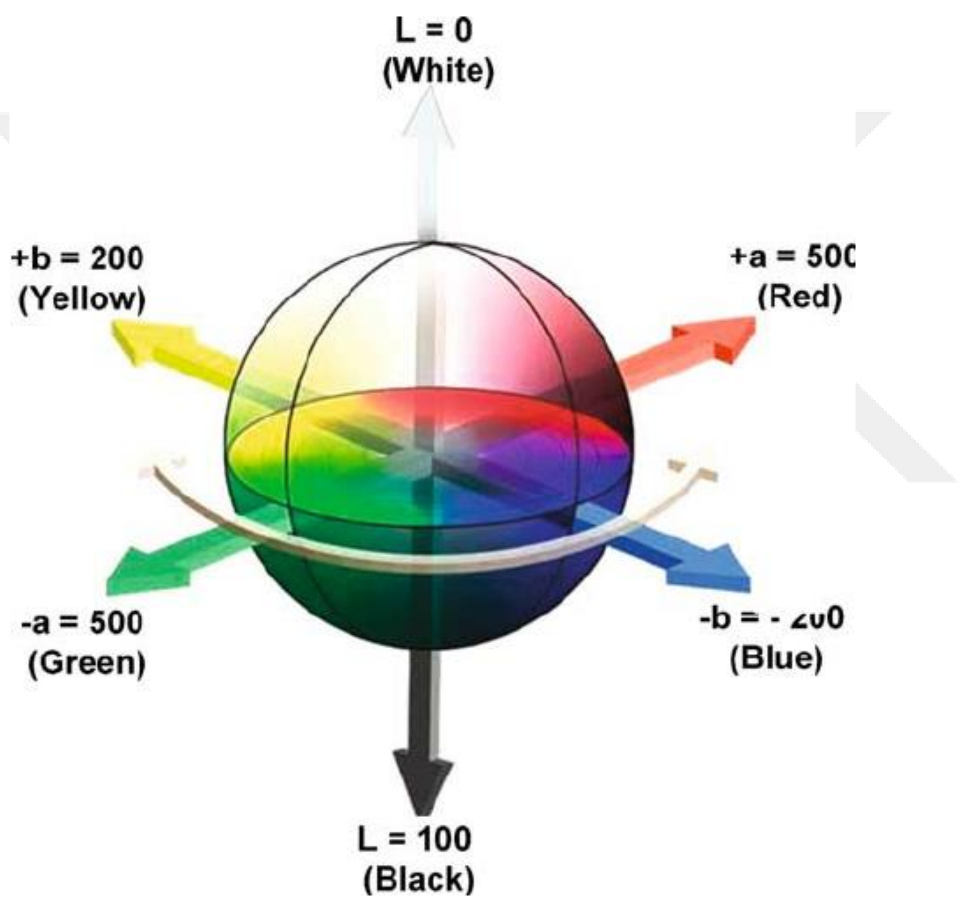


Figure 36. The CIELAB Color Space (https://www.researchgate.net/figure/The-cubical-CIE-Lab-color-space_fig3_23789543)

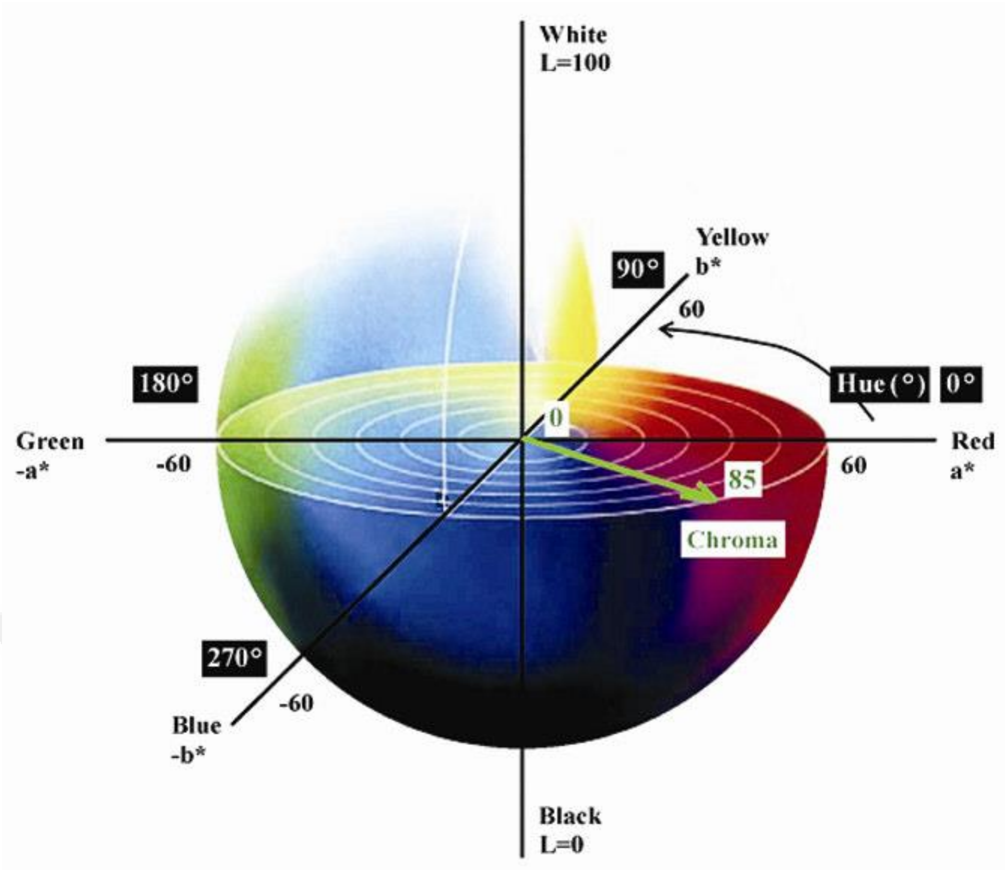


Figure 37. The CIELAB three-dimensional color space

(https://www.researchgate.net/figure/CIELab-colour-space_fig7_230787017)

Like in other color systems, each color has a unique location in CIELAB. Those colors are defined according to their locations using Cartesian coordinates (axes L, a, b) (See Figure 37). The L (metric-lightness axis) shows hue- less colors starting with white towards going down to neutral gray and then to black. The other axes; a and b are representing hues, a represents red and green, whereas b represents yellow and blue coordinates. L represents the lightness of those hues.

The CIE color system uses tri-stimulus which is a combination of three colors that are close to red, blue and green, which are schemed on a 3D space. By combining these three colors, any color can be obtained that a human eye can perceive by using

CIELAB. The CIE color specifications are representing the colors as accurate as human eyes can perceive. The CIELAB system evenly distributes colors which is important in designating colors. The CIELAB system provides a uniform color space for the judgment of color differences by mathematical calculation of two sets of tri-stimulus values X, Y and Z (Helvacıoğlu, 2011). Since CIELAB was developed to become a standard in color world, it is widely being used by researchers in color and image processing fields. CIELAB gives the opportunity to the researchers to measure colors systematically and objectively. Also, it provides exact conversions among different color systems. Another important property of CIELAB that it is being used in material productions in various industries since it has a systematical standard. This objective standard provides obtaining exactly the same colors by eliminating the differences in human color interpretation and notation.

The CIE color chromaticity chart (See Figure 38) represents colors by giving their wavelengths in nanometers which was developed in 1931. This chromaticity chart is still being used as a standard in defining colors. Also, this chromaticity chart was a pioneer for the creation of other color spaces. The chromaticity chart was based on how human perceives colors by representing colors with the same brightness.

As a summary all perception-based color systems are discontinuous and they all have advantages and disadvantages.

> "They contain only a definite number of colors from the color space. In most of the systems, the letter or number notating the color indicates the location of

the color in the color atlas. In most of the systems, the color notation gives the additive or subtractive components for color mixing. In some systems, it defines a particular color perception. In the case of some color systems for example Munsell and NCS, the color coordinates of the CIEXYZ color system have been linked to a definite number of their colors. It allows the calculation of CIE coordinates – by interpolations with different degrees of inaccuracy – also for colors not presented in the color atlas" (Nemcsics & Caivano, 2014, p. 331).

Among all previously mentioned color systems above, colors were chosen from CIE Chromaticity Chart within the Wide Gamut RGB for the new generated abstract image (See Figure 38).

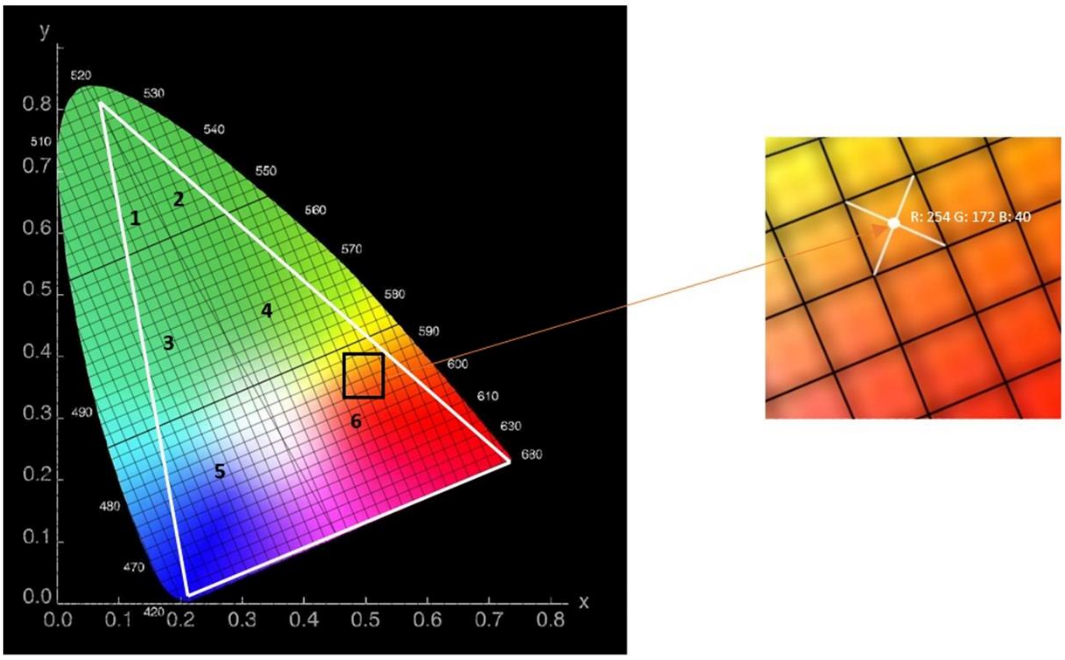


Figure 38. The Chromaticity Chart within the Wide Gamut RGB (shown with white triangle) and an example of a color sample (R: 254, G: 172, B: 40) (Figure captured by Rengin Aslanoğlu)

3.4. Measuring Color- Delta E

As hypothesized before, in order to understand and develop a theoretical measure about the role of color in visual complexity and visual interest in abstract images, the Delta E (ΔE) values of each color used in abstract images were calculated. Delta E is often used in color science, paint, textile, food, pharmaceuticals and cosmetics industries, display and digital color imaging fields (Sharma & Bala, 2002). Usually colors are described with words and adjectives but Delta E allows to communicate with numbers while mentioning about the difference between two colors.

Delta E indicates the perceived difference between two colors. In other words, it is the measure of change in visual perception of two given colors. Delta (Δ) is a mathematical term meaning change in a variable and E is coming from a German word *Empfindung* which means sensation (Backhaus, Kliegl & Werner, 1998; Sharma, Wu & Dalal, 2005). ΔE is a metric for understanding how the human eye perceives color difference which can be calculated by Delta E 2000 equation (See Equation 1) (Backhaus, Kliegl & Werner, 1998; Sharma, Wu & Dalal, 2005). This equation calculates all color components together.

$$\Delta L' = L_2^* - L_1^* \qquad \bar{L} = \frac{L_1^* + L_2^*}{2} \qquad \bar{C} = \frac{C_1^* + C_2^*}{2} \tag{1}$$

$$a_1' = a_1^* + \frac{a_1^*}{2}\left(1 - \sqrt{\frac{\bar{C}^7}{\bar{C}^7 + 25^7}}\right) \qquad a_2' = a_2^* + \frac{a_2^*}{2}\left(1 - \sqrt{\frac{\bar{C}^7}{\bar{C}^7 + 25^7}}\right) \tag{2}$$

$$\bar{C}' = \frac{C_1' + C_2'}{2} \; and \; \Delta C' = C_2' - C_1' \; where \; C_1' = \sqrt{a_1'^2 + b_1^{*2}} \quad C_2' = \sqrt{a_2'^2 + b_2^{*2}} \tag{3}$$

$$h_1' = \operatorname{atan2}(b_1^*, a_1') \;\; mod360^\circ, \quad h_2' = \operatorname{atan2}(b_2^*, a_2') \;\; mod360^\circ$$

$$\Delta h' = \begin{cases} h_2' - h_1' & |h_1' - h_2'| \leq 180^\circ \\ h_2' - h_1' + 360^\circ & |h_1' - h_2'| > 180^\circ, h_2' \leq h_1' \\ h_2' - h_1' - 360^\circ & |h_1' - h_2'| > 180^\circ, h_2' > h_1' \end{cases} \tag{4}$$

$$\Delta H' = 2\sqrt{C_1' C_2'}\sin(\Delta h'/2), \qquad \bar{H}' = \begin{cases} (h_1' + h_2' + 360^\circ)/2 & |h_1' - h_2'| > 180^\circ \\ (h_1' + h_2')/2 & |h_1' - h_2'| \leq 180^\circ \end{cases}$$

$$T = 1 - 0.17\cos(\bar{H}' - 30^\circ) + 0.24\cos(2\bar{H}') + 0.32\cos(3\bar{H}' + 6^\circ) - 0.20\cos(4\bar{H}' - 63^\circ) \tag{5}$$

$$S_L = 1 + \frac{0.015(\bar{L} - 50)^2}{\sqrt{20 + (\bar{L} - 50)^2}} \qquad S_C = 1 + 0.045\bar{C}' \qquad S_H = 1 + 0.015\bar{C}'T \tag{6}$$

$$R_T = -2\sqrt{\frac{\bar{C}'^7}{\bar{C}'^7 + 25^7}}\sin\left[60^\circ . exp\left(-\left[\frac{\bar{H}' - 275^\circ}{25^\circ}\right]^2\right)\right] \tag{7}$$

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C}\frac{\Delta H'}{k_H S_H}} \tag{8}$$

Equation 1. Delta E 2000 equation

3.5. Color in Built Environment

> "Color is a gift we have received to enhance our total experience of the world in which we live. In a narrow sense color vision may have helped us to survive as a species; in a wider sense color represents much more than a simple aid to survival. Our contacts with world and universe are by way of our senses. Persons with a normally functioning visual system obtains perhaps the largest amount of information about their surroundings from the visual sense and color plays a most important part in this flow of communication." (Kuehni, 1983, p.1)

The main aspect of vision is color perception which involves aesthetic and psychological responses. As well, color is one of the most important and inseparable part of physical environment; human perceives and interprets their environment with the help of color. Color guides human to find their ways both in nature and built environment, it pleases them aesthetically and effects them psychologically. This sub chapter is going to discuss color in various contexts like its effects in built environment, its role in visual complexity and visual interest with providing related literature review.

Color can be studied in various media such as art, graphic design, architecture and built environment, etc. Built environment, with a broader meaning, is a volume which is convenient for inhabitants to carry out their actions without any obstruction within which boundaries can be perceived through form, color, texture, proportion, etc. Interior space is most often associated with the limits of a building's envelope, or the surfaces presented by architectural built forms. According to Ching (2007) space is the three-dimensional field in which objects and events occur and have relative position and direction. According to Frank Lloyd Wright, "space within a built environment is the reality of that building and space is not simply something that is inherited from the past or is determined by the rules of spatial geometry, but space is produced and reproduced by inhabitants in which they construct their lives". As Lefebvre (1991) mentioned, space is produced by the inhabitants who occupy it and influenced by those who design and produce it. Designers use various geometries, colors and materials to produce spaces which are the qualities of space. Those tools are; form, color, texture, pattern, sound, proportion, scale, definition, degree of enclosure, view and light (Ching, 2007). The mentioned qualities of space are the tools of the designers and according to the results of the design decisions and the abstract values upon which they are based, designers create spaces for inhabitants which contribute to their lives, emotions, safety, physical comfort of being, general wellbeing, productivity and sense of belonging, etc. (Perolini, 2011). Thus, with the help of color, various built environments with various colors can influence its inhabitant's perceptions.

Inhabitants do not merely exist in a physical environment- they interact with it, posit it with significance and derive important meaning from it. By taking various design decisions during designing processes, designers create spaces and shape their inhabitants' lives, emotions, choices, interests, perceptions (Kocaoğlu & Olguntürk, 2018). As described by Lefebvre (1991), space encourages and discourages certain forms of behavior and interaction among inhabitants and at the same time with their environment. Spatial experiences help inhabitants to make sense of their environments. According to the Berlyne's approach, collative properties are the attributes of a space that cause inhabitants to compare environmental details and, generally to stimulate interest in a space. Complexity is one of the core collative properties of interior architecture since it arouses pleasure in inhabitants (Berlyne, 1974).

One of the important predictors for arousing pleasure in inhabitants, is the degree of visual complexity of that space. In a built environment, numerous objects, textures and colors are composed and arranged in a variety of spatial layouts that frame the amount of visual complexity in an environment. For instance the below image (see Figure 39) from an interior seems not to have much detail in terms of complexity, but actually it contains several details about form, color, texture, proportion, scale, solid-void relationship and light, thus this simplistic interior space has a considerable level of visual complexity.

Figure 39. Stairs (by Steven Massart)

(https://architectuurreportage.be/)

Most of the visual complexity studies used greyscale images by ignoring the effect of color and the studies which researched the effects of color on visual complexity are limited. However, color adds interest, variety, and intensity. The artist utilizes structure, color, and even physical gestures (for example, Pollock's dripped paintings, or the brush marks of Monet) to interrelate with the observer. These assets work together to create a higher-level construct. Hence, eliminating a significant element such as *color* changes the spirit of the image and the meaning is lost (Forsythe et. al., 2011).

One of the earliest studies that examined the effects of geometric shapes' colors on visual complexity is conducted by Hall (1969). Hall created 30 geometric shapes randomly which varied in number of edges. Half of the participants rated the visual complexity of black and white versions of geometric shapes and the other half rated the colored versions of them. The results showed that there were no effects of color on visual complexity.

Recent studies about dimensions of visual complexity were conducted within various contexts; Ciocca, Corchs, Gasparini, Bricolo and Tebano (2015) investigated the influence of color in the perception of real world images' complexity, by performing two different types of experiments. In the first experiment, images are ranked based on their complexity (color), while in the second experiment images are ranked based on their complexity (grayscale). Their results demonstrated that there is no significant difference between the effects of color or grayscale on perception of image complexity. Guo, Asano, Asano, Kurita and Li (2012) identified texture characteristics that effect visual complexity; regularity, roughness, directionality, density, and understandability by used grayscale textures. Heaps & Handel (1996) asked participants to rank texture images along several perceptual dimensions including complexity, connectedness, depth, orientation, repetitiveness, and structure. Results indicated that textures with repetitive and uniform oriented patterns were judged less complex than disorganized patterns used in grayscale textures. In the study of Oliva, Mack, Shrestha and Peeper (2004) participants completed a hierarchical grouping task in which they divide scenes into consecutive groups of declining complexity, labeling verbally the measures they used at each stage. Their results demonstrated a multi-dimensional representation of visual complexity with; quantity of objects, clutter, openness, symmetry, organization, variety of colors.

Oliva, Mack, Shrestha & Peeper (2004) investigated “what visual complexity meant for the viewers of complex indoor scenes, and found that the viewers substantiated their sorting decisions according to the number of objects, colors and details (the amount of information), clutter, open space, symmetry and organization (the organization of information) and figure-ground contrast (the discriminability of information). Low figure-ground contrast reflects the difficulties in seeing rather than in processing information”. Color variability is a very salient feature of scene. In this study, the number of colors ranked second among the most important factors of visual complexity (after the number of objects). However, Oliva, Mack, Shrestha & Peeper (2004) did not elaborate on the role of number of colors, participants only evaluated indoor scenes by the number of dominant colors (i.e., the colors they could easily identify), which is different from color depth (large variety of eye-unperceivable color shades).

The absence of agreement on what color variability i.e. number of colors has resulted in a variety of different procedures (Miniukovich & De Angeli, 2014). Hasler and Suesstrunk (2003) proposed a measure of “colorfulness, which combined the mean and standard deviation of red-green and blue-yellow color components in the Lab color space”. Similarly, Wu, Chen, Li & Hu (2011) used the “average values and variation in hue, brightness and saturation, and again, colorfulness (Hasler & Suesstrunk, 2003). They could explain 46% of distinction in webpage visual quality ratings. Lastly, Purchase, Freeman & Hamer (2012) accounted for almost 25% of distinction in the ratings of image visual complexity. They used the number of image colors before color reduction, the number of image colors after color reduction (adopting 3 different color reduction procedures) and standard deviation in pixel luminance”. According to Miniukovich and De Angeli (2014) the variety of proposed measures of color variability could be divided into three categories: the number of dominant colors (Purchase, Freeman & Hamer’s (2012) image colors after reduction), perceived color depth (Wu, Chen, Li & Hu’s (2011) variation in hue, brightness and saturation) and personal color preferences (Reinecke et al., 2013).

As a conclusion, despite the limited number of studies searched about the role of color on visual complexity, color is an important indicator of visual complexity. Thus, this study aimed to find the role of color on visual complexity and visual interest since the association between color, visual complexity and visual interest is significant in terms of understanding the fundamentals of design. Learning how to design starts with basics; making decisions with 2D compositions and colors. Then, 2D colored compositions were evaluated into 3D built environments. Therefore, understanding the role of color on both visual complexity and interest aids to develop fundamentals of design which are the basics of various disciplines; art, graphic design, architecture and environmental psychology.

CHAPTER 4

EXPERIMENTAL STUDY

4.1. Aim of Study

Color, color vision, color perception, color systems and its theories, color and emotion, color and aesthetics, color and its naming, and etc. have been studied a lot by various disciplines. Also the effects of color on human visual system have always been a focus of interest and continues to be studied (Ramanarayanan, Bala, Ferwerda & Walter, 2008). Despite the vast amount of studies on the role of color on human vision and perception, there are limited number of studies on the association between color, visual complexity and visual interest.

The study aims to find the association between color, visual complexity and visual interest with two interconnected experiments enhanced with both mathematical measurements and participants' ratings. In other words, the methodology of this study aims to develop a theoretical measure for understanding the role of color on visual complexity and visual interest by merging varied disciplines such as mathematics, psychology, design and art. With the outcomes of this study, both scientific and artistic approaches can be explained together in terms of color, visual complexity and visual interest together which makes the current study novel.

In order to have a full picture of the effect of color on visual complexity, two connected experiments were conducted by using both existing abstract images and generated abstract images. To understand the role of color on visual complexity and visual interest, it was necessary to go to the basics of this phenomenon. Therefore, abstract images were used. Also by using abstract images, various colors can be presented and tested in a whole, since for understanding the role of color in isolated color patches are not enough for explaining the reasons of the phenomenon. In the first experiment, Piet Mondrian's two abstract paintings and Vasily Kandinsky's two abstract paintings were used. The aim of this study was to understand the association between color and visual complexity in abstract images with examining dimensions of visual complexity; intelligibility, disorganization, and variety of colors. Those dimensions in abstract compositions were tested to understand if they have any effect on visual complexity and interest. According to the results of the first experiment, the second experiment was designed. After examining the outcomes of the first experiment by considering the dimensions of visual complexity, an abstract image was generated for the second experiment. The generated abstract image had intelligibility of color, organization of color, variety of color, and visual interest with a dependent variable of the perceived total color difference (Delta E) values of used colors in the generated abstract image. The second experiment's aim was to develop a theoretical measure for understanding the effect of color on visual complexity and visual interest. By varying the perceived total color difference (Delta E) values of used colors in the generated abstract image, a measurable and numerical rule can be obtained for determining the visual complexity and visual interest levels of an image (See Figure 40).

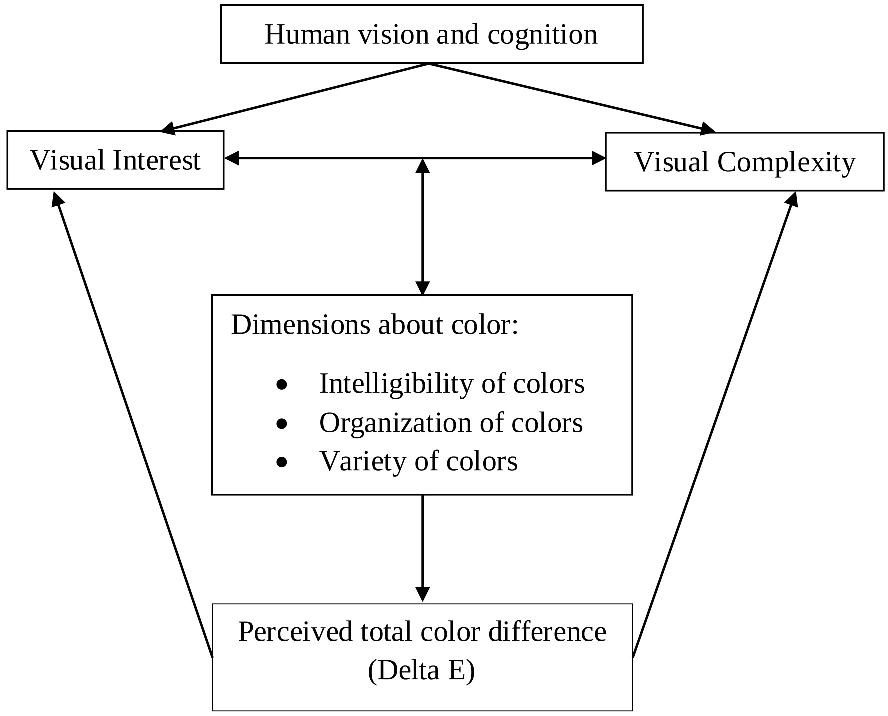


Figure 40. Graph showing the framework of experiments (illustrated by Rengin Aslanoğlu)

4.1.1. Research Questions

As mentioned in section 4.1, there are two interconnected experiments in this study and the first part aimed to find the most effective visual complexity dimensions about color. The related research questions of the first experiment are:

RQ1.1. How do *intelligibility of colors* in abstract images effect visual complexity and visual interest?

RQ1.2. How do *organization of colors* in abstract images effect visual complexity and visual interest?

RQ1.3. How do *variety of colors* in abstract images effect visual complexity and visual interest?

Also, the first part of the experiment aimed to find the association between visual complexity and visual interest with the research question mentioned above:

RQ1.4. Is there a relationship between visual complexity and visual interest in abstract images?

The second part of the study aimed to develop a theoretical measure for understanding the role of color in visual complexity and visual interest in abstract images by using perceived total color difference (Delta E). The research questions of the second experiment are:

RQ2.1. How do the perceived total color difference (Delta E) values of colors used in an abstract image effect the perception of visual complexity?

RQ2.2. How do the perceived total color difference (Delta E) values of colors used in an abstract image effect the perception of visual interest?

4.1.2. Hypotheses

Hypotheses for the first experiment are:

H1.1. As intelligibility of colors in an abstract image increase, visual complexity and visual interest will also increase until there is over unintelligibility where both will decrease.

H1.2. As difficulty in distinguishing the rules used in images increase, visual complexity and visual interest will also increase.

H.1.3.As the variety of colors used in abstract images increase, visual complexity and visual interest will both increase.

The hypothesis for finding the association between visual complexity and visual interest:

H1.4. There is an inverted U- curve relationship between visual complexity and visual interest in abstract images.

Hypotheses for the second experiment are:

H2.1.As the average perceived total color difference (Delta E) values of colors in an abstract image increases, visual complexity will increase until a threshold where visual complexity start to decrease.

H2.2. As the average perceived total color difference (Delta E) values of colors in an abstract image increases, visual interest will increase until a threshold where visual interest start to decrease.

4.2. Methodology- Part 1

4.2.1. Specifying the Abstract Images

For evaluating the association between color and visual complexity, abstract images are selected since they are independent from the visual references in the actual world, culture-independent and are basics of art, design and architecture. A visual language is composed in abstract images by just using line, form, shape, and color. Piet Mondrian's two abstract artworks; Ocean 5 (see Figure 41) and Composition No. VII (see Figure 42) and Vasily Kandinsky's two abstract paintings; Composition 8 (see Figure 43) and Decisive Rose (see Figure 44) were selected since all the artworks consists of various colors with different geometric shapes. All of the four artworks can be called as "Abstract Plasticism" which consist of elements, especially primary colors and straight lines that never occur in a pure form in the natural world. Organic and natural patterns are transformed into artificial and geometric ones (Taylor et. al., 2005). All of the selected artworks have lines, shapes, and motives, but they are different from each other in terms of visual complexity especially with intelligibility, disorganization, and variety of colors since in some of the artworks it is easier to distinguish the colors because of figure- ground relationship and borders around the colors used. The chosen artworks accomplish color harmony, visual interest and visual complexity.

Figure 41. Ocean 5 by Piet Mondrian

(https://www.guggenheim.org/artwork/3009)

Figure 42. Composition No. VII by Piet Mondrian

(https://www.guggenheim.org/artwork/3007)

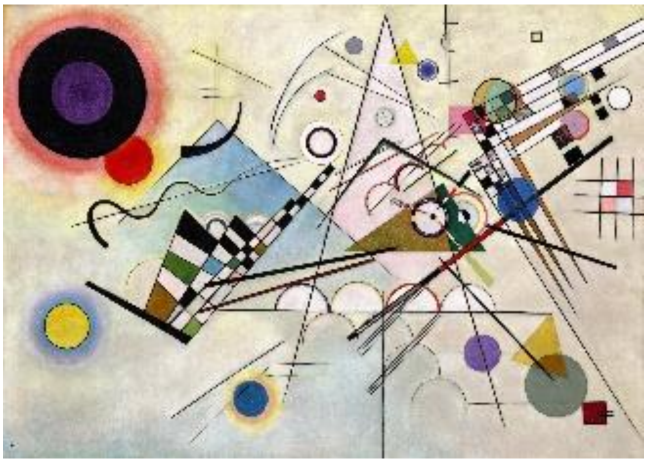


Figure 43. Composition 8 by Vasily Kandinsky

(https://www.guggenheim.org/artwork/1924)

Figure 44. Decisive Rose by Vasily Kandinsky

(https://www.guggenheim.org/artwork/2039)

4.2.2. Evaluating the Abstract Images with K-Mean

Complexity aspects of color in these abstract images were analyzed with image processing algorithms. This operation could also be done manually since human vision is able to distinguish millions of different colors but it is not easy to distinguish all colors by a conscious and expert eye (Gouras, 1991; Pointer & Attridge, 1998). It aids to identify the color shades which are normally hard to distinguish by normal eye. Thus, with image processing algorithms, it is more objective and manageable to identify colors in those images. One of the recent image processing algorithms; K-Means Color Clustering was used.

K- Means of Color Clustering is a method of unsupervised learning, which is used when there is unlabeled data (i.e., data without defined categories or groups or where there is gradation). The goal of this algorithm is to find groups in the data, with the number of groups represented by the variable K (in this study, the variable K was 10 000 so the algorithm can identify 10 000 groups) (Kocaoğlu & Olguntürk, 2018). Thus, if there is 10 000 colors in an abstract painting, by the help of K- Means Color Clustering, it is possible to distinguish 10 000 different colors in that particular abstract painting. But in Kandinsky's painting, there are only 103 different colors. Also the algorithm works iteratively to assign each data point to one of K groups based on the features that are provided. Data points are clustered based on feature similarity, so even if there is a color gradation in an abstract image, the algorithm clusters them according to their similarities.

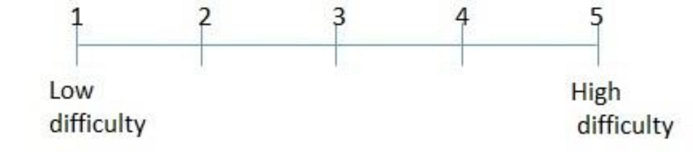
K- Means of Color Clustering clusters the data according to the given similarities in a digital image and it becomes a widely used method for image searching and retrieval. K- Means of Color Clustering can be used in various disciplines such as biomedicine; skin and lesion segmentation, image segmentation; texture and color segmentations, infected fruit part detection, forensics, artificial intelligence, military, education, web image searching (Dubey, Dixit, Singh & Gupta, 2013; Juang & Wu, 2010; Maheshwari, Silakari & Motwani, 2009; Murthy, Vamsidhar, Kumar & Rao, 2010; Patil & Jondhale, 2010; Ravichandran & Ananthi, 2009).

4.2.3. Preparing the Questionnaire

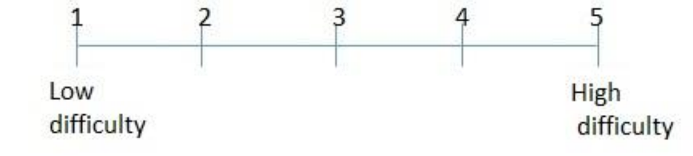
For exploring the association between color, visual complexity and visual interest in abstract images, a questionnaire having five questions were prepared (see Table 3 and Appendix A). After color identification with K-Means Color Clustering in terms of the variety of colors, selected abstract images were rated (with a 5-point scale) by the 120 participants in terms of intelligibility, disorganization, variety of colors, visual interest and visual complexity (Kocaoğlu & Olguntürk, 2018). The questionnaire consisted of questions about demographic information, intelligibility, and disorganization, variety of colors, visual interest and visual complexity with the abstract images which were printed in color on A4 paper. The first three questions were about the dimensions of visual complexity. The fourth question concerned visual interest and the fifth question related to the overall visual complexity in the abstract image.

Table 3 Questions of questionnaire

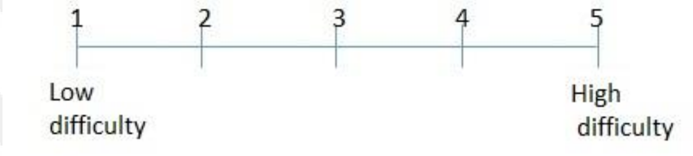
1. Rate the difficulty in differentiating each color in this composition.



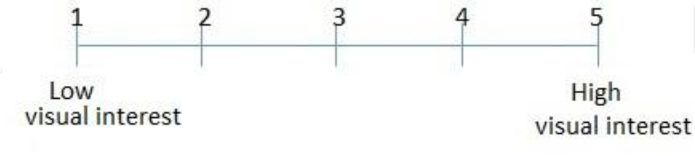
2. Rate the difficulty in distinguishing the rules in terms of usage of colors in this composition.



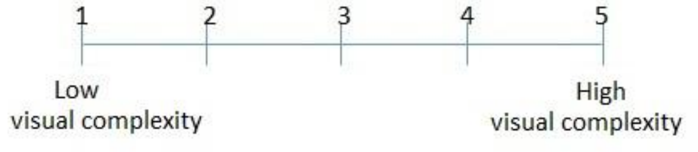
3. Rate the difficulty in distinguishing the variety of colors (hue, value, chroma) in this composition.



4. Rate this composition in terms of visual interest.



5. Rate this composition in terms of visual complexity.



4.2.4. Sample Group

The sample group for the study consisted of randomly selected undergraduate students (second, third, and fourth year) from the Interior Architecture and Environmental Design Department of Bilkent University, Ankara, Turkey. Each student studied color in their first-year and the total number in the sample group was

120 students. The age range of the students was from 19 to 31 years (mean age 22.5 years) and included both males and females, all with full corrected vision. Also, none of the students indicated they were color defective or color deficient. Each student was randomly assigned to an artwork and only answered one related questionnaire (Kocaoğlu & Olguntürk, 2018).

Table 4 Number of participants

	Number of Participants	Female	Male
Ocean 5	30	24	6
CompositionNo.VII	30	24	6
Composition 8	30	20	10
Decisive Rose	30	28	2
Total	120	96	24

4.3. Conducting the Experiment

The questions were asked in the subjects' native language in a controlled environment. Since there were four different abstract images, each of 30 subjects were randomly assigned to one abstract image in order to minimize the mere-exposure effect i.e. familiarity effect (Zajonc, 2001). Participants were asked to indicate their gender, age and department. Each participant indicated any color vision deficiencies before the experiment and the participants were requested to use their correction vision equipment if required. Each participant voluntarily answered one questionnaire where the images were distributed randomly by the researcher. There was no time limitation for answering the questionnaire and participants were free to ask questions (Kocaoğlu & Olguntürk, 2018).

4.4. Methodology- Part 2

According to the results of the experiment of Part I (See Chapter 5.1), the second experiment was designed in order to understand the role of color in visual complexity by isolating color from other variables of the artworks that existed in the first part of the thesis. As the results of the first experiment showed, participants rated Vasily Kandinsky's Composition 8 as the most visually complex, visually interesting and most intelligible (Kocaoğlu & Olguntürk, 2018). Also participants rated Piet Mondrian's Ocean 5 as the least visually complex, least visually interesting and least intelligible. After examining the results of previous study, a new abstract image was generated with using Adobe Photoshop CS6 (See Figure 45). The new generated abstract image gave the opportunity to examine only the effects of color on visual complexity and visual interest by controlling all other parameters as the number of colors in the generated abstract image is kept constant with 106 colors.

4.4.1. Analyzing the Kandinsky's Composition 8 and Preparing the generated abstract image

According to the results of the first experiment, Composition 8 by Vasily Kandinsky which was rated as the most visually complex one was selected for the second study for creating a new resembling abstract image. Kandinsky-like abstract image was created since the aim of this study was to understand the role of color in determining the level of visual complexity in abstract images.

There are various studies that used Mondrian, van Gogh, Matisse, Malevich, and Pissarro-like images for testing numerous phenomena. For example, a study conducted by McManus, Cheema, and Stoker (1993) used 25 Mondrian- like images in order to test whether participants could distinguish them from the original Piet Mondrian paintings. According to their results, participants could distinguish the original paintings from the Mondrian- like images (Noll, 1966; Swami, Grant, Furnham & McManus, 2007). Another study (Vartanian, Overbay, Podsiadlo & Martindale, 2005) asked participants to compare 15 original artworks of van Gogh, Matisse, Malevich, and Pissarro and some altered compositions of those artworks. Vartanian, Overbay, Podsiadlo & Martindale (2005) found that original artworks were preferred over the altered compositions. Swami, Grant, Furnham & McManus (2007) conducted a study to test the effect of change in lower waist-to-hip ratio (WHR) in paintings and sculptures. They manipulated WHR of each artwork and asked participants to rate both manipulated and original artworks according to aesthetic appeal and originality and concluded that higher WHR as the most aesthetically pleasing. For the second part of this thesis, Kandinsky-like abstract image was created in the light of the methods encountered in literature search mentioned above.

The generated abstract image could be called as "Abstract Plasticism" like Vasily Kandinsky’s works which consisted of geometric elements and straight lines colored with flat colors since Kandinsky’s Composition 8 includes 103 different colors with different geometric shapes such as triangles, circles, rectangles and polygons varying in size, orientation and allocation (Kocaoğlu Aslanoğlu & Olguntürk, 2019). The new generated abstract image was as visually complex and interesting as the original one since it included the same proportions, same geometric shapes at the same allocations as the original one and has 106 different geometric shapes (See Figure 45). The new generated abstract image is a Kandinsky- like abstract image in order to minimize mere- exposure effect (Zajonc, 2001). As Forsythe et. al. (2011) mentions; a 'still life' traditionalist painting of an apple may be created to contain the same elements, lines, and colors, as a cubist painting of an apple, but the former would receive lower complexity ratings because it were more familiar to the viewer. Thus, familiarity could act as a mediating variable reducing its perceived complexity (Forsythe et. al., 2011). Also using rectangles, squares or circles without a reference painting could cause familiarity as the elementary components become organized they are perceived as familiar objects (Forsythe et. al., 2011). Hence, the generated abstract image can be called as the resembled reproduction of Composition 8 i.e. Kandinsky-like abstract image which contained 106 geometric shapes and 106 different colors (Kocaoğlu Aslanoğlu & Olguntürk, 2019).

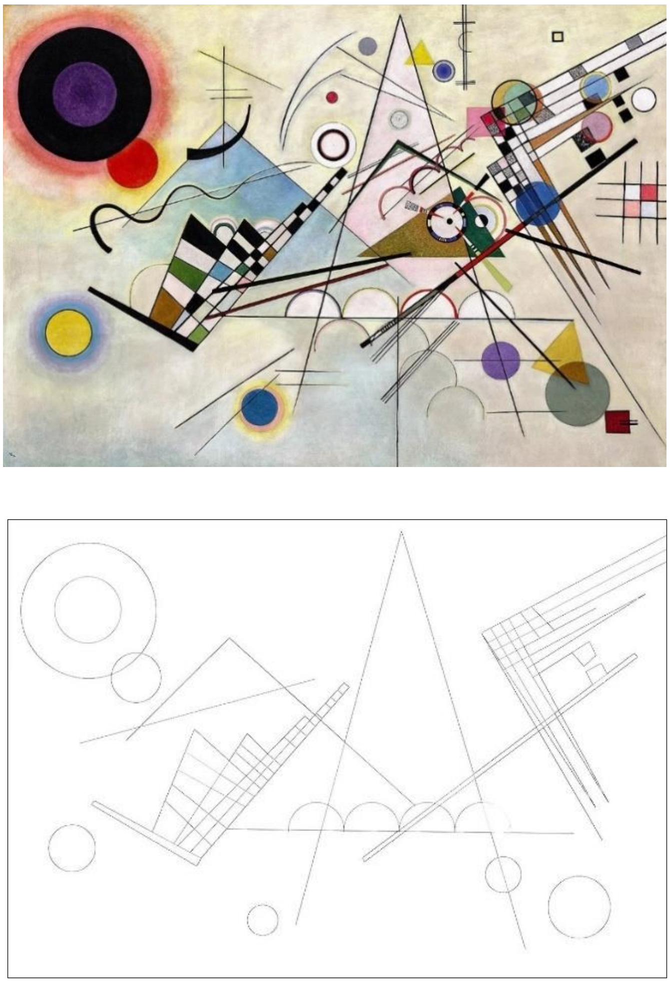


Figure 45. The original Composition 8 (top) and the generated abstract image (bottom)

For the new generated abstract image, colors were selected from the CIE Chromaticity Chart (See Figure 46). CIE Chromaticity Chart was selected for this study because its tongue shape curve shows the limits of the visible colors that human can perceive and distinguish. In order to have 106 different colors for each generated abstract images, the CIE Chromaticity Chart was divided into 6 zones for including all the colors presented in the chart. The tongue shape curve was first divided in half and then with 2 perpendicular lines, 6 equivalent zones have obtained (See Figure 46). With this particular division, each zone have at least 53 colors. Also by this way of zonal division, the in-between colors such as yellow, cyan and magenta can be obtained and equally distributed among zones.

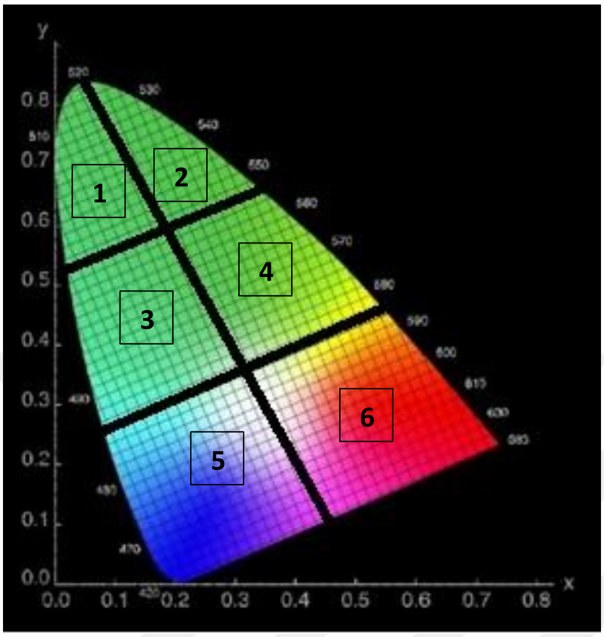


Figure 46. The CIE Chromaticity Chart and 6 zones

By using the all 6 zones in the CIE Chromaticity Chart, 19 zone combinations were obtained (1-2, 1-3, 1-4, 1-5, 1-6, 2-3, 2-4, 2-5, 2-6, 3-4, 3-5, 3-6, 4-5, 4-6, 5-3, 5-6, 6-2, 6-4, 6-5; only 2-6 and 6-2, 3-5 and 5-3, 4-6 and 6-4, 5-6 and 6-5 were colored in reversed order since their appearances dramatically changes when colors were used in different places rather than the other abstract images) for coloring the generated abstract image. The rest of the generated abstract images were not colored in reverse order since there was not a distinguishable difference. Since there are 106 colors in the abstract composition, 53 colors were selected from one zone (e.g. zone number 2 starting from the square at right bottom corner to left upper corner) and the other 53 colors were selected from another zone (e.g. zone number 5 starting from the square at left bottom corner to right upper corner). The way of selecting colors from furthest corners was for maximizing the proximities between colors for having varying Delta E values. In order to understand if there was an effect of the allocations of colors in the abstract image, 3 abstract images were colored by using the same zones but in reverse order (2-6 and 6-2, 3-5 and 5-3, 4-6 and 6-4, 5-6 and 6-5). The background color of each abstract image was a mid-grey having no chroma in it (L: 50, a: 0, b: 0) (See Figure 47) (Rosenholtz, Nagy & Bell, 2004).

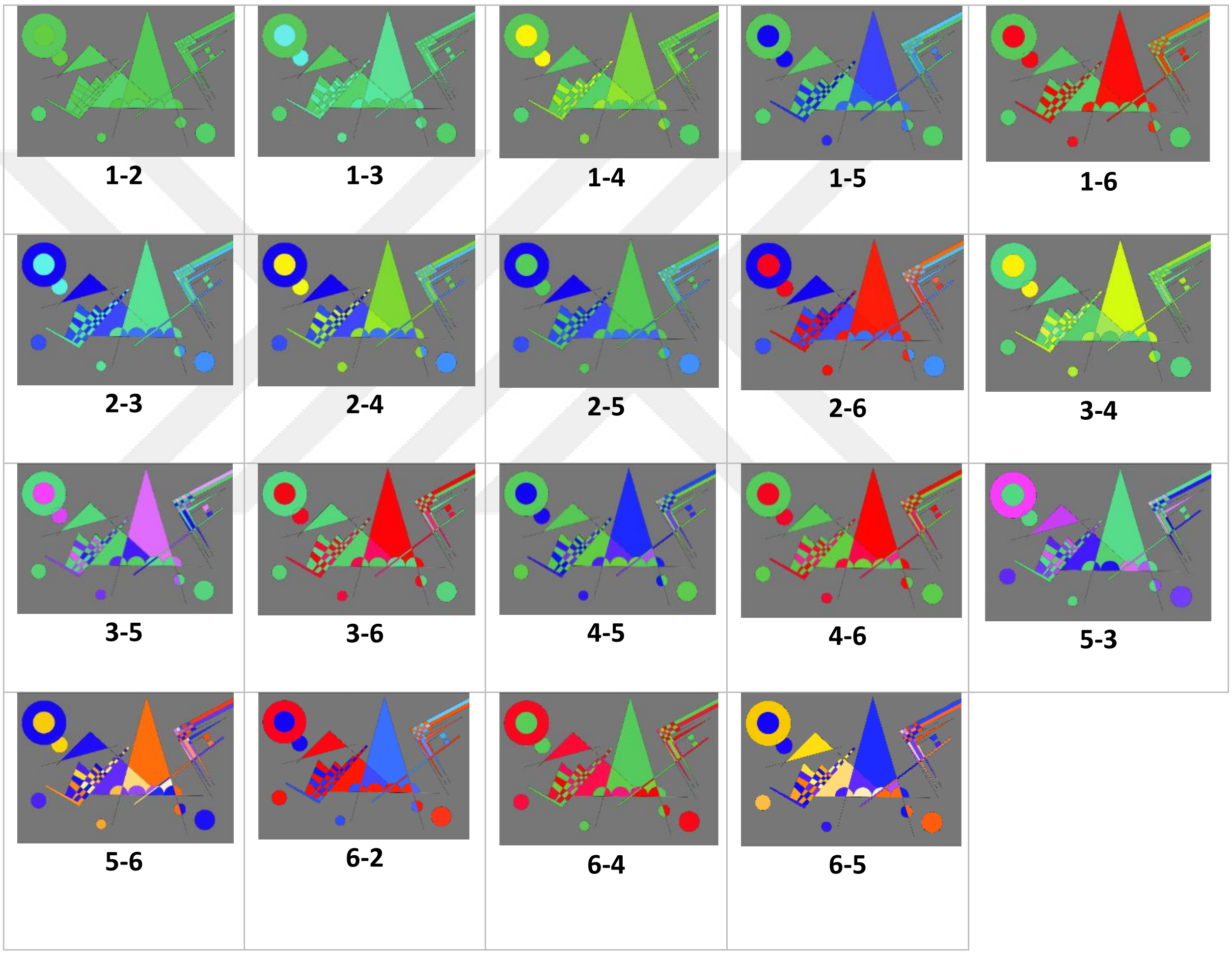


Figure 47. The 19 generated abstract images colored according to the zones in the CIE Chromaticity Chart

4.4.2. Preparing the Questionnaire

For exploring the effect of ΔE values of colors in an abstract image on visual complexity and visual interest, a questionnaire having 38 (19 questions for visual complexity and 19 questions for visual interest) questions was prepared. Participants were asked to rate the randomly ordered 19 generated abstract images according to the level of visual complexity and visual interest with a 5-point scale (1= least, 5= most). The questionnaire has a short consent form and demographic information part printed in an A4 paper, the questions related with the abstract images were shown to students via Google Form on a calibrated computer screen (See Appendix E and https://docs.google.com/forms/d/1KaYENtHtSUPBU7tLohPMRLTsRu8bM49_IzQbI4Y4GOU/edit).

4.4.3. Sample Group

The sample group for the study consisted of 120 undergraduate students (first, second, third, and fourth year interior architecture, architecture and graphic design students) from the Faculty of Art, Design and Architecture of Bilkent University, Ankara, Turkey. All the students did not participated the first experiment. The age range of the students was from 18 to 28 years (mean age 21.3 years) and included both females and males (See Table 5), all with full corrected vision. Also, none of the students indicated they were color defective or color deficient. Each student had an education about color within the scope of Faculty of Art, Design and Architecture courses.

Table 5 Number of participants

	Number of Participants	Female	Male
Experiment Part II	120	86	34

4.5. Conducting the Experiment Part 2

The experiments were conducted in a windowless controlled lab environment under controlled lighting conditions without any daylight penetration (See Figure 48 and Figure 49) in February 2019. For exploring the effect of ΔE values of colors in an abstract image on visual complexity and visual interest, a set of procedures was conducted. For each experiment session, only one participant participated in the experiment. First, the participant was seated in front of the computer, then asked to fill the short consent form and demographic information questions. After filling those questions, the lights were turned off and participant started to rate the randomly ordered 19 generated abstract images according to the level of visual complexity and visual interest with a 5-point scale (1= least, 5= most) on a calibrated computer screen (Intel Core i7 HD Graphics 2.2GHz) (See Appendix E). Each experiment session took approximately 10-15 minutes per participant.

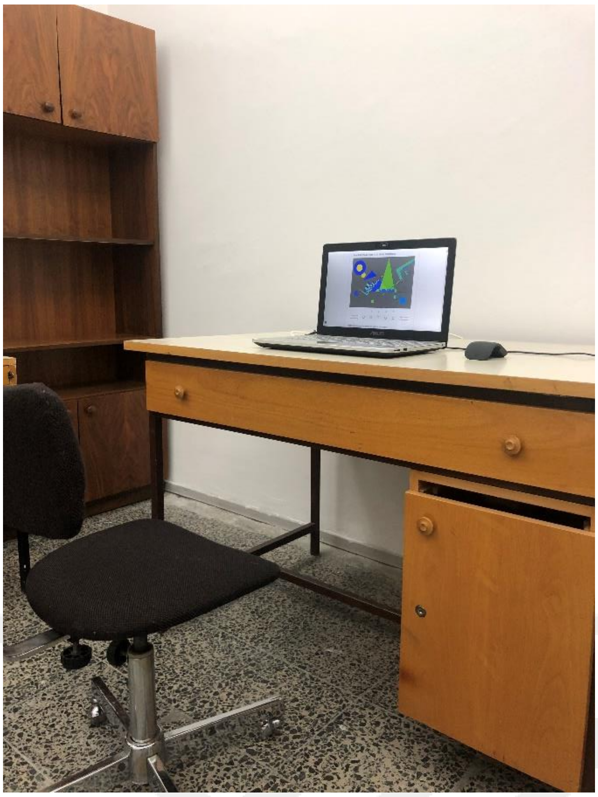


Figure 48. Photo taken by the researcher showing the experimental setup for Experiment- Part 2

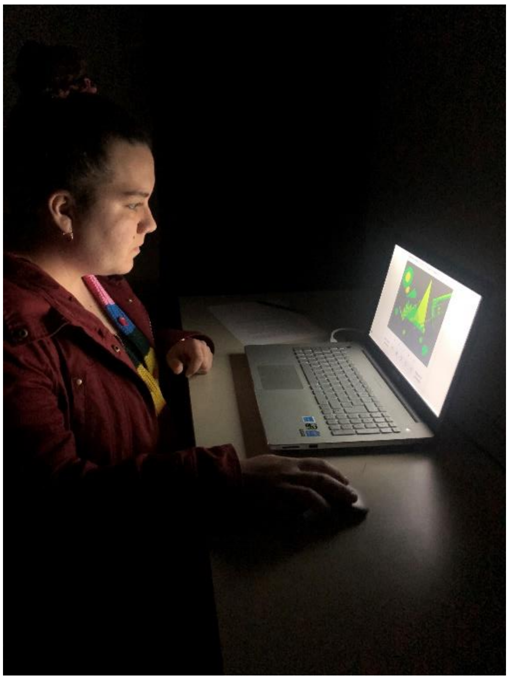


Figure 49. Photo taken by the researcher during Experiment- Part 2

CHAPTER 5

DATA ANALYSIS OF THE EXPERIMENTAL STUDIES

5.1. Results of the Experiment- Part 1

K-Means Color Clustering and participant ratings were used for developing a deeper understanding about visual complexity and visual interest in abstract images. The two hypotheses of the first part of the study verified;

H1.1. As intelligibility of colors in an abstract image increase, visual complexity and visual interest will also increase until there is over unintelligibility where both will decrease.

H1.2. As difficulty in distinguishing the rules and variety of colors used in images increase, visual complexity and visual interest will also increase.

According to the results of K-Means Color Clustering (see Appendix B), Composition 8 has the highest visual complexity in terms of variety of colors, it has 103 different colors. The second highest visual complexity is in Composition No.VII with 85 colors, and the third one is Decisive Rose with 52 colors. Ocean 5 has the lowest visual complexity, it has 37 colors. According to the ratings of design students, Composition 8 has the highest visual complexity, the second highest one is Decisive Rose followed by Composition No.VII, and the lowest visual complex one is Ocean 5. The highest and the lowest visual complex abstract images were the same according to both K-Means Color Clustering and participants. Also the association between intelligibility, organization, variety of colors, visual complexity, and visual interest were analyzed according to the results of participants (see Appendix C). According to the results of ANOVA, there is a significant difference [F (3, 116) = 4.12, p= 0.008] between Composition 8, Composition No VII, Ocean 5 and Decisive Rose in terms of unintelligibility. Ocean 5 was rated as the most unintelligible image, it was followed by Decisive Rose, Composition No VII and Composition 8 respectively. A significant difference could not be found in terms of organizing colors and variety of colors in abstract images. According to the results of ANOVA, there was a significant difference [F (3, 116) = 4.57, p= 0.005] between Composition 8, Composition No VII, Ocean 5 and Decisive Rose in terms of visual interest. Composition 8 was rated as the most visually interesting image, it was followed by Decisive Rose, Composition No VII and Ocean 5 respectively. Also, there was a significant difference [F (3, 116) = 6.00, p= 0.001] between Composition 8, Composition No VII, Ocean 5 and Decisive Rose in terms of visual complexity. Composition 8 was rated as the most visually complex image, it was followed by Decisive Rose, Composition No VII and Ocean 5 respectively (See Table 6) (Kocaoğlu Aslanoğlu & Olguntürk, 2019).

Table 6 K- Mean Color Clustering results and participant ratings' mean values (5 point likert- scale- 5 is the most and 1 is the least value) of all four abstract images

		K- Mean	Unintelligibility of Colors [F (3, 116) = 4.12, p= 0.008]	Disorganization of Colors [F (3, 116) = 2.54, p= 0.060]	Variety of Colors [F (3, 116) = 1.11, p= 0.347]	Visual Complexity [F (3, 116) = 6.00, p= 0.001]	Visual Interest [F (3, 116) = 4.57, p= 0.005]
	**Composition 8**	103	**<u>1.8</u>**	3.5	2.0	**<u>4.0</u>**	**<u>3.9</u>**
	**Composition No. VII**	85	2.3	3.2	2.3	3.3	3.2
	**Decisive Rose**	52	2.4	3.3	2.4	3.4	3.7
	**Ocean 5**	37	2.7	2.8	2.5	2.8	2.9

The human visual system has natural limits, e.g., the minimal perceivable luminance difference between two areas or minimal perceivable dot size (Miniukovich & De Angeli, 2014). Such limitations influence the discriminability of information and might cause difficulty in understanding the information in the stimuli even if the amount and organization of information stays the same. When there is inadequate edge congestion or low figure-ground contrast in the stimulus, there might be uneasiness in identifying the information. The reason behind why Ocean 5 rated as the most unintelligible one might be because of these mentioned limitations. Ocean 5 has the least number of colors and rated as the least visually interesting and least visually complex one. On the other hand, Composition 8 rated as least unintelligible, most visually interesting and most visually complex one. It also has the most number of colors. This result can be explained by Berlyne's (1971) views for complexity; a stimulus is considered more complex, the larger the number of independently selected elements it contains. In Composition 8, there were more colors than Ocean

5, also the information in Composition 8 could be identified easier than Ocean 5 since there was a more definite figure- ground relation. Thus, a stimulus can be made more complex by simply multiplying incidents and characters, i.e. information; in painting, the objects depicted or the areas of uniform color can be made more numerous and more dissimilar (Berlyne, 1971).

The results revealed that images that were evaluated as visually complex and interesting were the ones that had less difficulty in differentiating hues (unintelligibility). Since the selected images are complex in nature, their degrees of complexity revealed that when there are over unintelligibility viewers start losing their visual interest.

5.2. Results of the Experiment- Part 2

It was hypothesized that, as the average ΔE value of colors in an abstract image increases, visual interest and visual complexity will increase until a threshold where visual interest and visual complexity start to decrease. In order to test the relationship between ΔE values of the colors, visual interest and visual complexity 120 design students rated the 19 generated abstract images. According to the results of an analysis of variance (ANOVA) for reliability check, the students' ratings for each 19 abstract image is significantly different from each other in terms of visual interest ($F [2261, 18] = 24.67$, $P = .000$) and visual complexity ($F [2261, 18] = 54.15$, $P = .000$). Thus with the previously mentioned significant results, it was possible to statistically analyze design students' ratings for each abstract image.

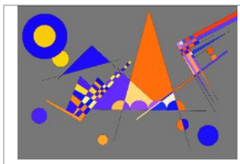
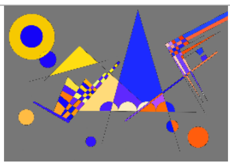
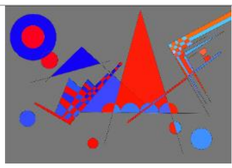
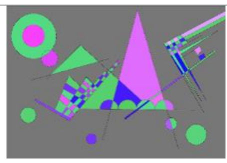
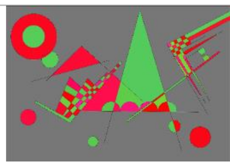
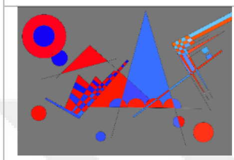
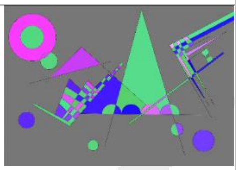
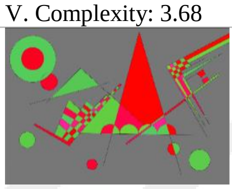
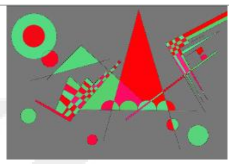
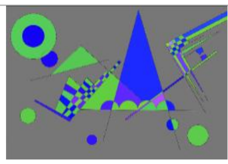
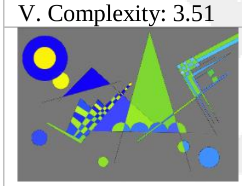
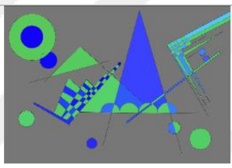
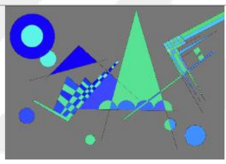
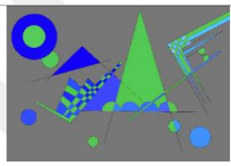
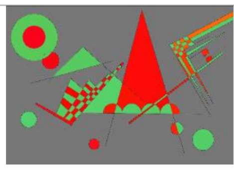
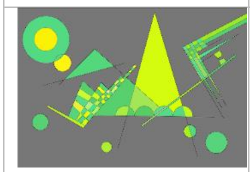
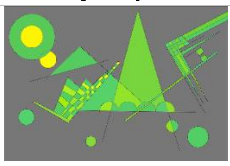
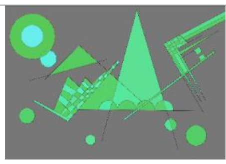
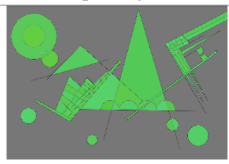
Analysis of Delta E Values: Each of the ΔE values were calculated by a Delta E Calculator using the equation above (See Equation 1) (http://colormine.org/delta-e-calculator/cie2000) and an average ΔE value were obtained per an abstract image. According to the calculations of 19 abstract images, the ΔE values vary between 4.50 and 79.53 (See Table 7). One of the abstract image's average ΔE value was 4,50 which can be still perceptible at a glance and the rest of the 19 abstract images' ΔE values were bigger than 11 which means the colors used were either more similar than opposite or were exact opposite according to human perception (See Table 7). The ΔE values of 19 abstract images varied in order to understand the association between visual complexity and color as hypothesized before.

Table 7 Association between Delta E Values and human perception (http://zschuessler.github.io/DeltaE/learn/)

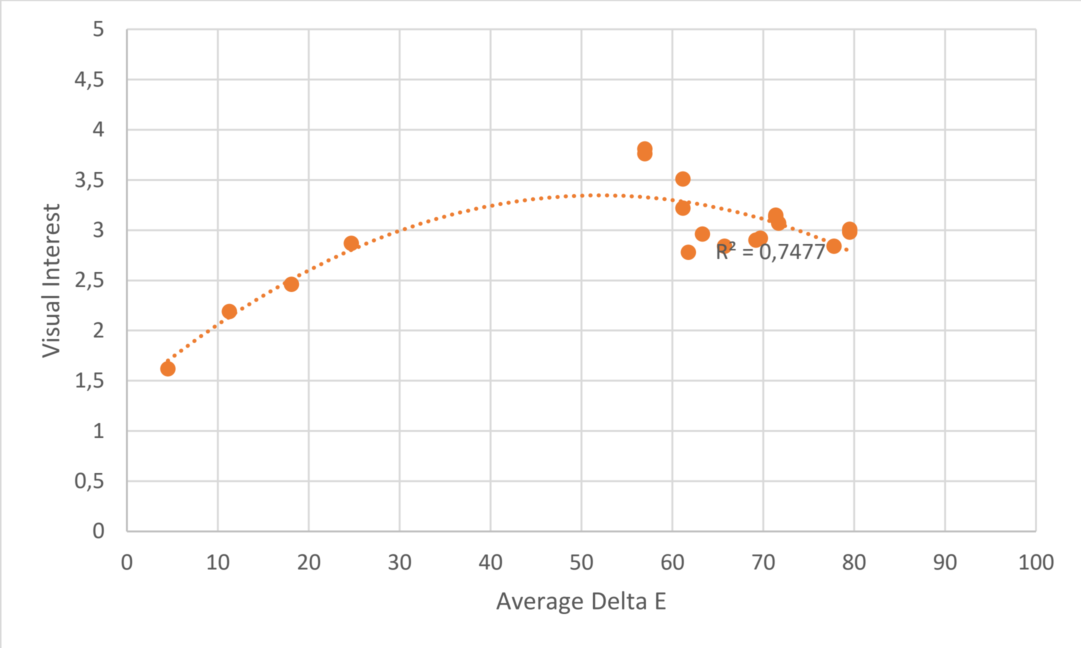
Delta E Values	Human Perception
≤1	Barely to Not perceptible
1-2	Perceptible through close observation
2-10	Perceptible at a glance
11-49	Difference between color pairs are perceptible
50-100	Color pairs are in strong contrast

Analysis of Students' Ratings: According to the results of design students' ratings with 5-point scale, the abstract image "5-6" rated as the most visually complex and visually interesting one among the other abstract images. Moreover "1-2" rated as the least visually complex and visually interesting (See Table 8). As this particular study seeks to find the relationship between ΔE values of the colors used in abstract images and visual complexity and visual interest; the abstract images (1-2 and 1-3) having the ΔE values 4.50 and 11.25 rated as least visually complex and least visually interesting whereas the abstract images (5-6 and 6-5) having the ΔE value 56.97 rated as most visually complex and most visually interesting among other images. The abstract images (3-5 and 5-3) having the highest ΔE value 79.53 had a moderate rating of visual interest and visual complexity (See Graph 1).

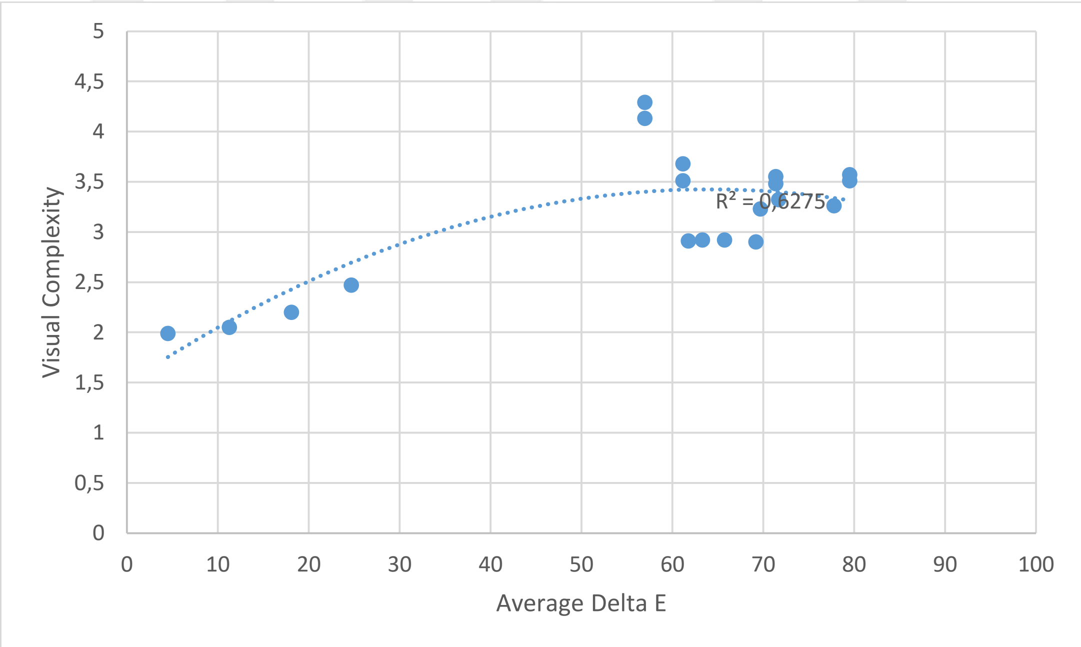
Table 8 The 19 generated abstract images using the colors from 6 different zones of CIE Chromaticity Chart and their Average ΔE, Visual Interest and Visual Complexity values (Ranked from the highest visual complexity rating to the lowest

 **5-6** **(Tetradic)** Average ΔE: 56.97 V. Interest: **3.81** V. Complexity: **4.29**	 **6-5** **(Tetradic)** Average ΔE: 56.97 V. Interest: 3.76 V. Complexity: 4.13	 **2-6** **(Split-complementary)** Average ΔE: 61.16 V. Interest: 3.51 V. Complexity: 3.68	 **3-5** **(Triadic)** Average ΔE: 79.53 V. Interest: 3.01 V. Complexity: 3.57	 **6-4** **(Complementary)** Average ΔE: 71.37 V. Interest: 3.15 V. Complexity: 3.55
 **6-2** **(Split-complementary)** Average ΔE: 61.16 V. Interest: 3.22 V. Complexity: 3.51	 **5-3** **(Triadic)** Average ΔE: 79.53 V. Interest: 2.98 V. Complexity: 3.51	 **4-6** **(Complementary)** Average ΔE: 71.37 V. Interest: 3.13 V. Complexity: 3.48	 **3-6** **(Complementary)** Average ΔE: 71.71 V. Interest: 3.07 V. Complexity: 3.32	 **4-5** **(Analogous)** Average ΔE: 77.80 V. Interest: 2.84 V. Complexity: 3.26
 **2-4** **(Analogous)** Average ΔE: 69.70 V. Interest: 2.92 V. Complexity: 3.23	 **1-5** **(Analogous)** Average ΔE: 65.76 V. Interest: 2.84 V. Complexity: 2.92	 **2-3** **(Analogous)** Average ΔE: 63.33 V. Interest: 2.96 V. Complexity: 2.92	 **2-5** **(Analogous)** Average ΔE: 61.76 V. Interest: 2.78 V. Complexity: 2.91	 **1-6** **(Complementary)** Average ΔE: 69.21 V. Interest: 2.90 V. Complexity: 2.90
 **3-4** **(Analogous)** Average ΔE: 24.69 V. Interest: 2.87 V. Complexity: 2.47	 **1-4** **(Analogous)** Average ΔE: 18.09 V. Interest: 2.46 V. Complexity: 2.20	 **1-3** **(Monochromatic)** Average ΔE: 11.25 V. Interest: 2.19 V. Complexity: 2.05	 **1-2** **(Monochromatic)** Average ΔE: 4.50 V. Interest: 1.62 V. Complexity: 1.99	

The abstract images rated as the least visually interesting and complex ones; “1-2” and “1-3” had a monochromatic color scheme with tints of green which could be perceptible or distinguishable at first glance (See Table 7). Thus, having a single hue and its tints makes an abstract image less interesting and less complex. It is followed by the abstract images “1-4” and “3-4” had an analogous color schemes with green and yellow which makes them rated as a moderate level of visual interest and complexity. In those two abstract images colors were more similar than the opposite but not as similar as a monochromatic scheme (See Table 8). Then, the other analogous color schemed abstract images with blue and green “1-5, 2-3, 2-4, 2-5, 4-5” were distinguished from the other analogous color schemed images since they had higher Average ΔE values (≥50) in which the colors could be evaluated as exact opposite to each other (See Table 7). The abstract images “1-6, 3-6, 4-6, 6-4” had a complementary color scheme with red and green. It is followed by the abstract images in terms of visual interest and visual complexity “3-5, 5-3” which had triadic color scheme with purple, purplish blue and green. Afterwards, the abstract images “2-6, 6-2” had a split-complementary color scheme with red and blue rated as the second most visual interesting and complex ones. The most visually interesting and visually complex abstract images were “5-6, 6-5” having a tetradic color scheme with blue, purplish blue, yellow and yellowish orange.



Graph 1. The rating results of 19 generated abstract image by design students according to visual interest and its relationship between Average ΔE values



Graph 2. The rating results of 19 generated abstract image by design students according to visual complexity and its relationship between Average ΔE values

As the Graph 1 and Graph 2 showed there was a positive correlation between Average ΔE values- visual interest (Pearson Correlation $r(19)=0.747$, $p=0.004$) and Average ΔE values- visual complexity (Pearson Correlation $r(19)=0.627$, $p=0.000$). An inverted U-curve relationship between Average ΔE values and visual complexity was visible which was similar to the relationship between Average ΔE values and visual interest (See Graph 1 and 2). Berlyne (1963) showed that complexity was a dominant factor of interestingness and pleasantness of a stimulus (Berlyne, 1963; Berlyne, 1971). Berlyne (1971) suggested that the relationship between complexity and pleasantness could be explained by an inverted U-curve, where the stimuli with intermediate levels of complexity are the most preferable ones.

CHAPTER 6

DISCUSSION

This thesis consists of two conjoint parts for analyzing the effects of color on visual complexity and visual interest. This particular study started with defining visual complexity and its dimensions, its relationship with visual interest by investigating previous research in empirical aesthetics. As literature review showed, visual complexity was a strong predictor for liking of and interest in artworks (Berlyne, 1963; Nadal, Munar, Marty, & Cela-Conde, 2010; Gartus & Leder, 2013). The first part of this thesis aimed to find the visual complexity dimensions that had an effective role in the determination of complexity and interest in colored abstract images.

Both first and second part of the thesis used abstract images in order to put forward an understanding about the effect of color on visual complexity and visual interest since abstract images, i.e. artworks with unambiguous content, for example a bottle would be perceived as less complex than a version of them with more ambiguous content like a bottle morphed into a carrot since a morphed bottle is harder to interpret and process perceptually. This can be a strong evidence that the perceived complexity of artworks can be dependent on content-related processes (Commare, Rosenberg & Leder, 2018). Thus, in the first and the second parts of this thesis, abstract images and a generated abstract image were used in order to test the effect of color both on visual complexity and visual interest.

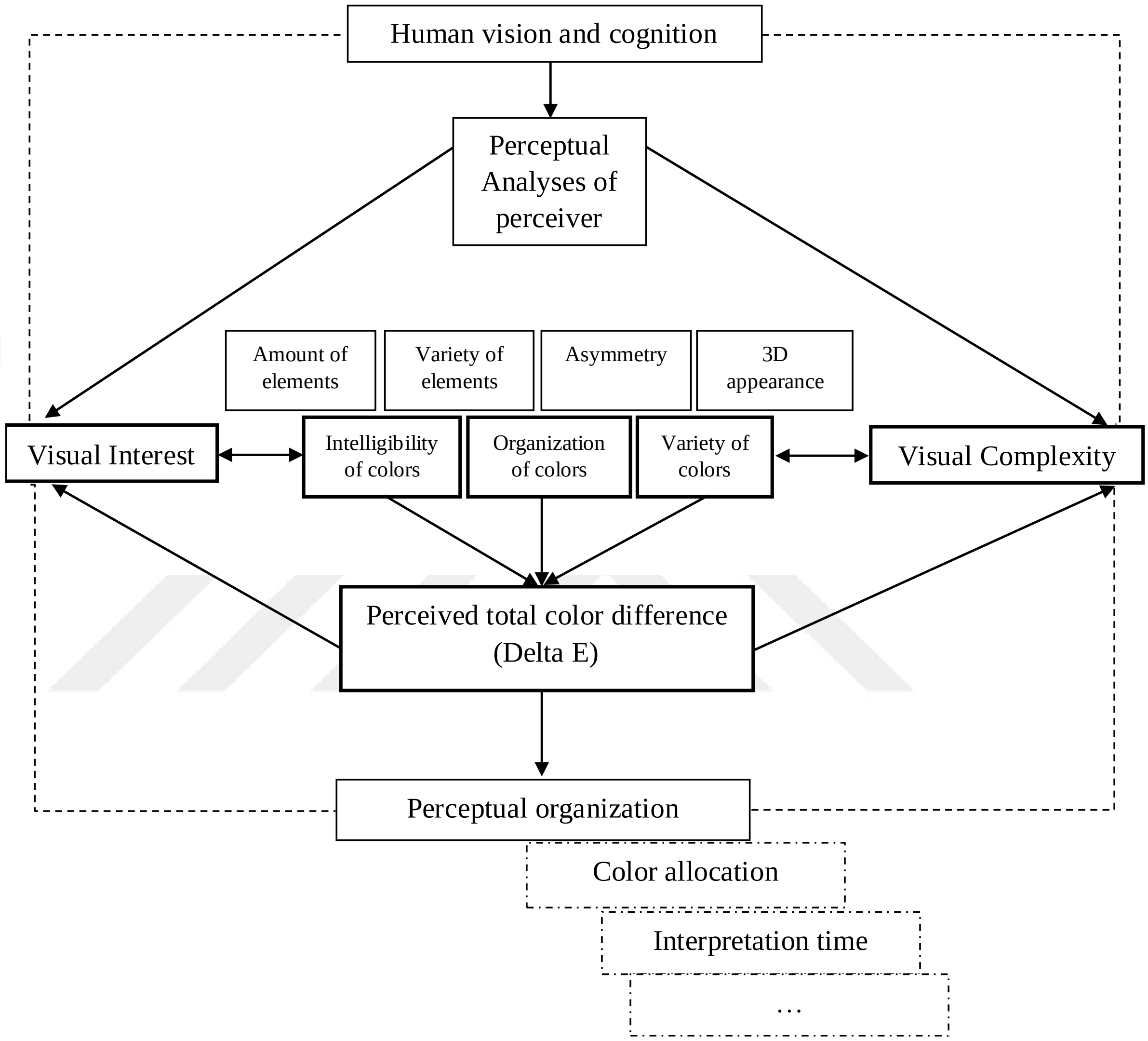


Figure 50. The theoretical framework developed by the thesis (illustrated by Rengin Aslanoğlu)

The theoretical framework (See Figure 50) of the thesis is showing the cause and effect relationship between visual complexity, visual interest and color which were tested by the two interconnected experiments; the perceptual analyses of the perceiver is directly linked with visual complexity and visual interest. Both visual complexity and visual interest are effected by amount of elements, variety of elements, asymmetry, 3D appearance, intelligibility of colors, organization of colors and variety of colors. The essence of the thesis was to develop a theoretical measure for understanding human vision and cognition system through visual complexity, visual interest and color. Hence, to develop this theoretical measure, the dimensions about color (intelligibility of colors, organization of colors and variety of colors) were examined (Part I). The first part of the thesis found that intelligibility of colors in an image was the most effective dimension among the others. In order to develop further knowledge about intelligibility of color, the second part of the thesis was designed by examining the perceived total color difference (Delta E) in abstract images. The second part's results indicated the Delta E value of colors for creating a visual complex and visual interesting image which can effect iteratively the perceptual analyses of the perceiver.

6.1. Discussion of Part 1

It was hypothesized that, as unintelligibility of colors in an abstract image increase, visual complexity and visual interest will also increase until there is over unintelligibility where both will decrease (Kocaoğlu & Olguntürk, 2018). As difficulty in distinguishing the rules and variety of colors used in images increase, visual complexity and visual interest will also increase.

There are several dimensions to frame visual complexity and this study focuses on intelligibility, disorganization, and variety of colors in a composition (Aloumi, Noroozi, Eves & Dupac, 2013). Unintelligibility is the difficulty in identifying colors in a composition i.e. differentiation of colors. If it is not difficult to differentiate colors in a composition, visual complexity of that composition is low. The second dimension for visual complexity is disorganization. It is the difficulty in *organizing* colors in the composition. If there is no or indiscernible rule in the usage of colors; in terms of the location of colors in the composition (symmetrical, radial, diagonal, grid etc.) and in terms of harmoniousness of colors (monochromatic, analogous, complementary contrast, split-complementary contrast), visual complexity of that composition is high. The last dimension is *variety* of colors (hue, value and chroma) in a composition. As the number of colors increase in a composition, visual complexity becomes high.

For evaluating the association between color and visual complexity, four abstract images were selected which were all accomplish color harmony, visual interest and visual complexity. Complexity aspects in these abstract images were analyzed with an image processing algorithm; K-Means Color Clustering and the results showed that Composition 8 has the highest visual complexity in terms of variety of colors. After color identification with K-Means Color Clustering in terms of variety of colors, 120 design students rated the selected abstract images with 5-point scale in terms of intelligibility, disorganization, variety of colors, visual interest and visual complexity. Results show that Composition 8 has the highest visual complexity, the second highest one is Decisive Rose followed by Composition No.VII, and the lowest visual complex one is Ocean 5. The highest and the lowest visual complex abstract images were the same according to both K-Means Color Clustering and participants. The results revealed that images that were evaluated as visually complex and interesting were the ones that they had difficulty in finding a color harmony (disorganization) and indicate a huge variety of colors to the extent that differentiation between hues becomes very difficult (unintelligibility). Since the selected images were complex in nature, their degrees of complexity revealed that when there are over unintelligibility viewers start losing their visual interest. The reason could be explained with some of the Gestalt principles; continuation, similarity, proximity and symmetry (Todorovic, 2008). Human vision system tend to see things by grouping them according to their similarities. In the case of this study, participants rated Ocean 5 as the least visual complex one among the other abstract images which might be caused by continuation, similarity and proximity principles. In Ocean 5 (See Figure 41), the shapes were continuous rectangles in varying sizes and all the shapes were spatially close (proximity) to each other (Han, Humphreys & Chen, 1999). Also the colors were similar (shades of yellow) which ease the perceptual groupings. Composition 8 rated as the highest visual complex abstract image since there were less continuation, symmetry, proximity and similarity which complicated the perceptual process during grouping the elements. All those previously mentioned discussions need a further examination; for instance, according to previous Gestalt principle studies proximity occurs prior to similarity. Similarity based on topological properties (e.g., similarity of closure) is perceived prior to similarity based on local geometrical properties (e.g., similarity of orientation) (Han, Humphreys & Chen, 1999). Thus, future studies should be done to have a more detailed explanation.

The previous research about visual complexity examined the complexity dimensions in order to categorize them according to the factors which influenced subjective complexity (Berlyne, Ogilvie & Parham, 1968; Nadal, Munar, Marty, & Cela-Conde, 2010). As Berlyne stated (1960), the subjective complexity of a stimulus is positively associated to the number of distinguishable elements and the dissimilarity between those elements. Also, he hypothesized that there was a negative association between perceived complexity and the degree to which several elements were responded to as a unit (Van Geert & Wagemans, 2019). It could be related with the limitations of human visual system has because of its nature such as processing capability during perceptive and cognitive processes. For example, the biased competition theory of attention (Desimone & Duncan, 1995; Wu et. al., 2016) suggests that the processing capacity of the human visual system is limited and that each element presented in the visual field competes with each other for neural representation and cognitive processing. The biased competition theory of attention could be related with the distinguishability of information in the stimuli which effects the visual complexity and visual interest perception. Such limitations caused by the biased competition theory of attention could influence the discriminability i.e. distinguishability of information; colors in the stimuli of an abstract image. Even if the amount and organization of information stays the same in the abstract image, visual complexity could be rated differently because of the difficulty in distinguishing the information within the stimulus. This kind of difficulty in understanding and interpreting the information in a stimulus might cause uneasiness in identifying the information like in the ratings of Ocean 5. Ocean 5 was rated as the most unintelligible abstract image since it contained the least number of colors which made it the least visually interesting and least visually complex one among the other abstract images.

In contrast to Ocean 5, Composition 8 rated as least unintelligible, most visually interesting and most visually complex one. It was rated as the easiest abstract image in terms of color discrimination (color intelligibility) since there was a more definite figure- ground relation than the other abstract images. It has definite borders around colors and shapes which eases distinguishing the all elements. Also, it had the most number of colors with 103 different colors which was associated with visual interest. As the results indicated, the increase in the number of colors in an abstract image was linked with the increase in the ratings of visual interest. These results could be supported by Berlyne, Ogilvie, and Parham (1968) study which indicated two main factors determining subjective complexity. The first factor was the number of independently selected component elements, which was called as the *information content dimension*; and the second factor was the *unitariness vs. articulation into easily recognizable parts*. With this theory, Berlyne, Ogilvie, and Parham (1968) referred to the degree in which the elements were grouped together as indistinguishable units in a cluster relative to a form of hierarchical organization in which the elements retain an important role as natural parts of a larger whole (Van Geert & Wagemans, 2019). Thus, a stimulus can be made more complex by simply multiplying incidents and characters, i.e. information; in painting, the objects depicted or the areas of uniform color can be made more numerous and more dissimilar (Berlyne, 1971).

To conclude, among the dimensions of visual complexity intelligibility was found as a more dominant factor than organization, variety of colors in an abstract image according to the ratings of participants. As the results of the first part of the thesis revealed, the images that were evaluated as visually complex and interesting were the ones that they had less difficulty in differentiating hues (unintelligibility).

6.2. Discussion of Part 2

Experiencing and encountering with color both in natural and built environment every day has led people to do research on color, its parameters and how it effects our visual sensation. As visual sensation is the most dominant factor for people in perceiving and understanding the natural and built environment (Jang, Baek, Yoon and Choo, 2018), several research has shown that visual sensation is effected by perceptual features such as color, color combinations, contour, or symmetry (Bertamini, Palumbo, Gheorghes & Galatsidas, 2016; Palmer, Schloss, & Sammartino, 2013; Pecchinenda, Bertamini, Makin & Ruta, 2014). One of those features, color, has been examined within various fields and topics.

There were limited number of studies examining color, visual complexity and visual interest together and one of the recent studies which tried to bring a new understanding to the association between color, visual complexity and visual interest was the first part of this thesis. Previous studies exploring the effects of color on human psychology; mood, emotion, attention and well-being, physiology, visual complexity and visual interest used isolated color patches which might be lacking in reflecting the dominating factors (Kocaoğlu & Olguntürk, 2018). Thus, the aim of the second part of the study was to find the relationship between visual complexity, visual interest and Delta E (ΔE) values of colors in abstract images and it was hypothesized that, as the average Delta E value of colors in an abstract image increases, visual interest and visual complexity will increase until a threshold where visual interest and visual complexity start to decrease (Kocaoğlu Aslanoğlu & Olguntürk, 2019). In order to test the hypothesis, a new abstract image was generated, colored and rated by 120 undergraduate students. As the results of the study indicated, there was an inverted U- curve relationship between average Delta E values and both visual interest and visual complexity in abstract images.

An inverted U-curve relationship between Average ΔE values and visual complexity was visible which was similar to the relationship between Average ΔE values and visual interest (See Graph 1). As the average Delta E value of colors in an abstract image increases, visual complexity and visual interest will increase until a threshold where visual complexity start to decrease. Berlyne (1963) showed that complexity was a dominant determinant of interestingness and pleasantness of a stimulus (Berlyne, 1963; Berlyne, 1971). Berlyne (1971) suggested that the relationship between complexity and pleasantness could be explained by an inverted U-curve. This concept of an optimal amount of stimulus complexity has been supported by numerous studies that found an inverted U-curve when characterizing aesthetic preference as a function of complexity (Berlyne, 1971; Farley and Weinstock, 1980; Güçlütürk, Jacobs and Von Liar, 2016; Saklofske, 1975).

Most of the prior visual complexity and visual interest studies did not consider the role of color both on complexity and interest and the ones which considered color used isolated color patches, not measured as a whole. Also individual differences such as age and education level were considered as a problem in previous complexity studies and in this study those were eliminated since design students with equivalent age were selected as participants and they were all coming from the same understanding of design education. Thus, this study revealed the relationship between color, visual interest and visual complexity by adding color and evaluating it as a whole through representing it with a quantitative value (ΔE) to the complexity field and brought a new understanding which was pioneered by Berlyne (1971).

This study also revealed the role of color schemes on visual complexity and visual interest in abstract images; the monochromatic color schemes (1-2 and 1-3) with tints of green (500-565 nm) were rated as the least visually interesting and complex ones (See Figure 51). Analogous color schemes (1-4 and 3-4) with green (500-565 nm) and yellow (565-600nm) and the other analogous color schemed abstract images with blue (435-500 nm) and green (500-565 nm) “1-5, 2-3, 2-4, 2-5, 4-5” rated as a moderate level of visual interest and complexity. So it can be discussed that, the abstract images having similar and/ or neighboring colors evaluated as less visually interest and complex which could be because of low variety of colors. The abstract images “1-6, 3-6, 4-6, 6-4” had a complementary color scheme with red (630-780 nm) and green (500-565 nm). The triadic color schemed abstract images (3-5, 5-3) with purple (380-435 nm), purplish blue and green (500-565 nm) green rated as the third most visually interesting and complex ones. Afterwards, the abstract images “2-6, 6-2” had a split-complementary color scheme with red (630-780 nm) and green (500-565 nm) rated as the second most visually interesting and complex ones. The most visually interesting and visually complex abstract images were “5-6, 6-5” having a tetradic color scheme with blue (435-500 nm), purplish blue, yellow (565-600nm) and yellowish orange. The ratings of visual complexity and visual interest might be related with one of the important characteristics of the colors; wavelengths.

According to the trichromatic color theory people with normal vision needed three different wavelengths while creating all ranges of colors. In the eye, there are three types of cones (L, M, S) that are sensitive to certain wavelength ranges. Each cone was stimulated by a different wavelength that come to the eye; for instance, both L and M cones are stimulated equally while looking at a yellowish green (Jacobs & Nathans, 2009; Kandel, Schwartz & Jessell, 2000). Also S cone is stimulated but at a lower level and human brain combines and interprets all the information (wavelength and intensity) which is coming from each receptor for perceiving colors. For instance, as the process of combining and interpreting the color information becomes intricate, the interpretation time might increase. Therefore, the interpretation time during the color perception process might effect visual complexity and visual interest interpretations which needs further examinations. For future studies the interpretation time can be recorded and eye tracking devices can be also used in order to understand which color takes the longer time to interpret.

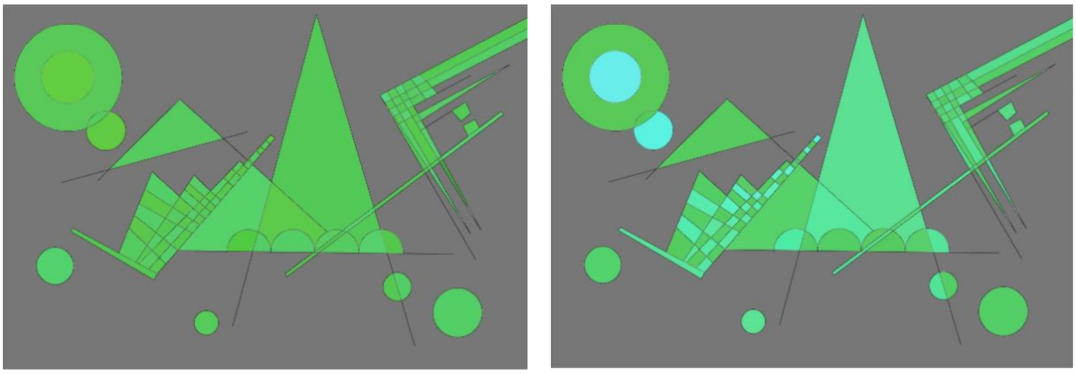


Figure 51. Abstract image: 1-2 (Left) and 1-3 (Right)

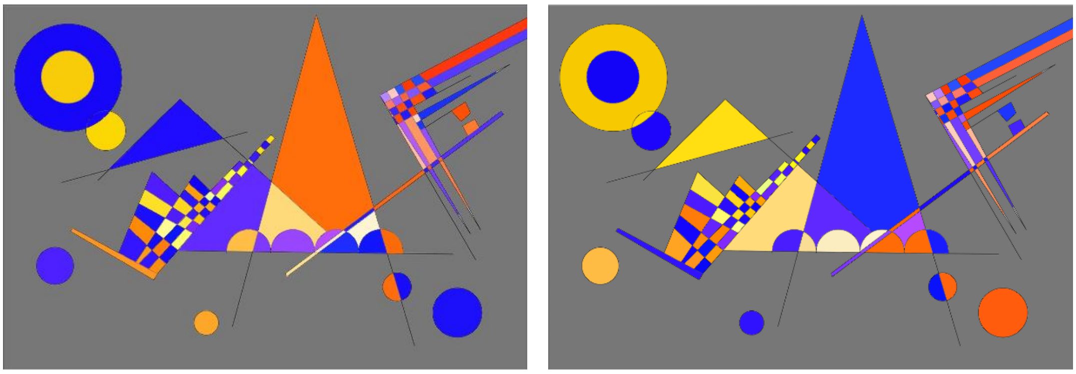


Figure 52. Abstract image: 5-6 (Left) and 6-5 (Right)

Both abstract images “5-6” and “6-5” have the same ΔE values and same tetradic color scheme with blue, purplish blue, yellow and yellowish orange. Participants rated “5-6” as the most visually interesting and visually complex abstract image (See Figure 52). The reason why “5-6” was rated as the most visually interesting and visually complex abstract image could be the allocations of colors used, since the only difference between those two abstract images was colors’ places. In other words, the combinations of each color with other colors in abstract image might have an important effect. For instance, the presence and the amount of orange in the middle of the abstract image in “5-6” might effect the visual complexity and visual interest ratings. Thus, the allocations of colors might have an effect on visual complexity and visual interest in abstract images. Also the human visual system needs to be examined more in the context of visual complexity, visual interest and color since, visual system consists of separate and independent subdivisions; magnocellular and parvocellular geniculate subdivisions. The parvocellular system’s ability is to analyze objects’ shape, color, and surface properties in detail (Livingstone & Hubel, 1988). Thus, for further studies, parvocellular system should studied deeply in order to develop a more detailed theoretical framework (See Figure 50).

> "Every color is combined in a certain way with other colors. Such as words (which in a dictionary appear isolated) are combined with other words in order to make sentences and phrases with some sense and give origin to poetry, narrative, essay, etc., and also in the same way as sounds are combined according to the criteria and invention of a music composer to give origin to musical pieces, so colors are grouped in larger compositional units. And it is the context, the particular combination, the way in which colors are grouped together and related to one another, what gives a sense, a certain kind of signification or meaning, some utility to the whole composition and to each of the involved colors (Caivano, 2016, p. 275 in *Encyclopedia of color science and technology* edited by Luo, M. R.)."

In order to analyze the effect of color allocation on visual complexity and visual interest, further examinations should be done by using eye tracking devices for understanding the perceptual organizations (Hogeboom & van Leeuwen, 1997) made during the evaluation of colors of abstract images. Also, during exploring the perceptual organizations of participants, predictability and being able to control things should be taken into consideration. Evolutionary research mostly indicated that humans prefer moderately complex coherent environments like a grasslands with scattered trees (Heerwagen & Orians, 1993; Orians, 1980). They tended to prefer the environments which are both interesting and complex but also coherent and intelligible at the same time that gave them the opportunity of involvement that made sense and grasped easily. Besides, they preferred uncertain environments since those environments awoke their interest. In other words, humans want a mixture of coherence and legibility in order to understand and interpret easily, but they seek some level of complexity for obscurity and mystery (Forsythe et. al., 2011).

The study aimed to develop a theoretical framework for understanding human vision and cognition system in terms of the association between color, visual complexity and visual interest by exploring the role of color with a quantitative value (Delta E). The other novelty of this study was colors evaluated as a whole instead of isolated color patches. As a conclusion, the outcomes of this study gathered by combining quantitative color measurements with self- report questionnaires.

CHAPTER 7

CONCLUSION

Complexity is usually associated with disorder and called as the edge of chaos although it is the equilibrator among chaos and ultimate simplicity so it is the transition space between order and disorder. However, this explanation is not enough to understand totally the concept of complexity. There are various definitions of complexity coming from different disciplines including art, design and architecture and in all, complexity is interpreted as the state of having countless parts which cause difficulty in understanding and interpreting it. The concept of complexity is defined by its opposition to simplicity, however it is the amount of detail or intricacy in a composition for instance, a simple composition (with lower amount of detail) has minimum level of complexity and a complex composition (with higher amount of detail) has maximum level of complexity. Thus, with optimum level of complexity i.e. with enough detail, visual interest can be created.

This study was conducted to find the level of visual complexity which makes an image visually interesting and the role of color within this phenomenon. There are several points which differentiate this study from the previous visual complexity studies and their methodologies. The first part of this study aimed to find out which of the visual complexity dimensions regarding color were effective in abstract images and the second part aimed to understand the role of color on visual complexity and visual interest ratings in abstract images. In contrast to previous studies, the first part of this current study focused only on the visual complexity dimensions about color. Most the previous studies did not even consider color, and the ones who had explored color as a dimension of visual complexity could not succeed. Another strength of this study is, it explored color without using color patches. In other words, this study examined the role of color on visual complexity and visual interest in abstract compositions without isolating them from each other like the previous studies. Thus, there was a chance to detect and predict the reasons behind the effect of color on visual complexity and visual interest in abstract images. For instance, color allocation might have an effect on visual complexity and visual interest ratings of participants. Also, for analyzing the number of colors used in abstract images, an image processing algorithm K-Means Color Clustering and Delta E was used which objectively exposed the quantity of colors. Using both objective and quantitative methods together aids to develop a theoretical measure about the association between color, visual complexity and visual interest which makes this study novel and pioneer.

The role of color in determining visual complexity in abstract images were tested with the following hypothesis; as the average Delta E value of colors in an abstract image increases, visual complexity and visual interest will increase until a threshold where perception of visual complexity start to decrease. This hypothesis was supported since the abstract composition rated as the most visually complex and interesting was “5-6” had a Delta E value of 56.9 which was a moderate level (Delta

E values ranges from 0 to 100, 100 is the biggest value) (See Figure 53). Also according to the results of this study, having tints and shades of blue, purplish blue, yellow and yellowish orange composed in an abstract image, makes the abstract image rated as the most visually complex and visually interesting. By using tetradic color schemes, an artwork can be made visually interesting and complex. As well as, an interesting interior space can be designed by using various tetradic color scheme variations.

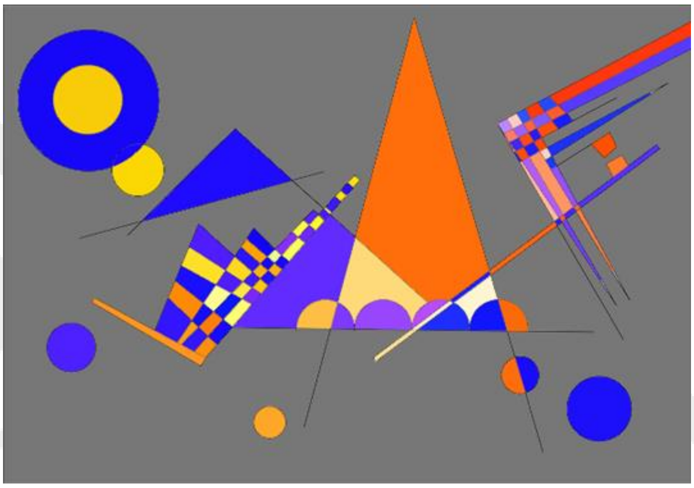


Figure 53. Abstract image: 5-6

For future studies, different color scheme variations can be used for strengthening the impact of the novel findings. Also, sample size can be increased. Moreover, for the first part of the study, types, sizes and number of artworks can be enriched. The number of generated abstract images can also be increased with various color combinations in future studies. Besides sample size and abstract image variations, eye tracking devices can be used for understanding the perceptual organizations of participants during their visual complexity and visual interest evaluations. Additionally, a software that can calculates the visual complexity and visual interest in terms of color by using K- Means Color Clustering and Delta E equation from an image, can be develop. This software can be integrated in smart phones, so artists, architects and interior architects can use it while creating and designing.

To conclude, this study contributes to the literature in terms of its novel methodology and its important results which can be used in building new theories and in real life applications. With the results of this study, a quantitative and an objective knowledge about the association between color and visual complexity was obtained. This study can be used as a guidance for who wants to generate visually complex and interesting images with colors. The outcomes of this study can be useful in both art, design and architecture. With the guidance of this study artists, designers and architects can knowingly create built environments that have ideal level of visual complexity and visual interest. New implications can be done in built environments by only being aware of the strength of color. Also, colorimetry, cognitive neuroscience, physiological optics and image science fields can benefit from the results and the novel methodology of the current study.

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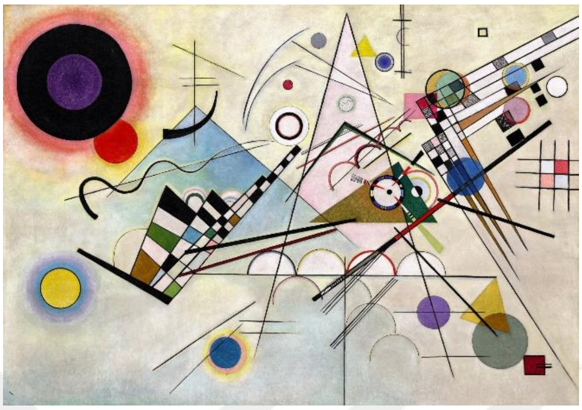
APPENDICES

Appendix A- Questionnaire of Part I



6. Rate the difficulty in differentiating each color in this composition.

1 2 3 4 5

Low difficulty — High difficulty

7. Rate the difficulty in distinguishing the rules in terms of usage of colors in this composition.

1 2 3 4 5

Low difficulty — High difficulty

8. Rate the difficulty in distinguishing the variety of colors (hue, value, chroma) in this composition.

1 2 3 4 5

Low difficulty — High difficulty

9. Rate this composition in terms of visual interest.

1 2 3 4 5

Low visual interest — High visual interest

10. Rate this composition in terms of visual complexity.

1 2 3 4 5

Low visual complexity — High visual complexity

1. Rate the difficulty in differentiating each color in this composition.

1 2 3 4 5

Low difficulty — High difficulty

2. Rate the difficulty in distinguishing the rules in terms of usage of colors in this composition.

1 2 3 4 5

Low difficulty — High difficulty

3. Rate the difficulty in distinguishing the variety of colors (hue, value, chroma) in this composition.

1 2 3 4 5

Low difficulty — High difficulty

4. Rate this composition in terms of visual interest.

1 2 3 4 5

Low visual interest — High visual interest

5. Rate this composition in terms of visual complexity.

1 2 3 4 5

Low visual complexity — High visual complexity

1. Rate the difficulty in differentiating each color in this composition.

1 2 3 4 5

Low difficulty — High difficulty

2. Rate the difficulty in distinguishing the rules in terms of usage of colors in this composition.

1 2 3 4 5

Low difficulty — High difficulty

3. Rate the difficulty in distinguishing the variety of colors (hue, value, chroma) in this composition.

1 2 3 4 5

Low difficulty — High difficulty

4. Rate this composition in terms of visual interest.

1 2 3 4 5

Low visual interest — High visual interest

5. Rate this composition in terms of visual complexity.

1 2 3 4 5

Low visual complexity — High visual complexity

1. Rate the difficulty in differentiating each color in this composition.

1 2 3 4 5

Low difficulty — High difficulty

2. Rate the difficulty in distinguishing the rules in terms of usage of colors in this composition.

1 2 3 4 5

Low difficulty — High difficulty

3. Rate the difficulty in distinguishing the variety of colors (hue, value, chroma) in this composition.

1 2 3 4 5

Low difficulty — High difficulty

4. Rate this composition in terms of visual interest.

1 2 3 4 5

Low visual interest — High visual interest

5. Rate this composition in terms of visual complexity.

1 2 3 4 5

Low visual complexity — High visual complexity

Appendix B- Color codes of the Abstract Paintings

B1- Composition 8

Number	Color	Color Code (HEX)	Percentage
1		#d8d8c0	0.142885
2		#c0c0c0	0.077179
3		#f0d8c0	0.065513
4		#d8c0c0	0.051538
5		#d8d8d8	0.049103
6		#f0f0d8	0.042500
7		#f0d8d8	0.039167
8		#c0c0a8	0.034487
9		#f0f0c0	0.026731
10		#d8c0a8	0.026090
11		#000000	0.022115
12		#f0f0f0	0.018782
13		#a8a8a8	0.017308
14		#a8a890	0.015897
15		#909090	0.014231
16		#d8d8a8	0.013718
17		#c0d8c0	0.012949
18		#181818	0.012308
19		#787878	0.011026
20		#a8c0c0	0.010449
21		#000018	0.009679
22		#c0a8a8	0.009231
23		#c0d8d8	0.009038
24		#a89090	0.008654
25		#f0d8a8	0.008462
26		#909078	0.008141
27		#787860	0.007436
28		#a8c0a8	0.007051
29		#303030	0.005962
30		#d87878	0.005897
31		#606060	0.005064
32		#484848	0.004615
33		#481860	0.004551
34		#78a8c0	0.004551
35		#90a8c0	0.004359
36		#907878	0.003846
37		#d87860	0.003782
38		#c00000	0.003718
39		#d89078	0.003462
40		#d8a890	0.003269

41		#d8c090	0.003205
42		#c0a890	0.002949
43		#f0c0a8	0.002949
44		#90a8a8	0.002885
45		#483060	0.002821
46		#606048	0.002756
47		#786060	0.002756
48		#c0c090	0.002692
49		#a8a8c0	0.002564
50		#483030	0.002500
51		#a89078	0.002500
52		#784800	0.002372
53		#d8c030	0.002308
54		#a8c0d8	0.002308
55		#d8c018	0.002179
56		#301848	0.002051
57		#c0c0d8	0.001987
58		#c0a830	0.001923
59		#d8d890	0.001859
60		#9090a8	0.001859
61		#6090a8	0.001859
62		#7890c0	0.001795
63		#906030	0.001795
64		#786030	0.001795
65		#d8a878	0.001731
66		#607860	0.001603
67		#f0d8f0	0.001538
68		#907860	0.001538
69		#184878	0.001538
70		#184830	0.001538
71		#7890a8	0.001538
72		#786018	0.001474
73		#90a890	0.001474
74		#180018	0.001474
75		#d89090	0.001410
76		#f0d878	0.001410
77		#f09078	0.001410
78		#d86060	0.001410
79		#907848	0.001410
80		#f0a890	0.001346
81		#604848	0.001346
82		#784848	0.001346
83		#486018	0.001282
84		#c09090	0.001282
85		#f0d890	0.001282
86		#603030	0.001218

87		#f0c090	0.001218
88		#301818	0.001218
89		#183060	0.001154
90		#a890a8	0.001154
91		#90c0c0	0.001090
92		#906060	0.001090
93		#c06060	0.001090
94		#c090a8	0.001090
95		#f09090	0.001026
96		#786048	0.001026
97		#907830	0.001026
98		#784818	0.001026
99		#789078	0.001026
100		#c07878	0.001026
101		#789090	0.001026
102		#a8a878	0.001026
103		#d8c048	0.001026

B2- Composition No. VII

Number	Color	Color Code (HEX)	Percentage
1		#a8a8a8	0.066813
2		#c0c0a8	0.066764
3		#c0c0c0	0.061119
4		#d8d8d8	0.039805
5		#c0a8a8	0.038686
6		#909090	0.037080
7		#d8c0a8	0.036107
8		#d8d8c0	0.033820
9		#d8c0c0	0.033090
10		#c0a890	0.031095
11		#a8a890	0.029878
12		#787878	0.029830
13		#606060	0.028710
14		#d8c090	0.023552
15		#484848	0.022190
16		#a89090	0.017372
17		#d8c078	0.017372
18		#a89078	0.017275
19		#c0a878	0.016934
20		#909078	0.016204
21		#303030	0.014404
22		#a89060	0.013382
23		#c0a860	0.012701
24		#787860	0.012652

25		#907860	0.012652
26		#d8c060	0.011387
27		#9090a8	0.010073
28		#c0a848	0.009586
29		#606048	0.009197
30		#d8d8a8	0.008954
31		#c0c090	0.008710
32		#a8a8c0	0.008564
33		#907878	0.008029
34		#786060	0.007981
35		#786048	0.007543
36		#907848	0.007445
37		#606078	0.007299
38		#484830	0.006667
39		#d8a848	0.006569
40		#787890	0.006229
41		#604848	0.005596
42		#a8a878	0.005547
43		#f0d8d8	0.005450
44		#a89048	0.005401
45		#c0c0d8	0.005255
46		#d8c048	0.005158
47		#484860	0.004866
48		#f0d890	0.004720
49		#909060	0.004428
50		#a89030	0.004185
51		#d8a830	0.003942
52		#907830	0.003747
53		#f0d8a8	0.003698
54		#f0d878	0.003698
55		#787848	0.003650
56		#604830	0.003504
57		#f0d8c0	0.003212
58		#786030	0.003017
59		#d8a860	0.002920
60		#303048	0.002920
61		#d8d890	0.002579
62		#c09030	0.002530
63		#c0a830	0.002287
64		#a87830	0.002238
65		#f0c060	0.002190
66		#483030	0.002092
67		#a890a8	0.001849
68		#c0a8c0	0.001849
69		#c0c078	0.001800
70		#907890	0.001752

71		#d8a818	0.001703
72		#f0c048	0.001655
73		#f0d860	0.001655
74		#606030	0.001606
75		#c09048	0.001460
76		#90a8a8	0.001460
77		#d8c0d8	0.001265
78		#a8a860	0.001217
79		#181830	0.001217
80		#d8c030	0.001168
81		#f0f0d8	0.001168
82		#c09018	0.001168
83		#c09060	0.001119
84		#181818	0.001022
85		#604860	0.001022

B3- Decisive Rose

Number	Color	Color Code (HEX)	Percentage
1		#d8c090	0.194230
2		#c0c090	0.120280
3		#c0c078	0.118599
4		#d8c078	0.069916
5		#c0a860	0.057479
6		#d8d890	0.054062
7		#d89090	0.037591
8		#c0c060	0.036246
9		#181818	0.034118
10		#c0c048	0.032605
11		#d8d8a8	0.022241
12		#c0a878	0.019216
13		#303030	0.014174
14		#c0a848	0.012101
15		#a8a860	0.010420
16		#a8a878	0.008515
17		#909048	0.008067
18		#606060	0.007899
19		#484848	0.007675
20		#a8a848	0.007283
21		#484830	0.007059
22		#907848	0.006106
23		#a89048	0.006050
24		#d8c060	0.005770
25		#d89078	0.005434
26		#606030	0.005378

27		#787848	0.005042
28		#d8c048	0.004426
29		#d8d878	0.004090
30		#a89060	0.003866
31		#d8c0a8	0.003754
32		#606048	0.003585
33		#c0c0a8	0.003361
34		#303018	0.003361
35		#787830	0.003137
36		#787860	0.003081
37		#c0a890	0.002969
38		#d87878	0.002913
39		#909090	0.002913
40		#604848	0.002857
41		#909078	0.002689
42		#484860	0.002129
43		#909060	0.002017
44		#a8a890	0.001905
45		#787878	0.001905
46		#c09078	0.001513
47		#a89090	0.001513
48		#604830	0.001513
49		#486060	0.001457
50		#c0a8a8	0.001289
51		#78a8a8	0.001176
52		#483030	0.001064

B4- Ocean 5

Number	Color	Color Code (HEX)	Percentage
1		#a87848	0.189602
2		#a87830	0.172110
3		#907830	0.085872
4		#c09048	0.068135
5		#906030	0.067156
6		#786030	0.064159
7		#604830	0.046850
8		#a89060	0.044832
9		#a89048	0.039572
10		#907848	0.030398
11		#c09060	0.026055
12		#c0a878	0.017982
13		#c07830	0.017798
14		#c0a890	0.017370
15		#786048	0.012110
16		#c09030	0.009541

17		#c09078	0.009480
18		#484830	0.009480
19		#a89078	0.009480
20		#483030	0.007829
21		#c07848	0.006911
22		#907860	0.006667
23		#c0c0a8	0.005872
24		#784830	0.003853
25		#906048	0.002936
26		#a87860	0.002813
27		#606030	0.002691
28		#606048	0.001957
29		#483018	0.001896
30		#c0a8a8	0.001835
31		#787860	0.001651
32		#604818	0.001590
33		#a8a890	0.001529
34		#787848	0.001529
35		#303018	0.001407
36		#604848	0.001346
37		#a8a878	0.001101

Appendix C- Data Analyses of Part I

ANOVA Q1 (Unintelligibility)

Descriptives

Q1

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Composition8	30	1.80	1.064	.194	1.40	2.20	1	5
DecisiveRose	30	2.43	.971	.177	2.07	2.80	1	5
Ocean5	30	2.67	1.093	.200	2.26	3.07	1	5
CompositionNoVII	30	2.33	.802	.146	2.03	2.63	1	4
Total	120	2.31	1.027	.094	2.12	2.49	1	5

ANOVA

Q1

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	12.092	3	4.031	4.119	.008
Within Groups	113.500	116	.978		
Total	125.592	119			

ANOVA Q2 (Unintelligibility)

Descriptives

Q2

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Composition8	30	3.57	1.135	.207	3.14	3.99	1	5
DecisiveRose	30	3.30	1.119	.204	2.88	3.72	1	5
Ocean5	30	2.77	1.165	.213	2.33	3.20	1	5
CompositionNoVII	30	3.20	1.157	.211	2.77	3.63	1	5
Total	120	3.21	1.166	.106	3.00	3.42	1	5

ANOVA

Q2

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9.958	3	3.319	2.536	.060
Within Groups	151.833	116	1.309		
Total	161.792	119			

ANOVA Q3 (Unintelligibility)

Descriptives

Q3

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Composition8	30	2.03	1.033	.189	1.65	2.42	1	5
DecisiveRose	30	2.40	1.133	.207	1.98	2.82	1	5
Ocean5	30	2.50	1.042	.190	2.11	2.89	1	4
CompositionNoVII	30	2.33	.959	.175	1.98	2.69	1	4
Total	120	2.32	1.045	.095	2.13	2.51	1	5

ANOVA

Q3

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.633	3	1.211	1.112	.347
Within Groups	126.333	116	1.089		
Total	129.967	119			

Q4 (Visual Interest)

Descriptives

Q4

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Composition8	30	4.00	.947	.173	3.65	4.35	2	5
DecisiveRose	30	3.37	1.402	.256	2.84	3.89	1	5
Ocean5	30	2.83	1.341	.245	2.33	3.33	1	5
CompositionNoVII	30	3.33	1.155	.211	2.90	3.76	1	5
Total	120	3.38	1.278	.117	3.15	3.61	1	5

ANOVA

Q4

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	20.567	3	6.856	4.576	.005
Within Groups	173.800	116	1.498		
Total	194.367	119			

Q5 (Visual Complexity)

Descriptives

Q5

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Composition8	30	3.87	1.042	.190	3.48	4.26	2	5
DecisiveRose	30	3.70	1.022	.187	3.32	4.08	2	5
Ocean5	30	2.87	.973	.178	2.50	3.23	1	4
CompositionNoVII	30	3.20	1.064	.194	2.80	3.60	1	5
Total	120	3.41	1.088	.099	3.21	3.61	1	5

ANOVA

Q5

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	18.958	3	6.319	6.007	.001
Within Groups	122.033	116	1.052		
Total	140.992	119			

Composition8

Pearson Correlations

		Q1	Q2	Q3	Q4	Q5
Q1	Pearson's r	—	0.240	0.697	-0.377	0.286
	p-value	—	0.202	< .001	0.040	0.125
Q2	Pearson's r		—	0.366	-0.289	0.533
	p-value		—	0.047	0.122	0.002
Q3	Pearson's r			—	-0.106	0.389
	p-value			—	0.578	0.034
Q4	Pearson's r				—	0.035
	p-value				—	0.854
Q5	Pearson's r					—
	p-value					—

Decisive Rose

Pearson Correlations

		Q1	Q2	Q3	Q4	Q5
Q1	Pearson's r	—	0.416	0.715	0.082	0.552
	p-value	—	0.022	< .001	0.667	0.002
Q2	Pearson's r		—	0.147	-0.007	0.534
	p-value		—	0.438	0.972	0.002
Q3	Pearson's r			—	0.339	0.167
	p-value			—	0.067	0.378
Q4	Pearson's r				—	0.007
	p-value				—	0.970
Q5	Pearson's r					—
	p-value					—

Ocean5

Pearson Correlations

		Q1	Q2	Q3	Q4	Q5
Q1	Pearson's r	—	0.180	0.333	-0.392	0.151
	p-value	—	0.340	0.072	0.032	0.425
Q2	Pearson's r		—	0.298	0.217	0.154
	p-value		—	0.110	0.249	0.416
Q3	Pearson's r			—	-0.259	0.034
	p-value			—	0.167	0.858
Q4	Pearson's r				—	0.035
	p-value				—	0.853
Q5	Pearson's r					—
	p-value					—

Compostition No.VII

Pearson Correlations

		Q1	Q2	Q3	Q4	Q5
Q1	Pearson's r	—	0.186	0.523	-0.087	0.323
	p-value	—	0.326	0.003	0.648	0.081
Q2	Pearson's r		—	0.062	-0.155	-0.006
	p-value		—	0.744	0.414	0.977
Q3	Pearson's r			—	0.208	0.507
	p-value			—	0.271	0.004
Q4	Pearson's r				—	-0.168
	p-value				—	0.373
Q5	Pearson's r					—
	p-value					—

Appendix D- Ethics Committee Approval

Bilkent Üniversitesi
Akademik İşler Rektör Yardımcılığı

Tarih	: 29 Ocak 2019
Gönderilen	: Rengin Kocaoğlu
Tez Danışmanı	: Nilgün Olguntürk
Gönderen	: Fatma Taşkın İnsan Araştırmaları Etik Kurulu Başkanı
Konu	: *"The Role of ..."* çalışması etik kurul onayı

Üniversitemiz İnsan Araştırmaları Etik Kurulu, 29 Ocak 2019 tarihli görüşme sonucu, *"The Role of Color in Determining Visual Complexity in Abstract Images"* isimli çalışmanız kapsamında yapmayı önerdiğiniz etkinlik için etik onay vermiş bulunmaktadır. Onay, ekte verilmiş olan çalışma önerisi, çalışma yürütücüleri, ve bilgilendirme formu için geçerlidir.

Bu onay, yapmayı önerdiğiniz çalışmanın genel bilim etiği açısından bir değerlendirmesine karşı gelmektedir. Çalışmanızda, kurulumuzun değerlendirmesi dışında kalabilen özel etik ve yasal sınırlamalara uymakla ayrıca yükümlüsünüz.

Etik Kurul Üyeleri:

Ünvan / İsim	**Bölüm / Uzmanlık**	**İmza**
1. Doç.Dr. Fatma Taşkın	İktisat	
2. Prof.Dr. Erdal Onar	Hukuk	
3. Prof.Dr. Haldun Özaktaş	Elektrik ve Elektronik Müh.	
4. Doç.Dr. Işık Yuluğ	Moleküler Biyoloji ve Genetik	
5. Yrd.Doç.Dr. Gül Günaydın	Psikoloji	
Yd.1.Doç.Dr. Çiğdem Gündüz Demir	Bilgisayar Mühendisliği	(yedek üye)
Yd.2. Yrd.Doç.Dr. A. Barış Özbilen	Hukuk	(yedek üye)

Kurul karar/toplantı No: 2019_01_29_03

Bilkent Üniversitesi, 06800 Bilkent, Ankara • Telefon: (312) 290 12 13 • (312) 290 12 14 • Faks: (312) 266 41 52

Appendix E- Questionnaire of Part II

Bilgilendirme Formu:

Bu çalışma, Bilkent Üniversitesi İç Mimarlık ve Çevre Tasarımı bölümü öğretim üyelerinden Doç. Dr. Nilgün Olguntürk ve Doktora öğrencisi Rengin Kocaoğlu Aslanoğlu tarafından yürütülmektedir. Deney öncesinde, sırasında ve sonrasında istediğiniz zaman sorularınızı araştırmacı Rengin Kocaoğlu Aslanoğlu'na yöneltebilirsiniz, herhangi bir sorun ya da sorunuz olma durumunda Rengin Kocaoğlu Aslanoğlu'na (rengin.kocaoglu@bilkent.edu.tr) ya da Doç. Dr. Nilgün Olguntürk'e (onilgun@bilkent.edu.tr) e-mail adreslerinden ulaşabilirsiniz.

Çalışmaya gönüllü olarak katılmanız durumunda, anket boyunca paylaştığınız hiçbir kişisel veri (ad, soyadı, e-mail adresi, vb.) sizin yazılı izniniz olmaksızın paylaşılmayacaktır. Anketlerden elde edilen veriler akademik amaçlarla kullanılacak ve araştırmacılar ve üniversitelerindeki konuyla ilgili diğer profesyoneller dışında kimse ile paylaşılmayacaktır. Çalışmada size göstertilen görselleri size verilen anket üzerinden değerlendirmeniz istenecektir ve çalışmanın bilinen ve/veya tahmin edilen hiçbir yan etkisi yoktur. Çalışmanın herhangi bir aşamasında, çalışmaya katılımınızı sonlandırabilirsiniz. Çalışmaya katılmayı reddetmenizin veya katılmaktan vazgeçmenizin üniversiteyle olan ilişkilerinizi etkileyemeyeceğini belirtmek isteriz.

Katılmakta olduğunuz bu çalışma Bilkent Üniversitesi İç Mimarlık ve Çevre Tasarımı Bölümü doktora tez kapsamında yapılmaktadır, bu nedenle, deney sırasında sizin cevaplarınızdan elde edilen verilerin, anonim olarak (isimsiz bir şekilde) ilerleyen zamanlarda yazılı ve sözlü olarak yayınlanması öngörülmektedir.

Onam Formu:

Çalışmaya katılmak için 18 yaşından büyük olmanız gerekmektedir.

Yukarıda yazılan bilgilendirme yazısını okudum ve anladım. Bilgilendirmeyi okumak ve düşünmek için yeterli zamanım oldu ve sorduğum sorulara araştırmacılar tarafından tatmin edici cevaplar verildi. Bu çalışmaya gönüllü olarak katılıyorum ve çalışma sırasında toplanan verilerin, anonim olmak koşulu ile araştırmacılar tarafından kullanılmasına ve yayınlanmasına izin veriyorum.

Ad-Soyadı:

E-mail adresi:

Tarih:

İmza:

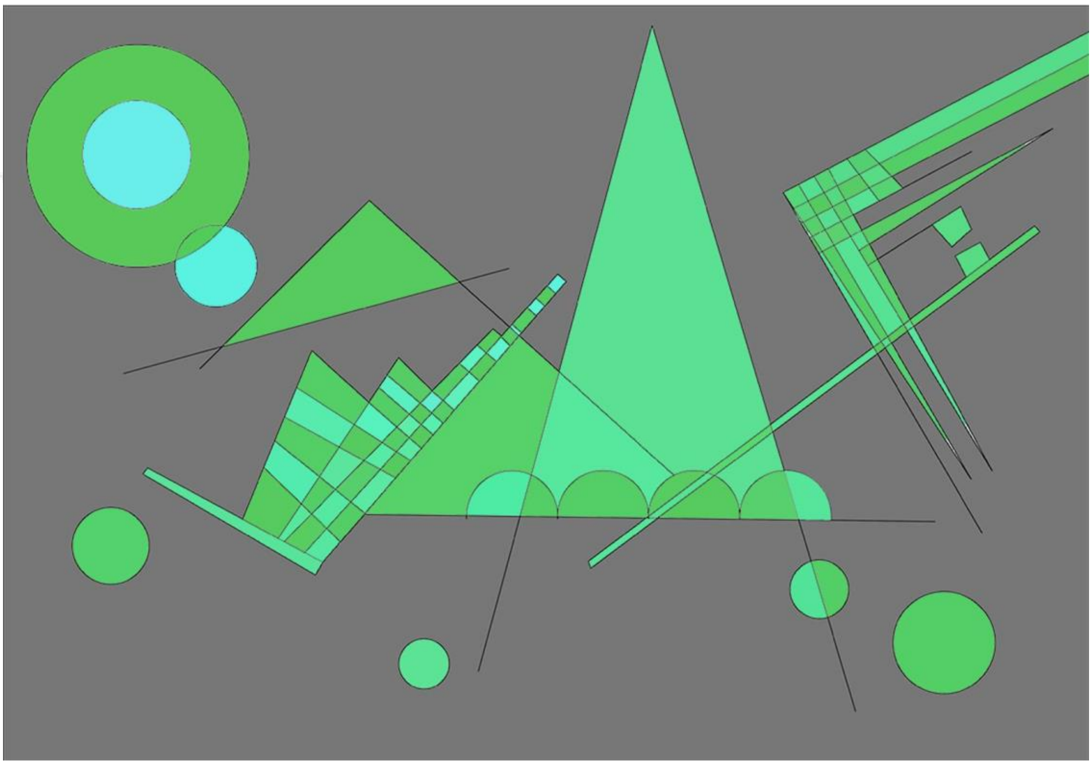
Çalışmaya katkılarınız için teşekkür ederiz.

Questionnaire link:
https://docs.google.com/forms/d/1KaYENtHtSUPBU7tLohPMRLTsRu8bM49_IzQbI4Y4GOU/edit

Abstract Images

* Required

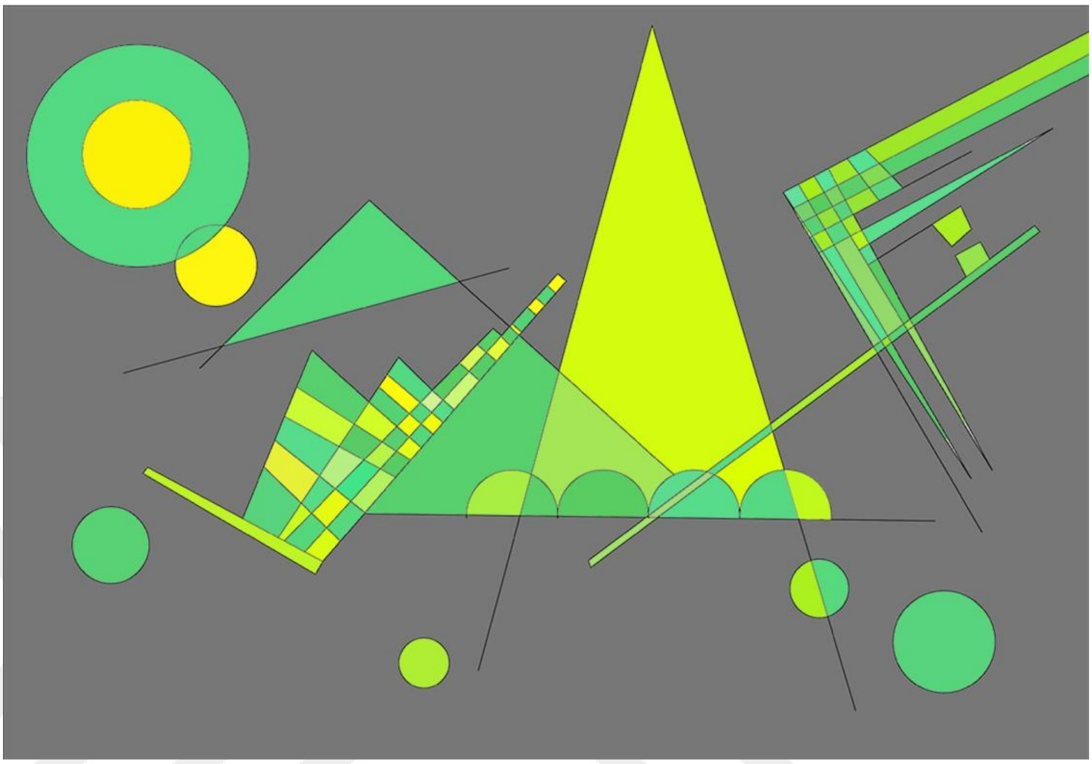
1. **Rate this image in terms of visual interest.** *



Mark only one oval.

	1	2	3	4	5	
Low visual interest						High visual interest

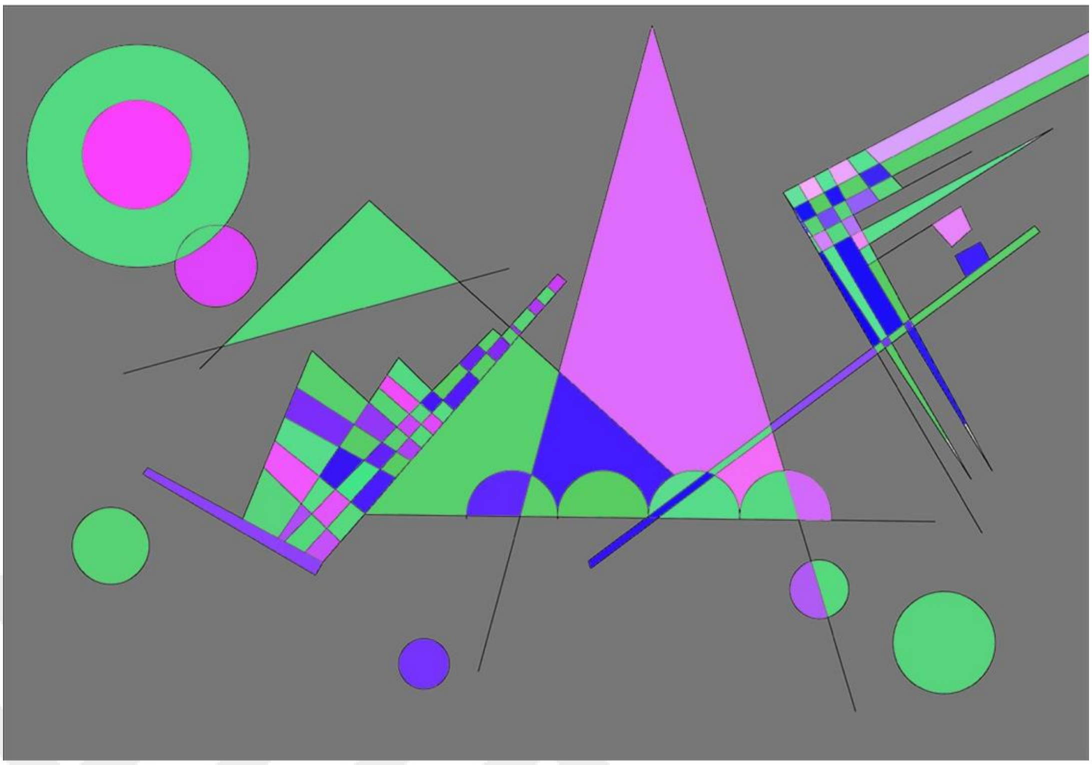
2. **Rate this image in terms of visual interest.** *



Mark only one oval.

	1	2	3	4	5	
Low visual interest	⬭	⬭	⬭	⬭	⬭	High visual interest

3. **Rate this image in terms of visual complexity.** *



Mark only one oval.

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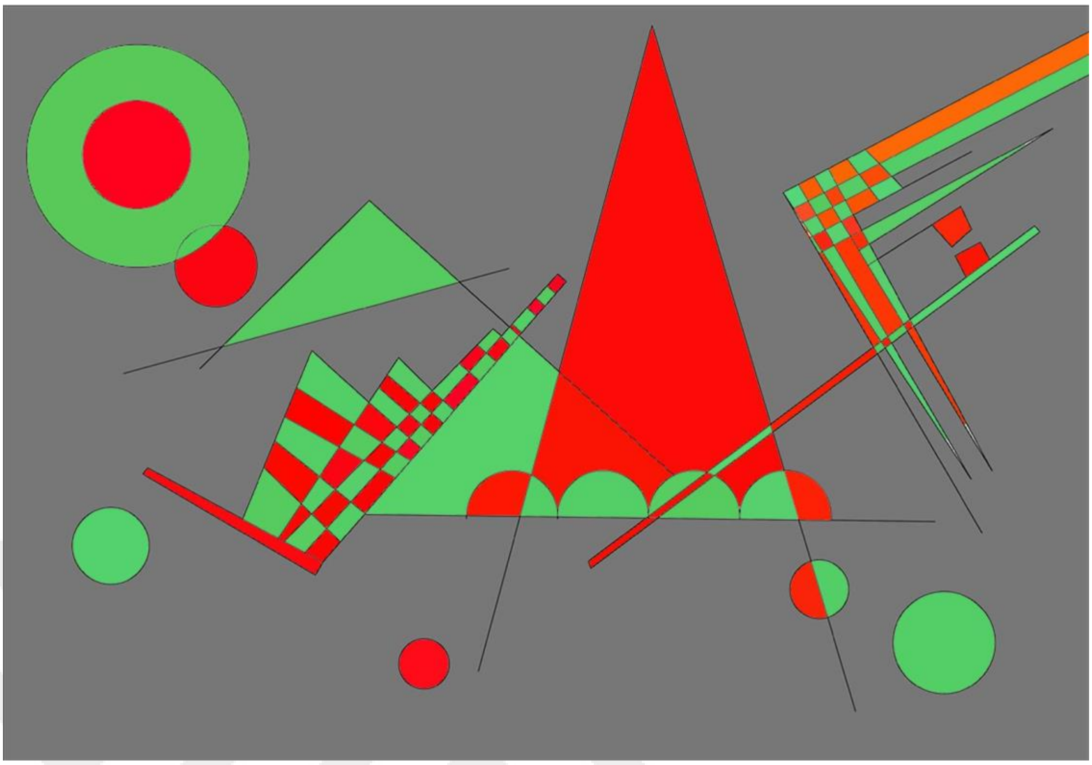
Low visual complexity	⬭	⬭	⬭	⬭	⬭	High visual complexity

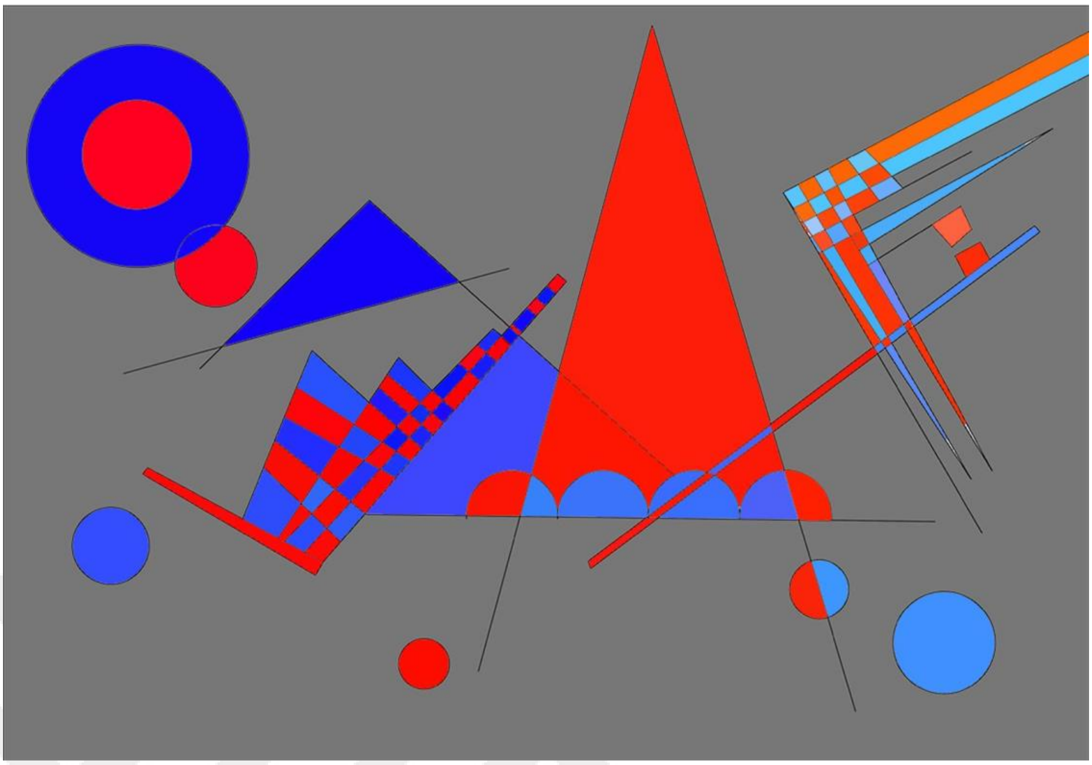
4. **Rate this image in terms of visual complexity. ***



Mark only one oval.

	1	2	3	4	5	
Low visual complexity	⬭	⬭	⬭	⬭	⬭	High visual complexity

5. **Rate this image in terms of visual interest.** *



Mark only one oval.

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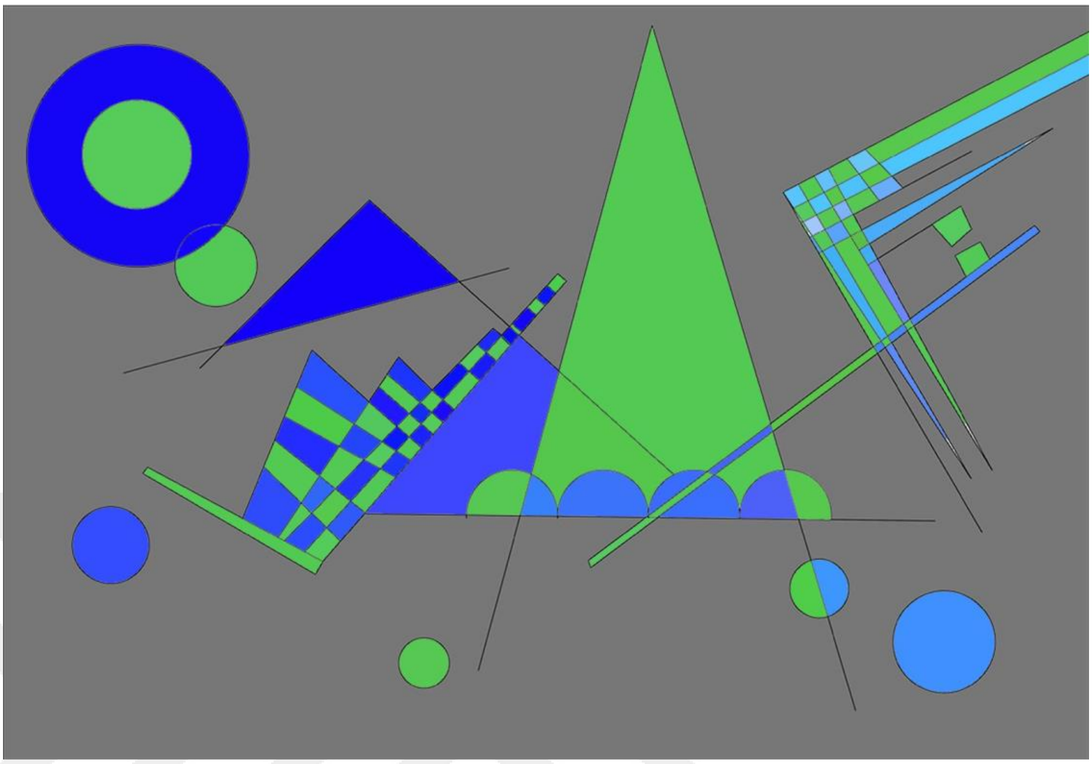
Low visual interest	⬭	⬭	⬭	⬭	⬭	High visual interest

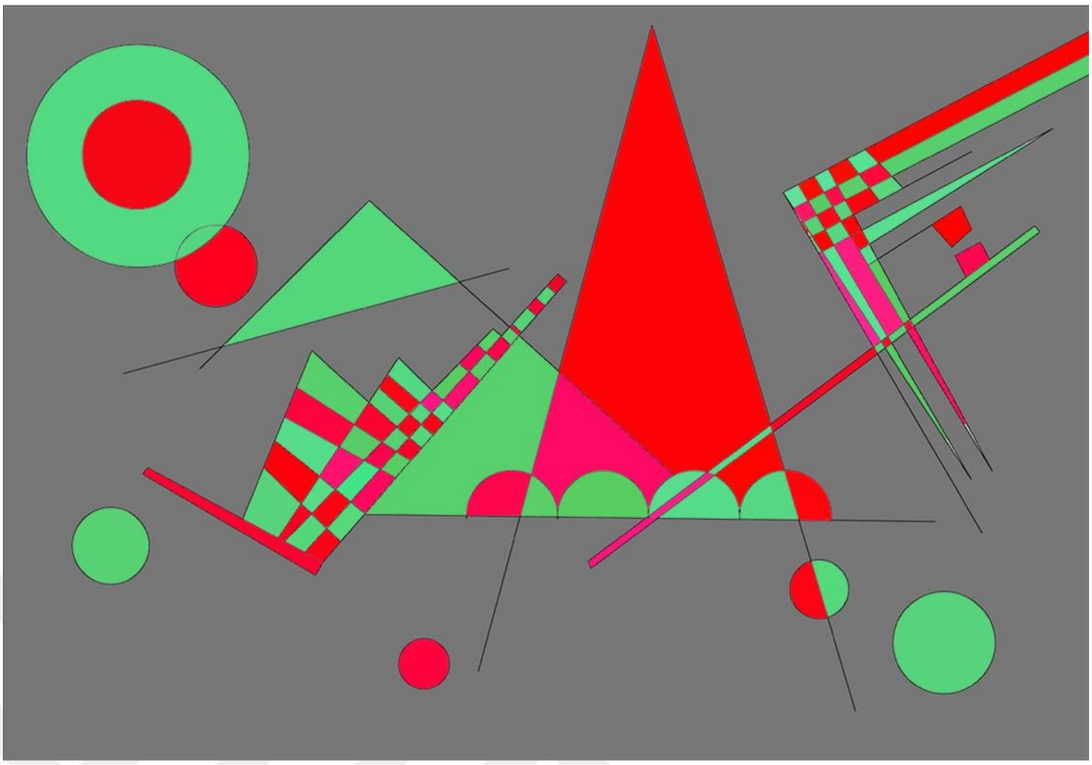
6. **Rate this image in terms of visual interest.** *



Mark only one oval.

	1	2	3	4	5	
Low visual interest	⬭	⬭	⬭	⬭	⬭	High visual interest

7. **Rate this image in terms of visual complexity.** *



Mark only one oval.

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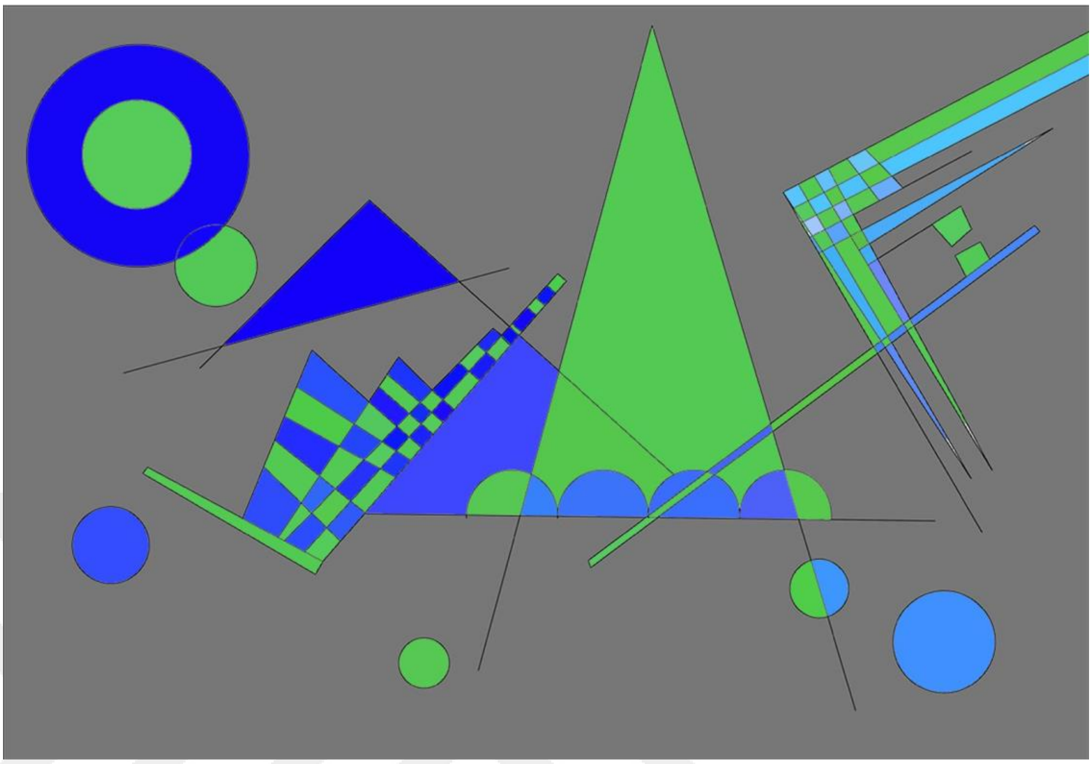
Low visual complexity	⬭	⬭	⬭	⬭	⬭	High visual complexity

8. **Rate this image in terms of visual interest.** *



Mark only one oval.

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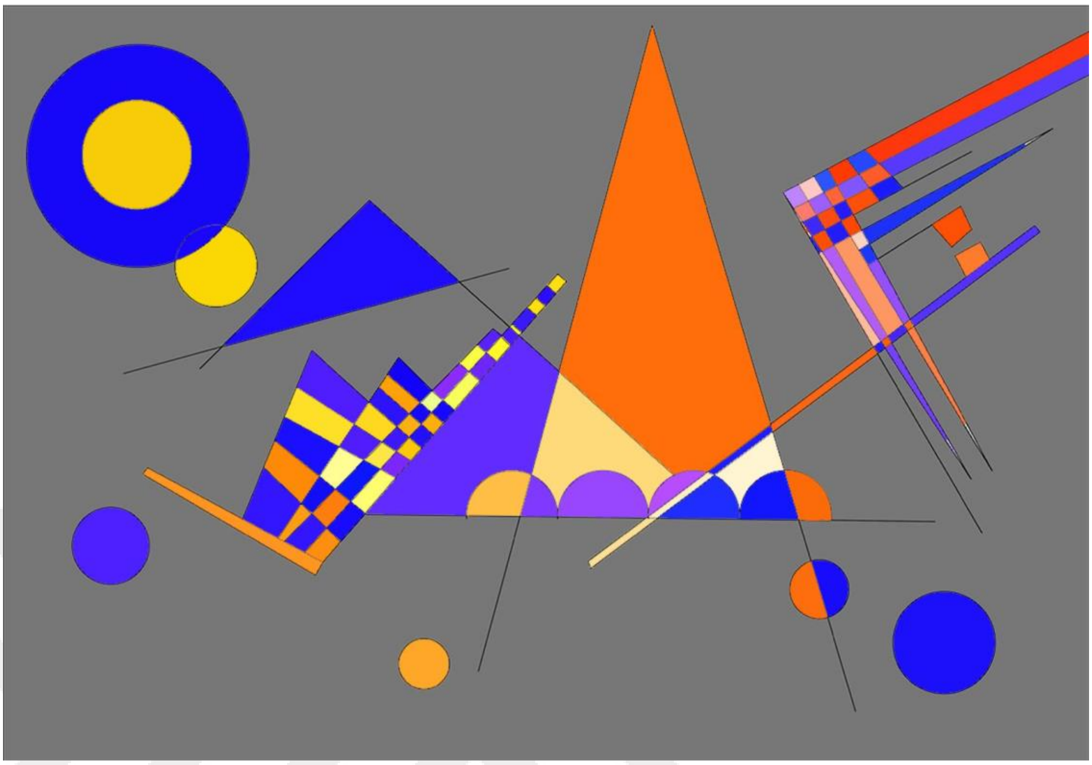
Low visual complexity	⬭	⬭	⬭	⬭	⬭	High visual complexity

9. **Rate this image in terms of visual interest.** *



Mark only one oval.

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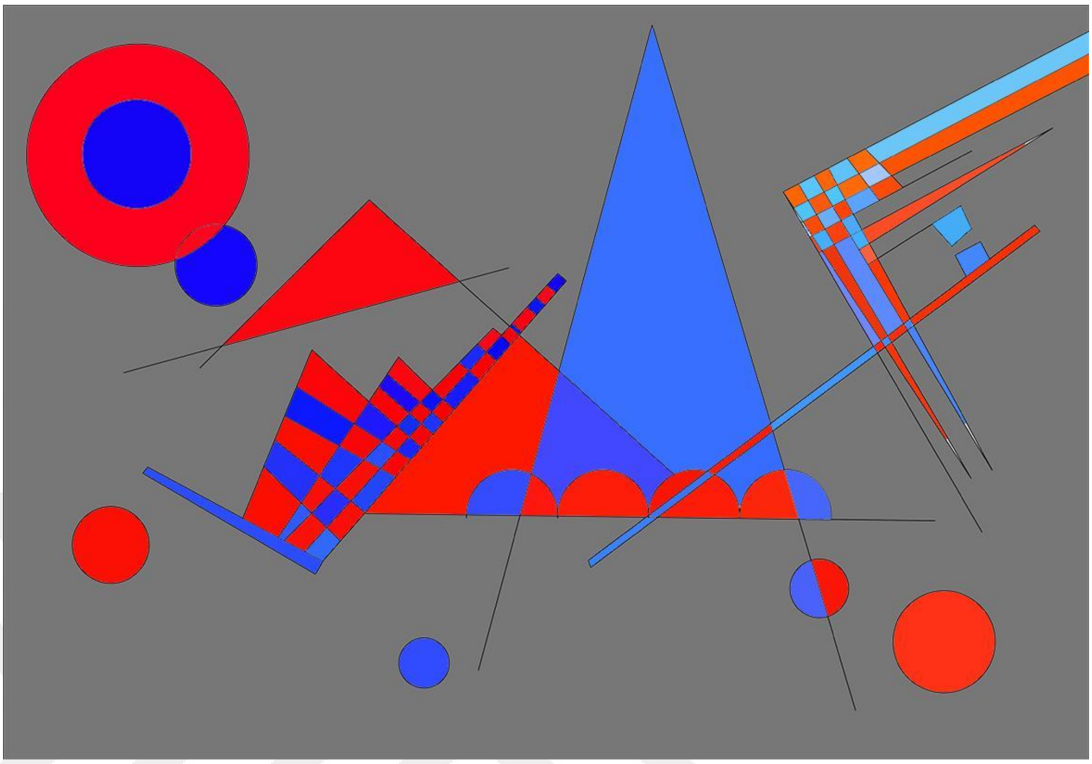
Low visual interest	⬭	⬭	⬭	⬭	⬭	High visual interest

10. **Rate this image in terms of visual complexity.** *



Mark only one oval.

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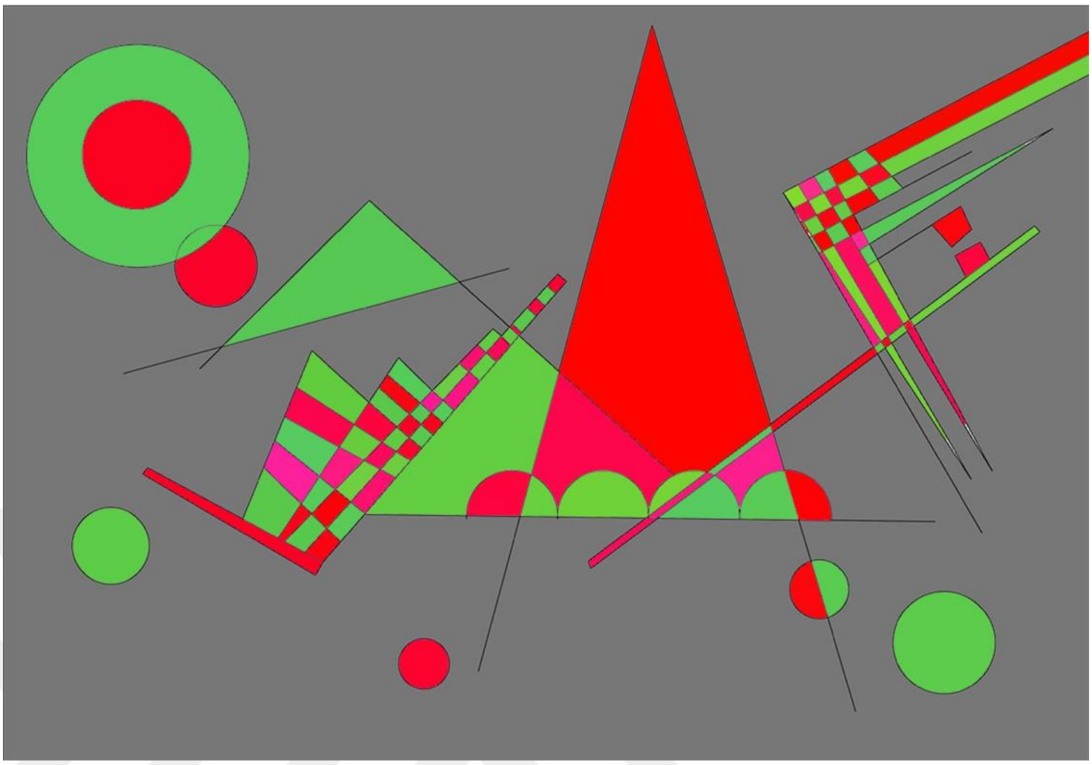
Low visual complexity	◯	◯	◯	◯	◯	High visual complexity

11. **Rate this image in terms of visual interest.** *



Mark only one oval.

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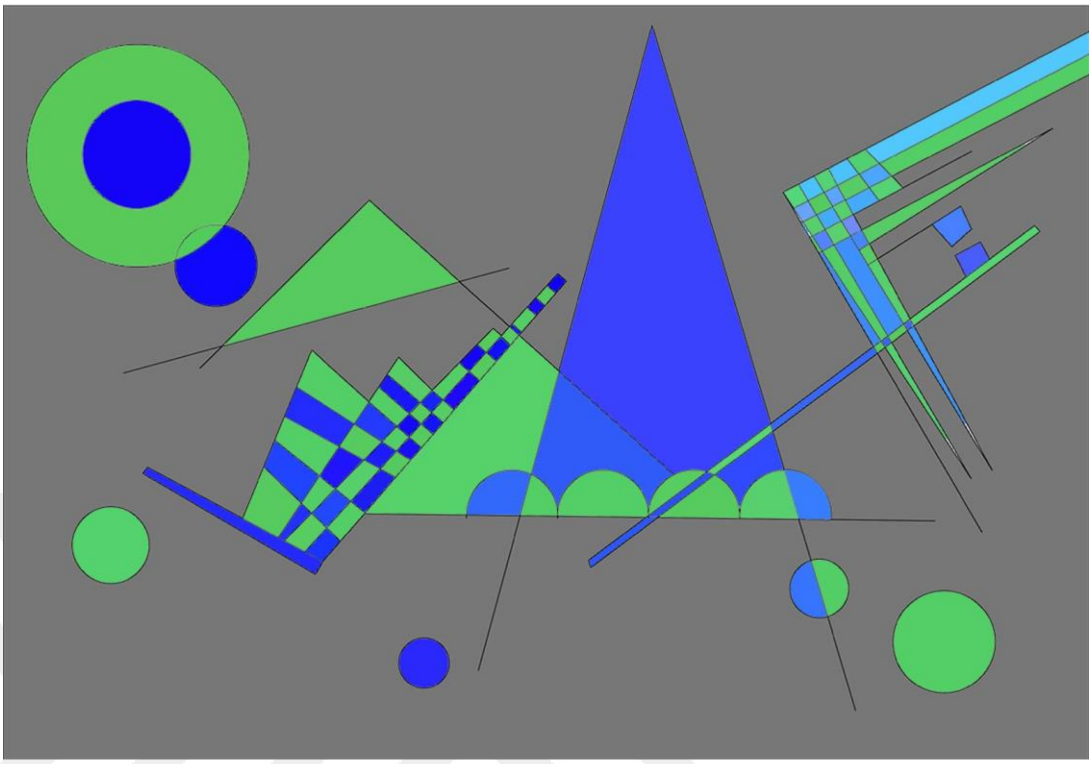
Low visual interest	⬭	⬭	⬭	⬭	⬭	High visual interest

12. **Rate this image in terms of visual complexity.** *



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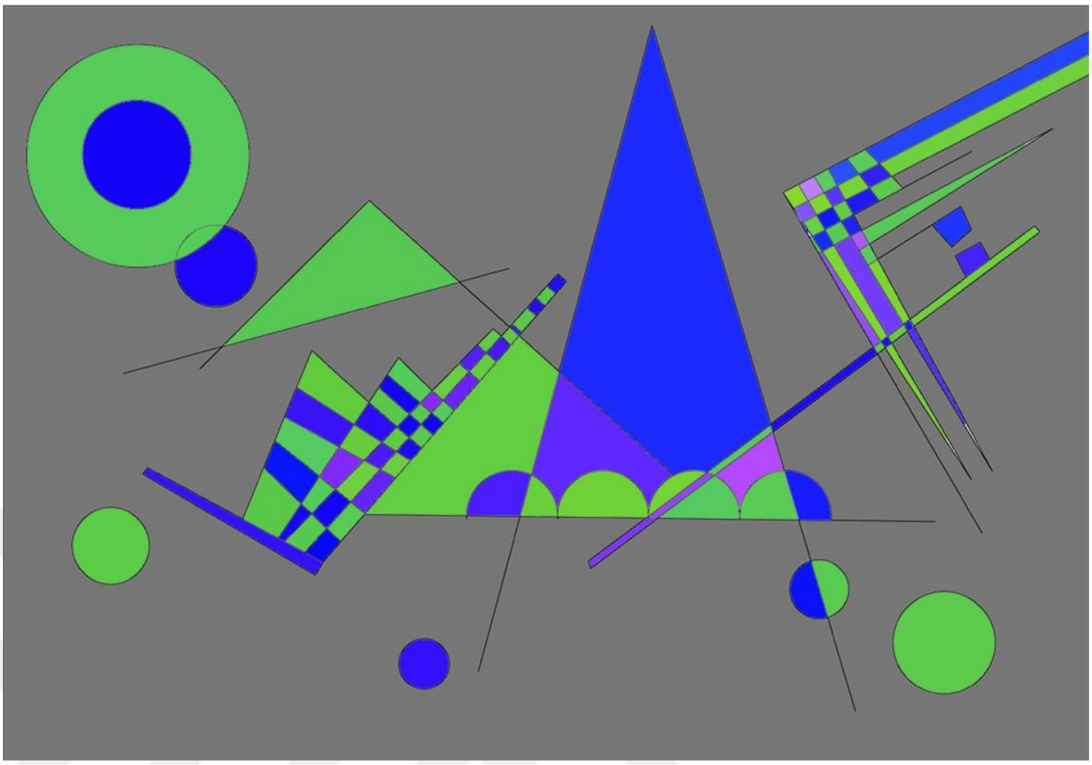
Low visual complexity	◯	◯	◯	◯	◯	High visual complexity

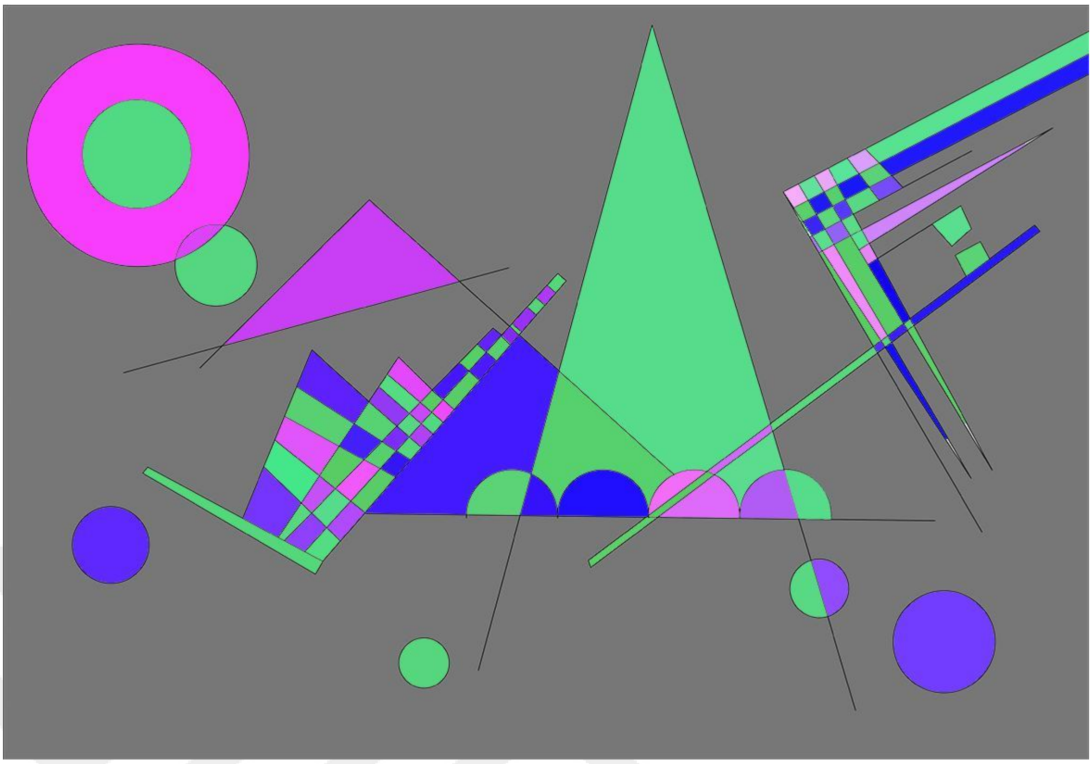
13. **Rate this image in terms of visual interest.** *



Mark only one oval.

	1	2	3	4	5	
Low visual interest	◯	◯	◯	◯	◯	High visual interest

14. **Rate this image in terms of visual complexity.** *



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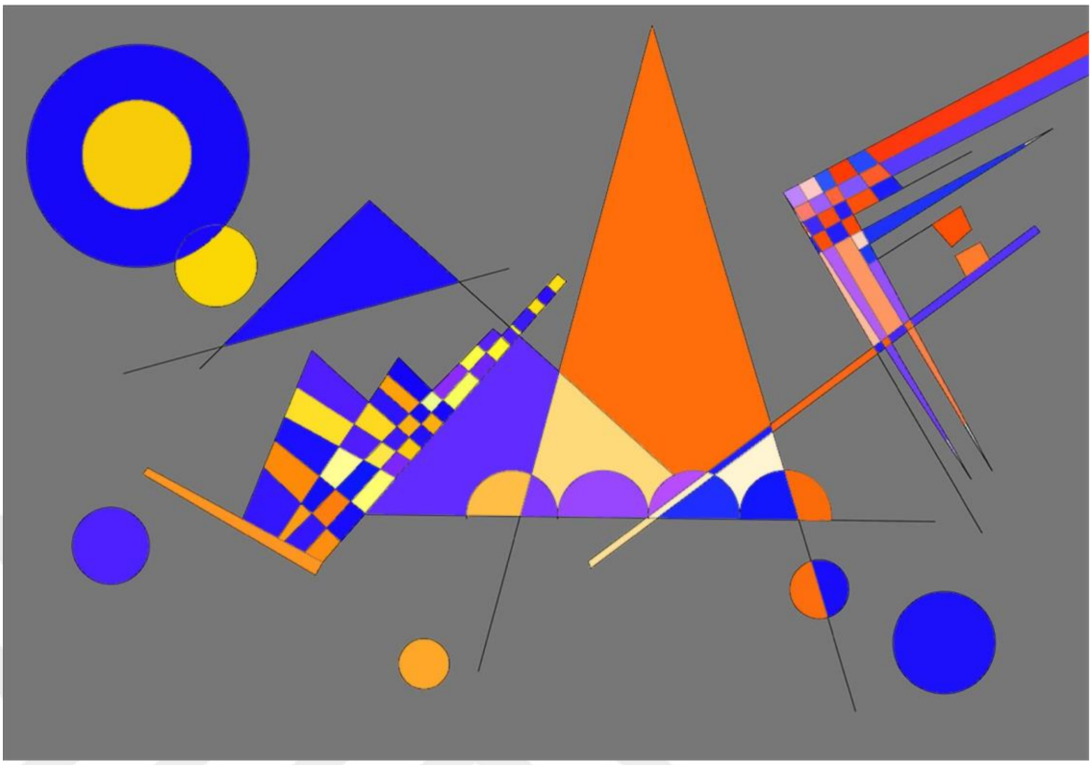
Low visual complexity	◯	◯	◯	◯	◯	High visual complexity

15. **Rate this image in terms of visual complexity.** *



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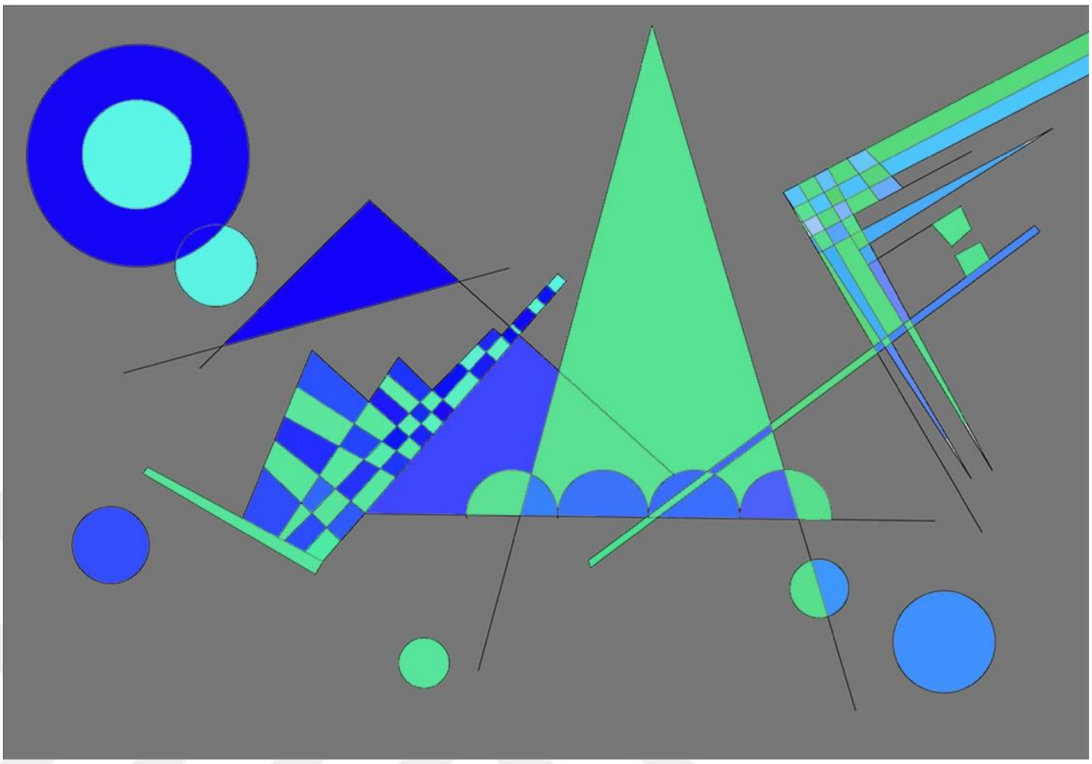
Low visual complexity	◯	◯	◯	◯	◯	High visual complexity

16. **Rate this image in terms of visual interest.** *



Mark only one oval.

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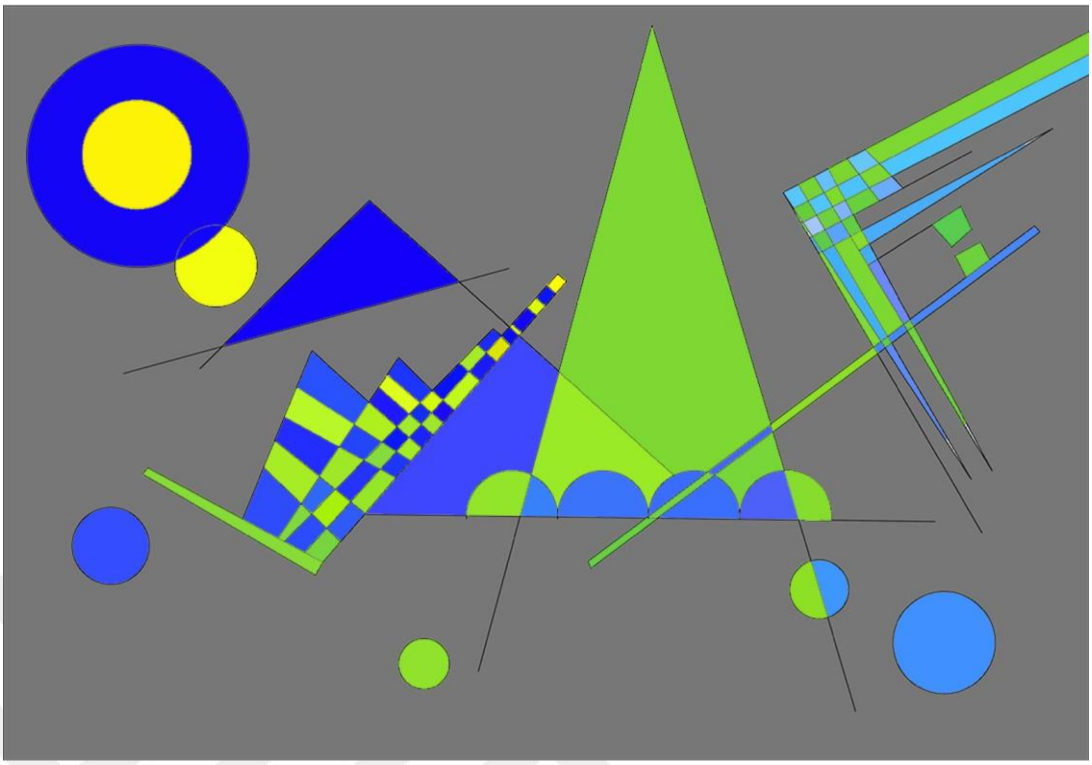
Low visual interest	⬭	⬭	⬭	⬭	⬭	High visual interest

17. **Rate this image in terms of visual interest.** *



Mark only one oval.

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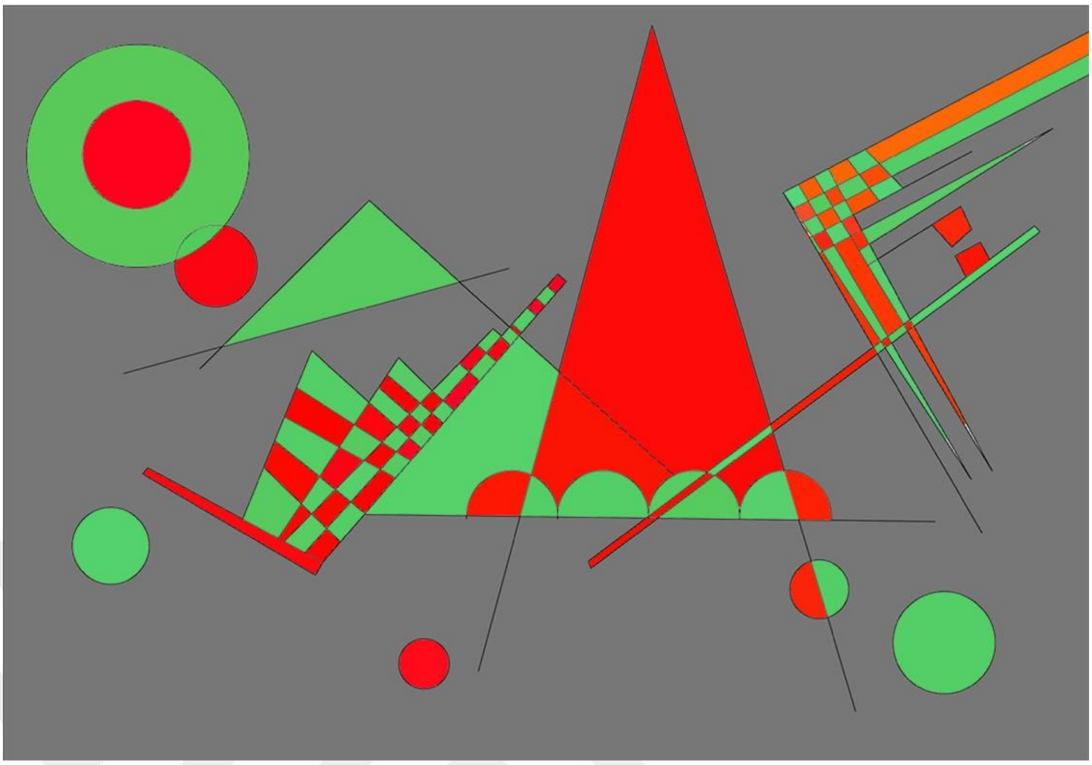
18. **Rate this image in terms of visual interest.** *



Mark only one oval.

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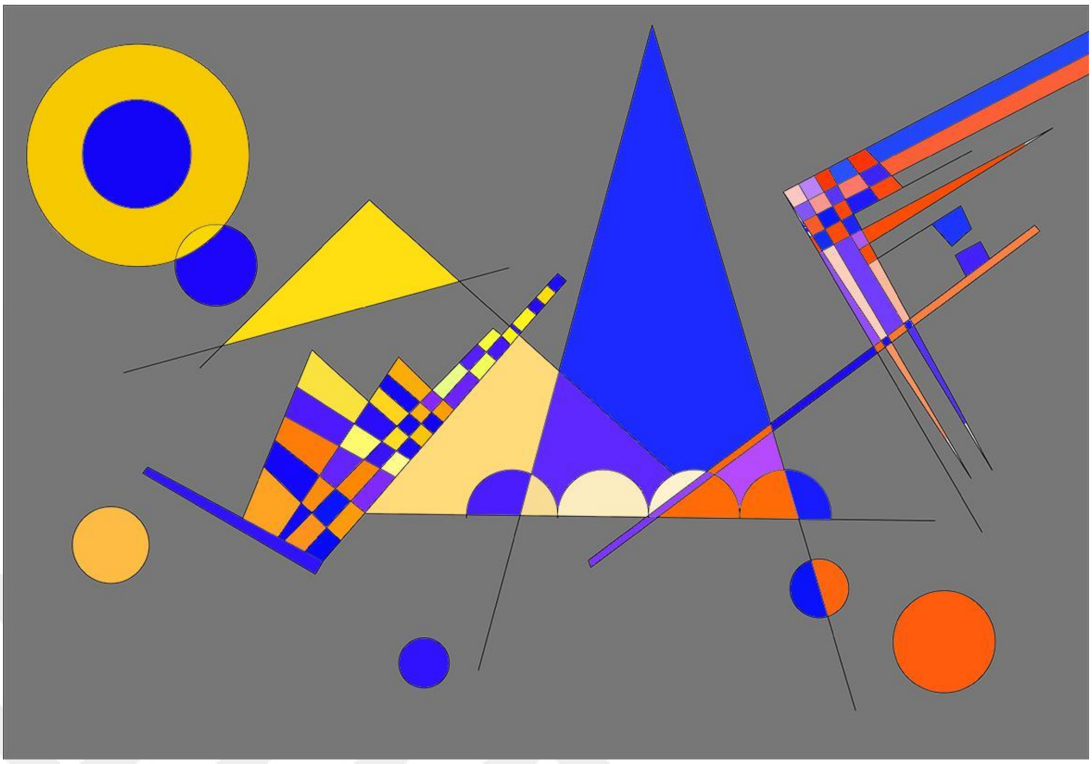
Low visual interest	⬭	⬭	⬭	⬭	⬭	High visual interest

19. **Rate this image in terms of visual complexity.** *



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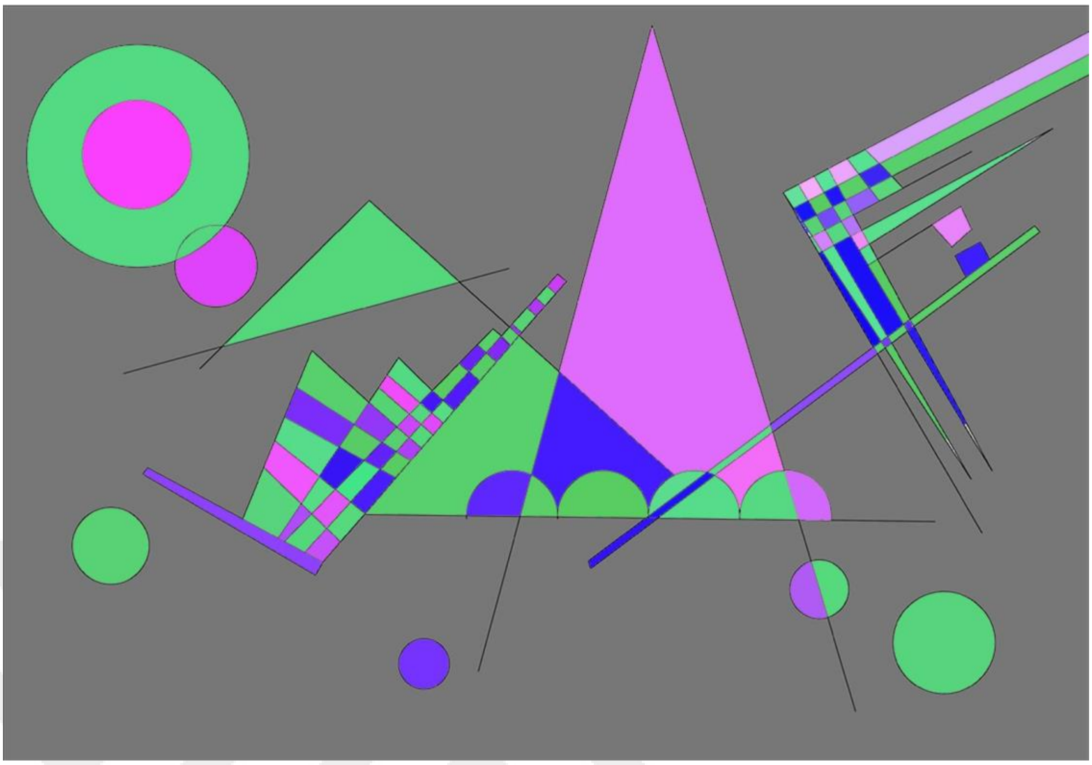

Mark only one oval.

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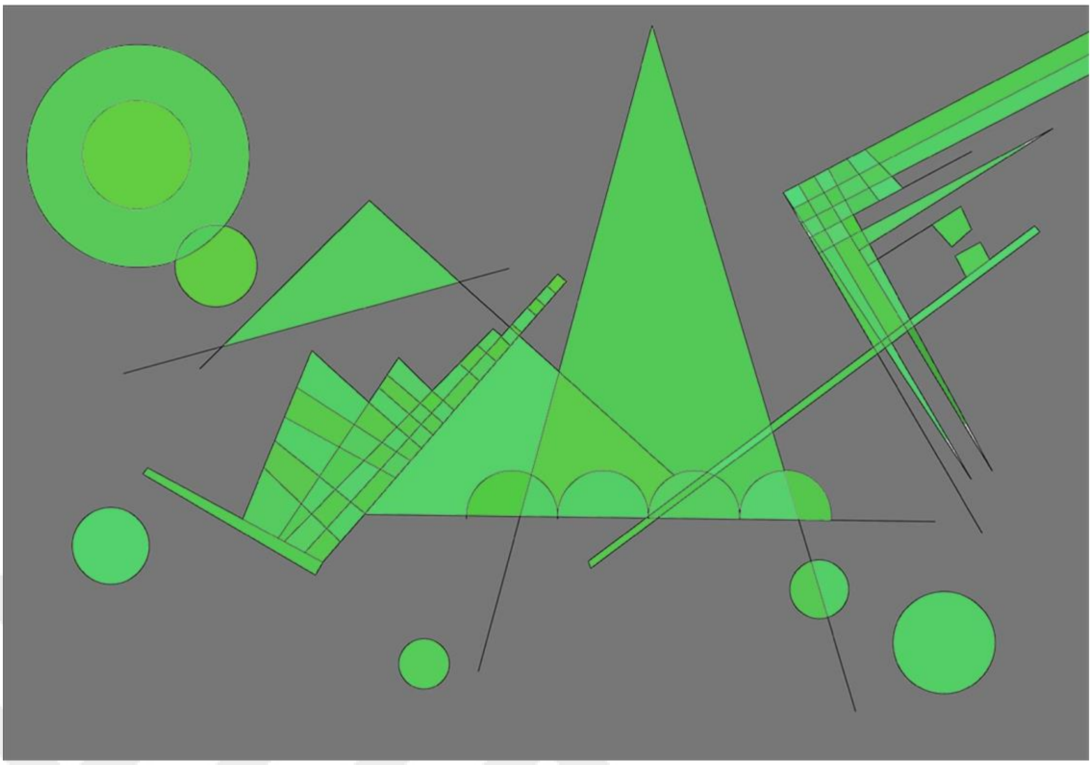
Low visual interest	⬭	⬭	⬭	⬭	⬭	High visual interest

21. **Rate this image in terms of visual complexity.** *



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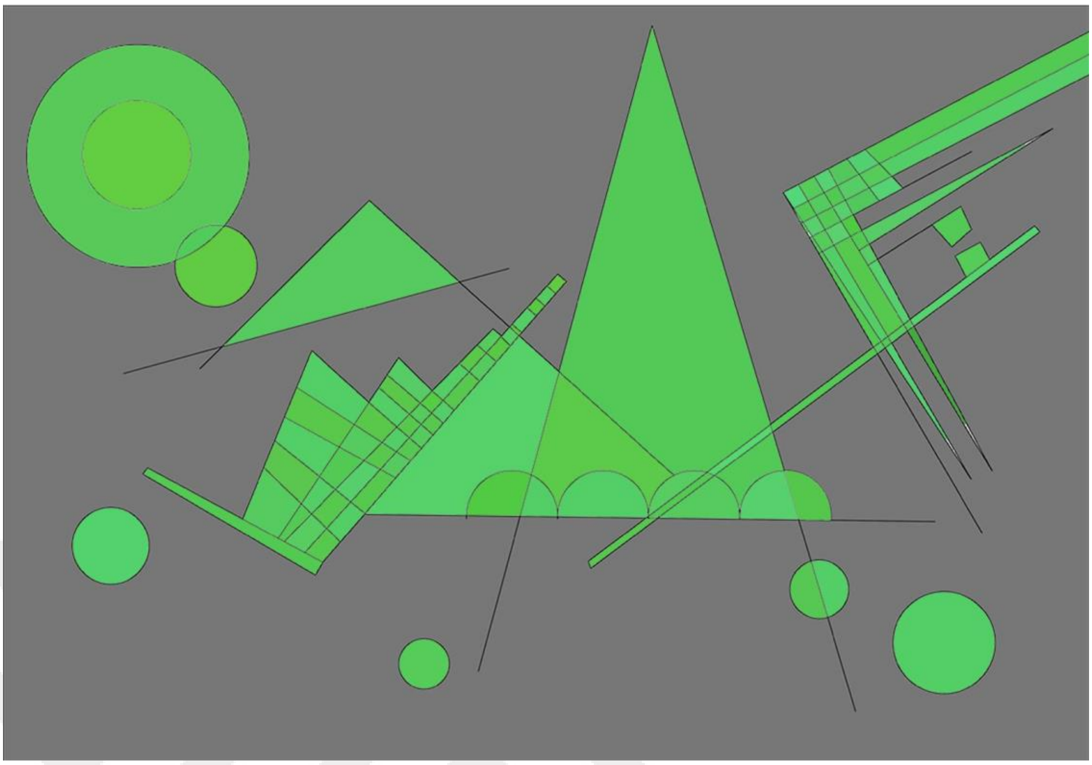
Low visual complexity	○	○	○	○	○	High visual complexity

22. **Rate this image in terms of visual interest.** *



Mark only one oval.

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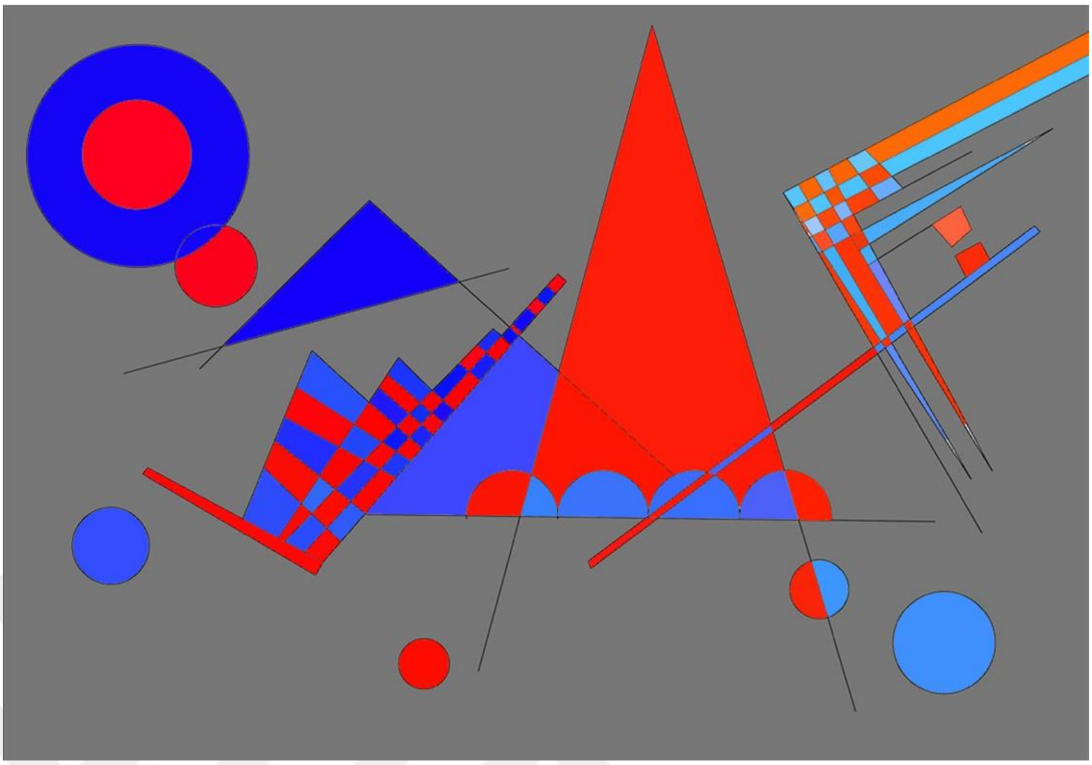
Low visual interest	⬭	⬭	⬭	⬭	⬭	High visual interest

23. **Rate this image in terms of visual complexity.** *



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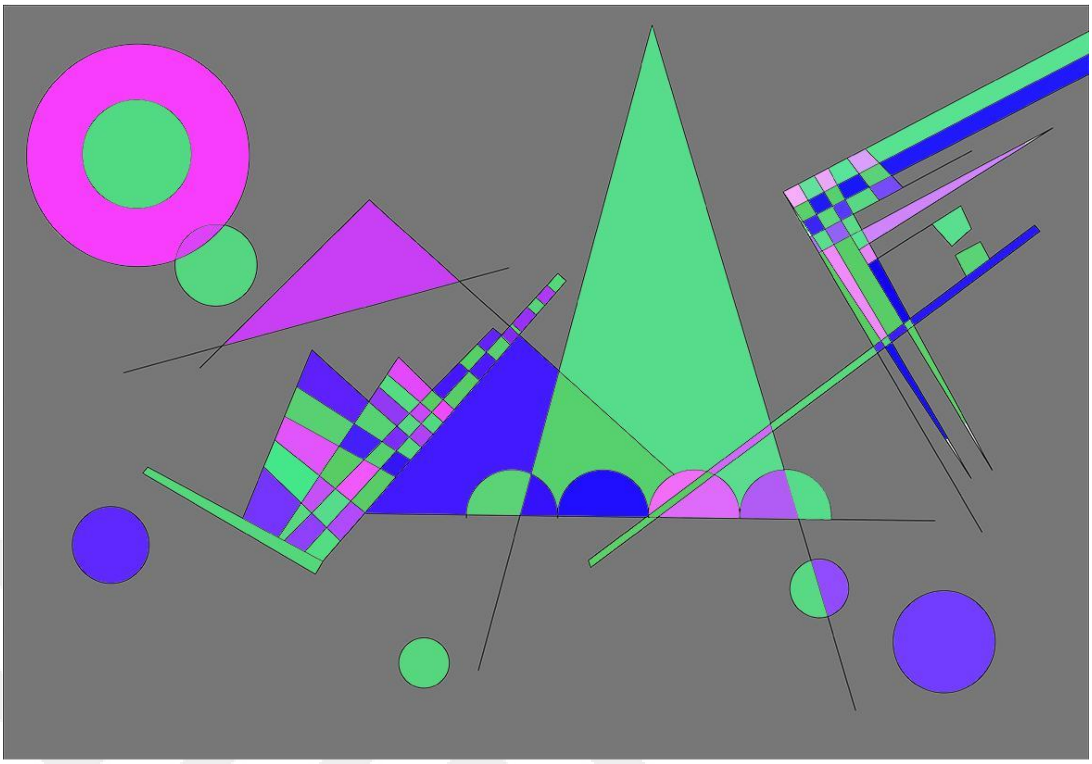
Low visual complexity	⬭	⬭	⬭	⬭	⬭	High visual complexity

24. **Rate this image in terms of visual interest.** *



Mark only one oval.

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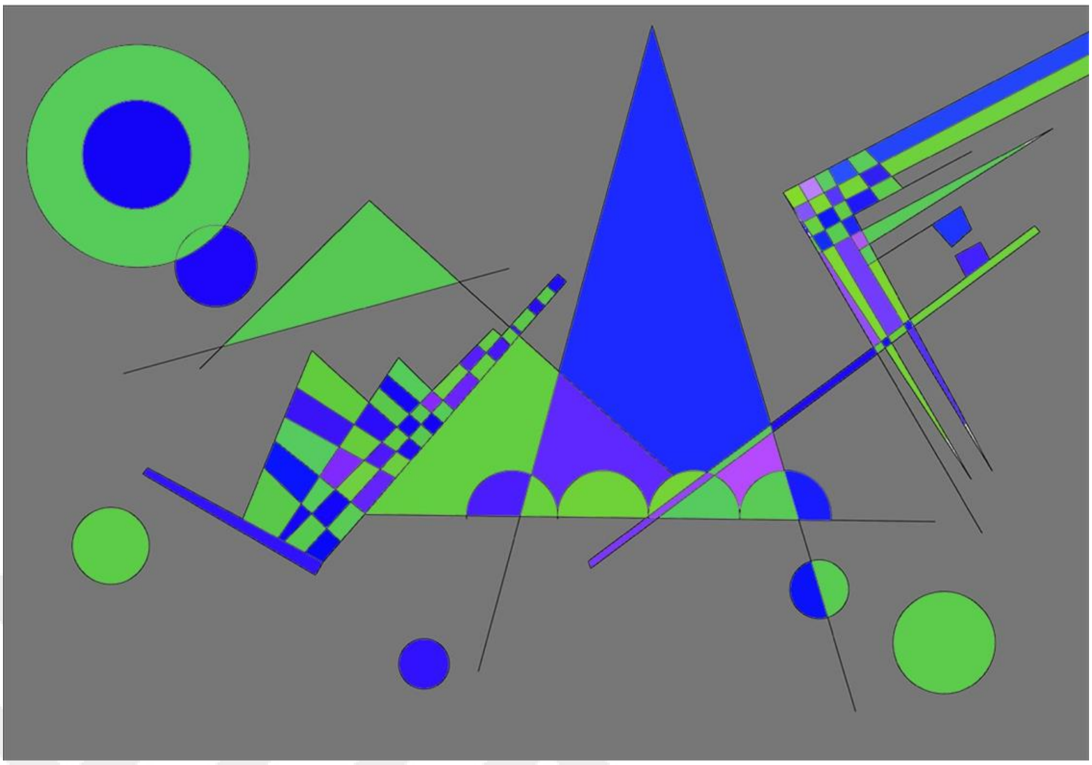
Low visual interest	⬭	⬭	⬭	⬭	⬭	High visual interest

25. **Rate this image in terms of visual complexity.** *



Mark only one oval.

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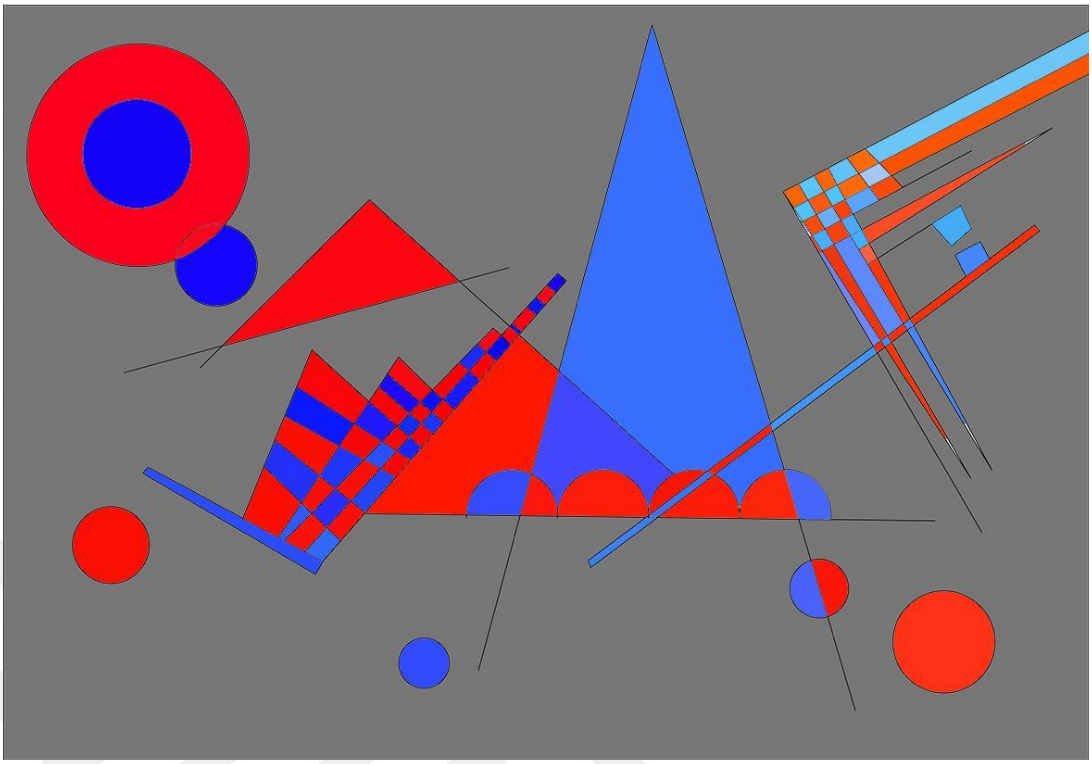
Low visual complexity	⬭	⬭	⬭	⬭	⬭	High visual complexity

26. **Rate this image in terms of visual interest.** *



Mark only one oval.

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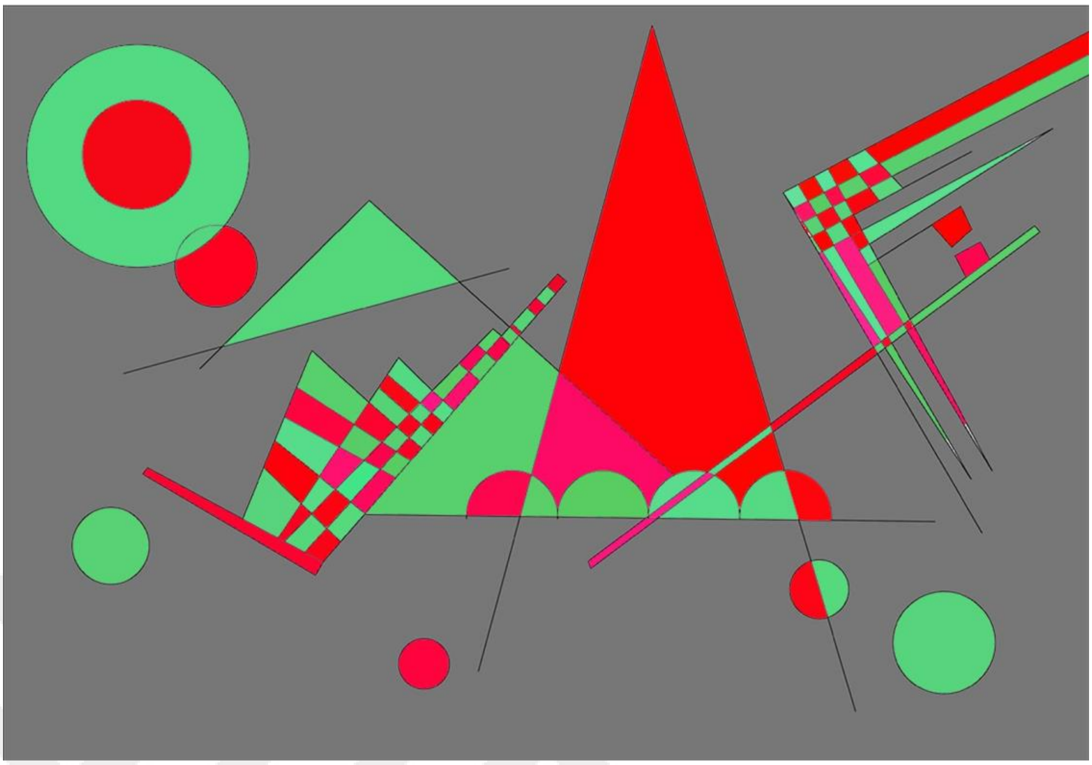
Low visual interest	⬭	⬭	⬭	⬭	⬭	High visual interest

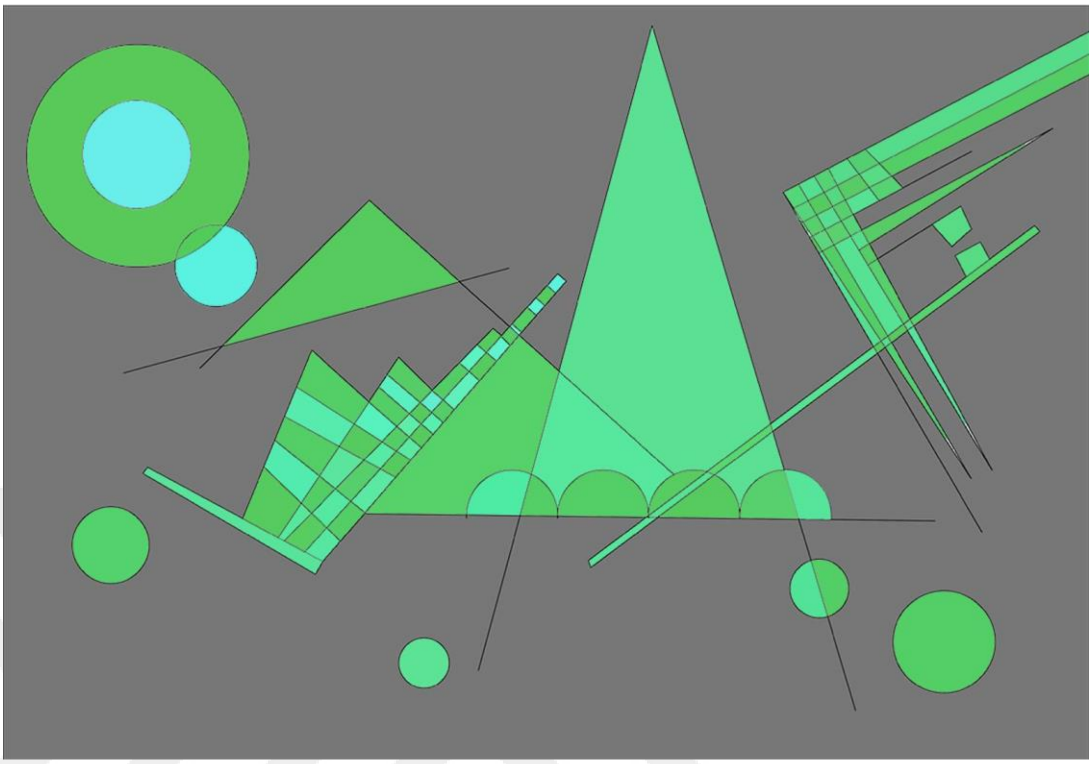
27. **Rate this image in terms of visual interest.** *



Mark only one oval.

	1	2	3	4	5	
Low visual interest	◯	◯	◯	◯	◯	High visual interest

28. **Rate this image in terms of visual complexity.** *



Mark only one oval.

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Low visual complexity	⬭	⬭	⬭	⬭	⬭	High visual complexity

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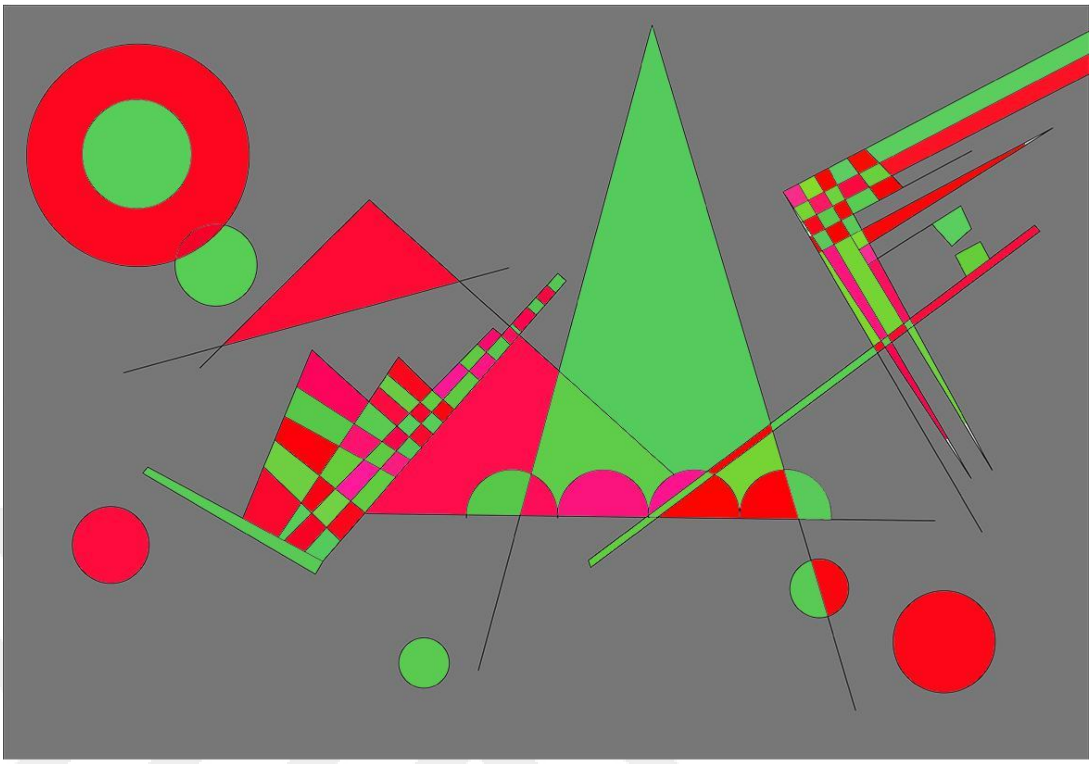

Mark only one oval.

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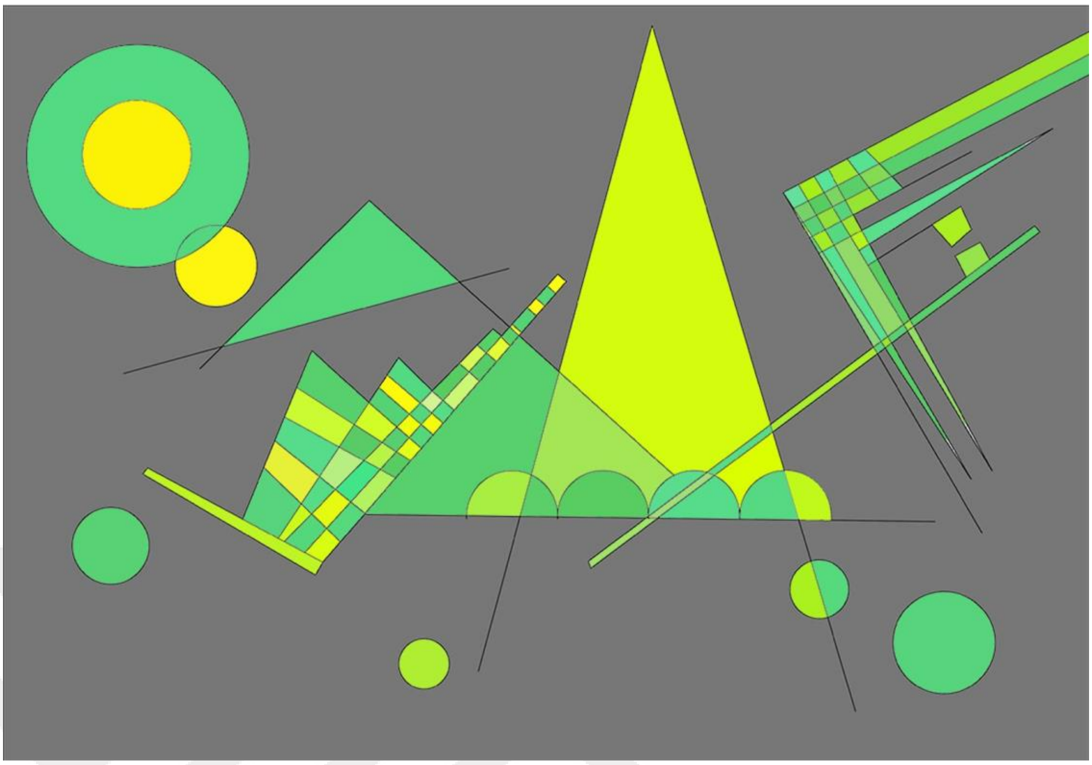
Low visual interest	⬭	⬭	⬭	⬭	⬭	High visual interest

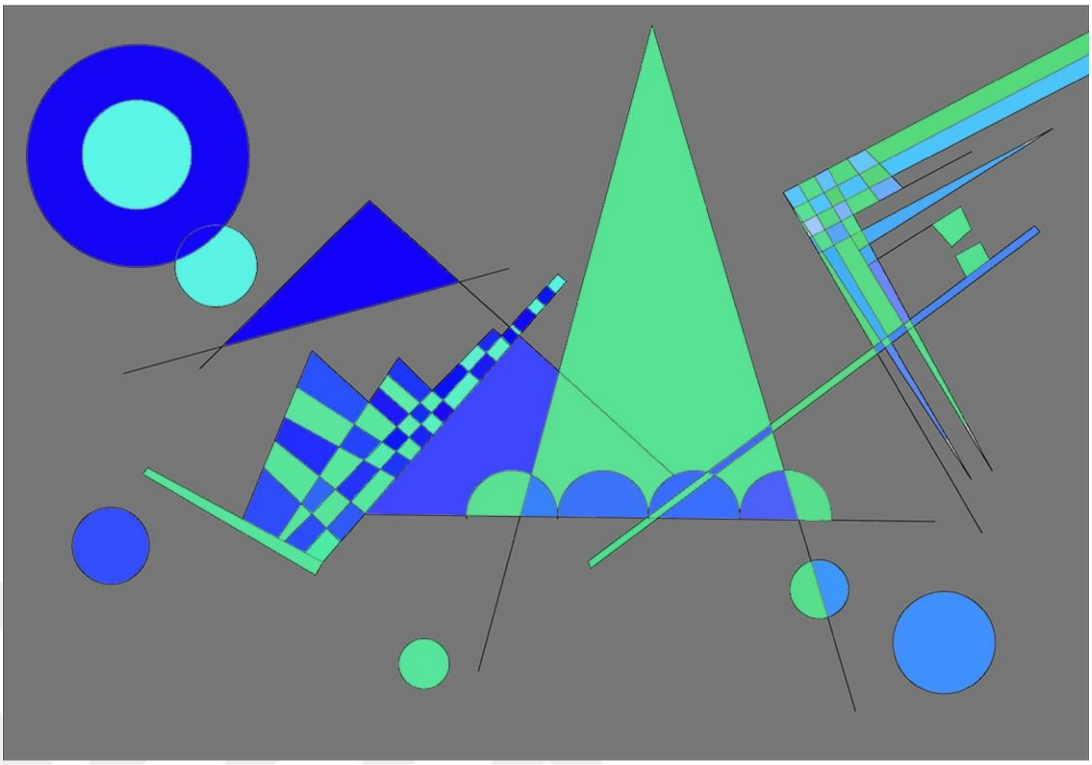
30. **Rate this image in terms of visual complexity.** *



Mark only one oval.

	1	2	3	4	5	
Low visual complexity	⬭	⬭	⬭	⬭	⬭	High visual complexity

31. **Rate this image in terms of visual complexity.** *



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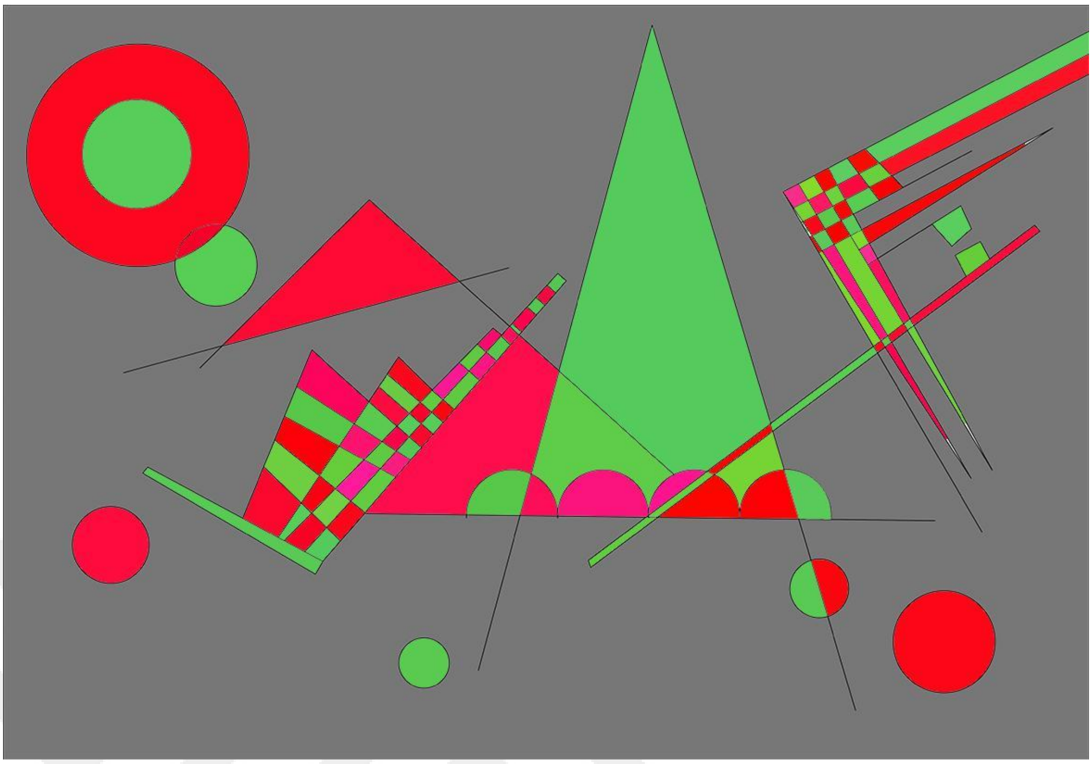
32. **Rate this image in terms of visual complexity.** *



Mark only one oval.

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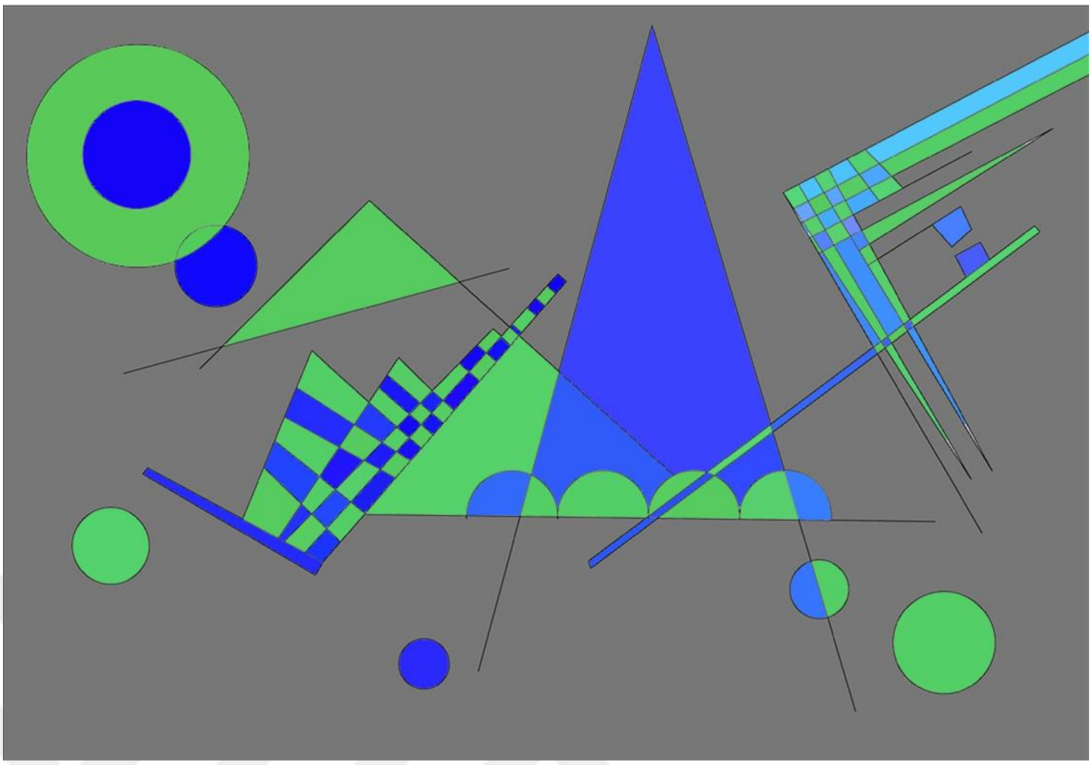
Low visual complexity	⬭	⬭	⬭	⬭	⬭	High visual complexity

33. **Rate this image in terms of visual interest.** *



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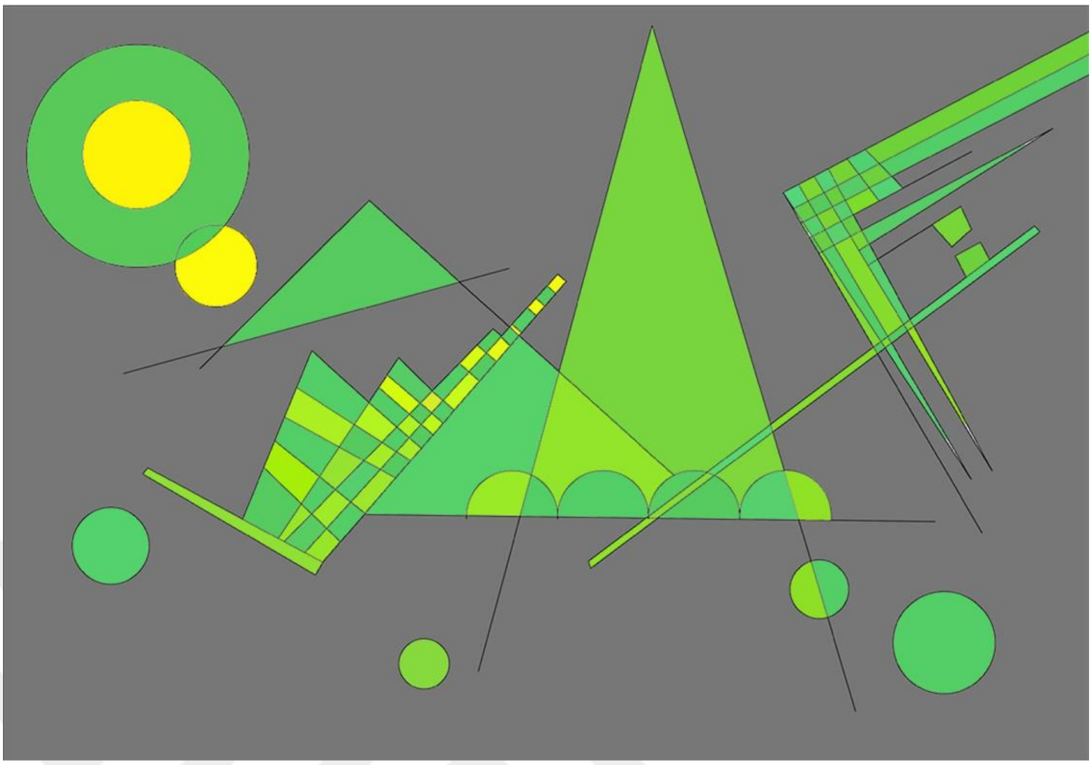
34. **Rate this image in terms of visual interest.** *



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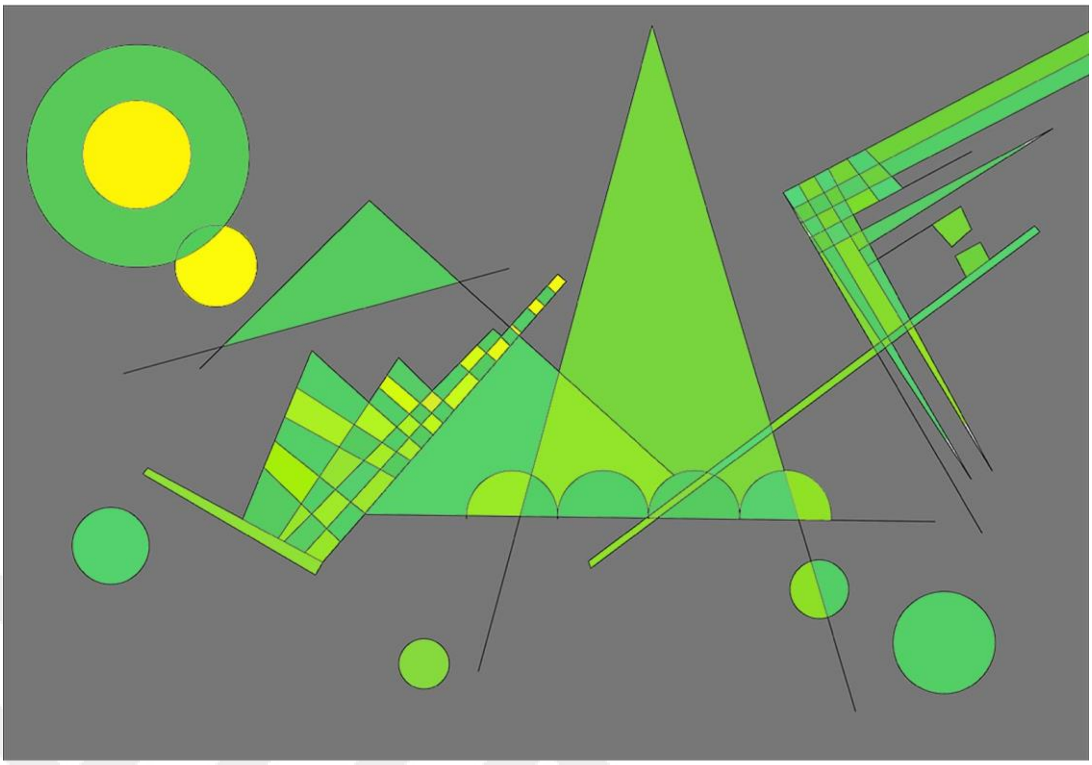
Low visual interest	⬭	⬭	⬭	⬭	⬭	High visual interest

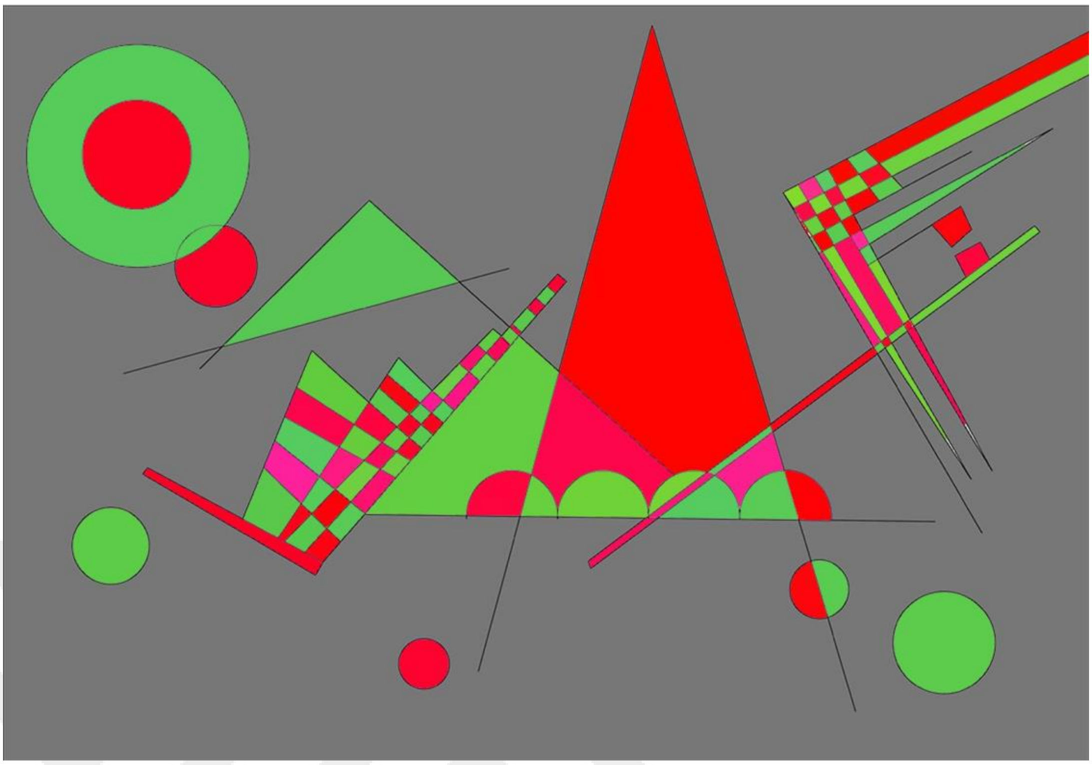
35. **Rate this image in terms of visual complexity.** *



Mark only one oval.

	1	2	3	4	5	
Low visual complexity	⬭	⬭	⬭	⬭	⬭	High visual complexity

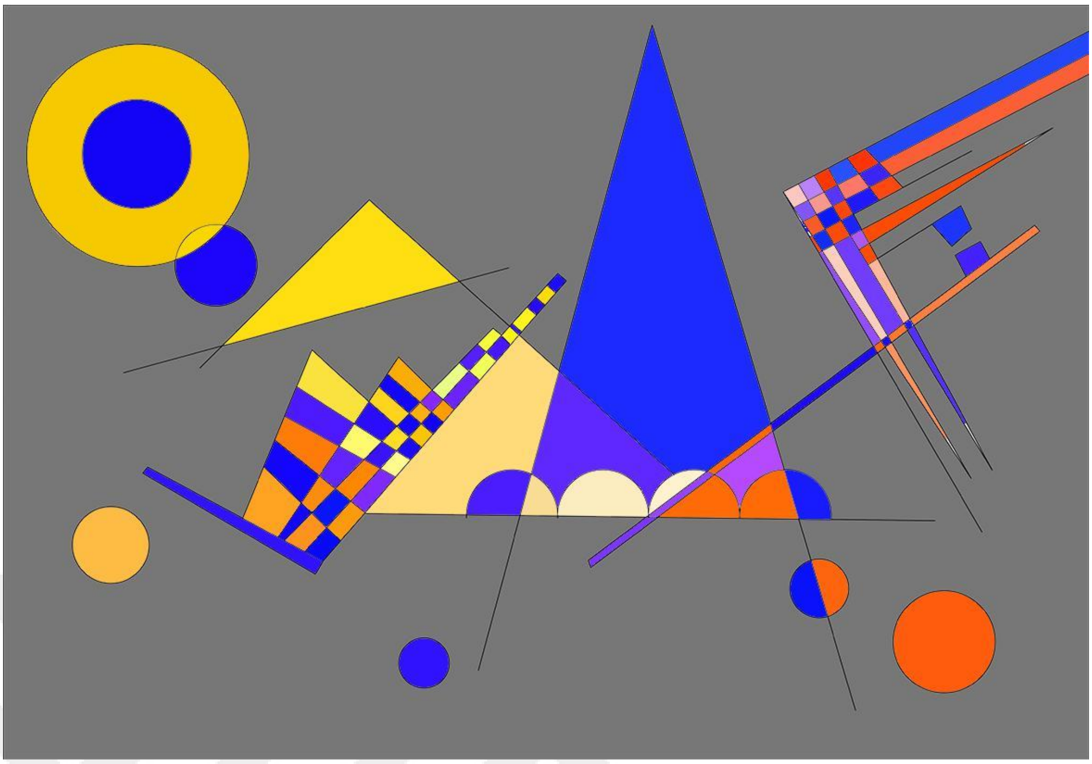
36. **Rate this image in terms of visual complexity.** *



Mark only one oval.

	1	2	3	4	5	
Low visual complexity	◯	◯	◯	◯	◯	High visual complexity

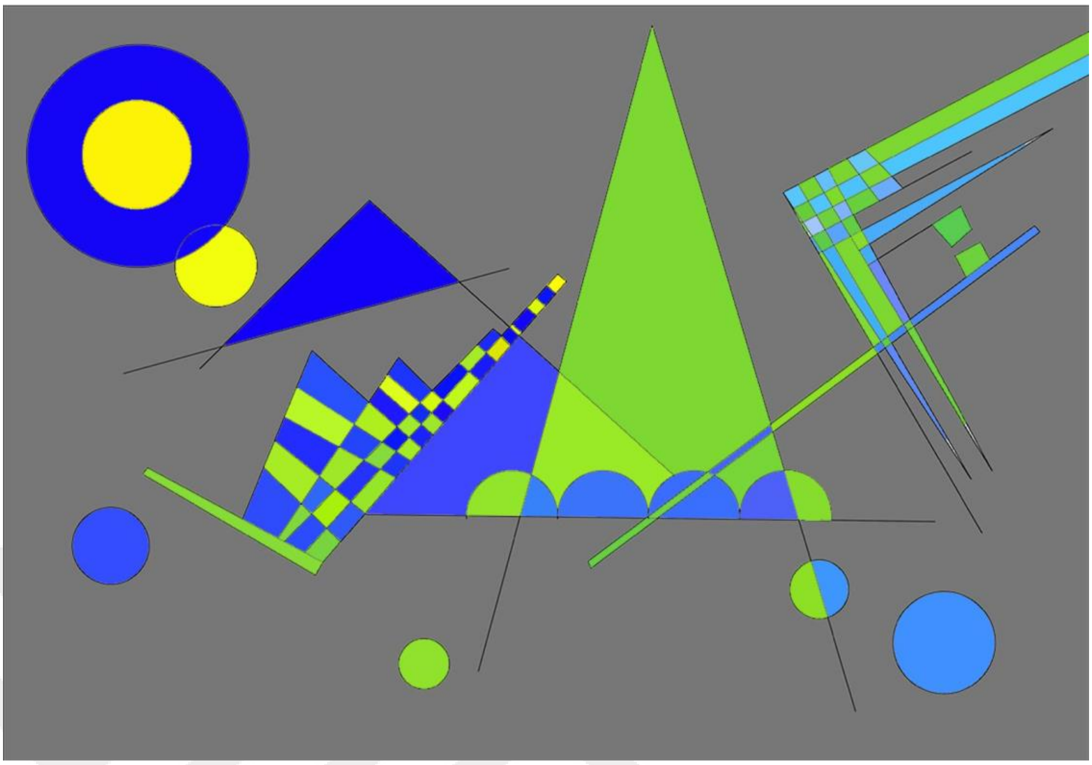
37. **Rate this image in terms of visual interest.** *



Mark only one oval.

	1	2	3	4	5	
Low visual interest	◯	◯	◯	◯	◯	High visual interest

38. **Rate this image in terms of visual complexity.** *



Mark only one oval.

	1	2	3	4	5	
Low visual complexity	⬭	⬭	⬭	⬭	⬭	High visual complexity

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Appendix F- Results of Delta E Values

1-2

7.0108 = L:73,A:-50,B:45 -> L:74,A:-51,B:57

6.5392 = L:74,A:-53,B:45 -> L:73,A:-51,B:55

6.4165 = L:73,A:-51,B:43 -> L:73,A:-51,B:55

6.4165 = L:73,A:-51,B:43 -> L:73,A:-51,B:55

10.6591 = L:74,A:-52,B:41 -> L:74,A:-53,B:62

9.3548 = L:74,A:-50,B:40 -> L:73,A:-51,B:55

5.2172 = L:73,A:-51,B:43 -> L:72,A:-53,B:53

0.9175 = L:73,A:-51,B:43 -> L:72,A:-51,B:49

9.0509 = L:74,A:-52,B:41 -> L:74,A:-55,B:55

2.4174 = L:74,A:-51,B:41 -> L:72,A:-51,B:51

6.309 = L:74,A:-50,B:40 -> L:73,A:-51,B:49

0.5266 = L:73,A:-51,B:43 -> L:73,A:-51,B:49

1.1277 = L:73,A:-51,B:43 -> L:72,A:-51,B:48

6.6018 = L:74,A:-52,B:41 -> L:72,A:-53,B:53

6.6018 = L:74,A:-52,B:41 -> L:72,A:-53,B:53

4.5133 = L:74,A:-52,B:41 -> L:73,A:-51,B:49

0.5266 = L:73,A:-51,B:43 -> L:73,A:-51,B:49

1.4188 = L:73,A:-51,B:43 -> L:73,A:-52,B:48

4.9545 = L:75,A:-51,B:38 -> L:72,A:-50,B:49

4.5133 = L:74,A:-52,B:41 -> L:73,A:-51,B:49

4.5133 = L:74,A:-52,B:41 -> L:73,A:-51,B:49

4.5133 = L:74,A:-52,B:41 -> L:73,A:-51,B:49

4.0127 = L:74,A:-51,B:42 -> L:73,A:-52,B:48

1.6015 = L:73,A:-51,B:43 -> L:74,A:-52,B:48

9.5703 = L:75,A:-53,B:39 -> L:73,A:-55,B:56

1.5224 = L:75,A:-52,B:41 -> L:73,A:-52,B:52

4.5133 = L:74,A:-52,B:41 -> L:73,A:-51,B:49

4.5133 = L:74,A:-52,B:41 -> L:73,A:-51,B:49

1.9681 = L:74,A:-51,B:42 -> L:72,A:-52,B:45

4.6626 = L:73,A:-51,B:43 -> L:72,A:-52,B:50

5.02 = L:78,A:-54,B:40 -> L:72,A:-52,B:50

7.3582 = L:75,A:-51,B:38 -> L:72,A:-52,B:48

0.6294 = L:74,A:-52,B:41 -> L:73,A:-52,B:49

0.6294 = L:74,A:-52,B:41 -> L:73,A:-52,B:49

0.5884 = L:73,A:-51,B:43 -> L:72,A:-52,B:45

1.6015 = L:73,A:-51,B:43 -> L:74,A:-52,B:48

11.309 = L:77,A:-53,B:39 -> L:63,A:-48,B:46

5.3409 = L:75,A:-52,B:36 -> L:73,A:-51,B:49

7.1666 = L:75,A:-51,B:38 -> L:73,A:-52,B:48

0.6294 = L:74,A:-52,B:41 -> L:73,A:-52,B:49

3.2584 = L:74,A:-50,B:40 -> L:72,A:-52,B:45

3.7784 = L:74,A:-50,B:40 -> L:74,A:-52,B:46

3.9696 = L:73,A:-51,B:43 -> L:73,A:-56,B:54

3.9626 = L:76,A:-51,B:38 -> L:72,A:-51,B:42

6.4298 = L:76,A:-51,B:36 -> L:72,A:-52,B:45

3.1281 = L:75,A:-51,B:38 -> L:72,A:-51,B:46

7.051 = L:75,A:-51,B:38 -> L:74,A:-52,B:48

0.6294 = L:74,A:-52,B:41 -> L:73,A:-52,B:49

6.309 = L:74,A:-50,B:40 -> L:73,A:-51,B:49

0.5884 = L:73,A:-51,B:43 -> L:72,A:-52,B:45

5.8833 = L:77,A:-52,B:34 -> L:74,A:-52,B:47

4.2511 = L:76,A:-51,B:36 -> L:72,A:-51,B:44

6.5365 = L:75,A:-52,B:36 -> L:73,A:-52,B:48

1-3

46.6974 = L:73,A:-50,B:45 -> L:87,A:-38,B:-11

41.2063 = L:74,A:-53,B:45 -> L:87,A:-44,B:-6

37.9484 = L:73,A:-51,B:43 -> L:88,A:-45,B:-3

26.835 = L:73,A:-51,B:43 -> L:87,A:-46,B:-2

8.5855 = L:74,A:-52,B:41 -> L:87,A:-44,B:0

8.132 = L:74,A:-50,B:40 -> L:88,A:-48,B:5

24.4813 = L:73,A:-51,B:43 -> L:87,A:-50,B:11

24.8987 = L:73,A:-51,B:43 -> L:86,A:-50,B:12

25.9676 = L:74,A:-52,B:41 -> L:86,A:-45,B:3

24.2576 = L:74,A:-51,B:41 -> L:86,A:-50,B:10

10.4454 = L:74,A:-50,B:40 -> L:86,A:-53,B:18

2.7891 = L:73,A:-51,B:43 -> L:85,A:-52,B:22

9.3227 = L:73,A:-51,B:43 -> L:83,A:-52,B:21

21.8205 = L:74,A:-52,B:41 -> L:86,A:-52,B:13

7.066 = L:74,A:-52,B:41 -> L:84,A:-52,B:18

13.0216 = L:74,A:-52,B:41 -> L:84,A:-52,B:22

9.3227 = L:73,A:-51,B:43 -> L:83,A:-52,B:21

4.0129 = L:73,A:-51,B:43 -> L:82,A:-52,B:23

15.3912 = L:75,A:-51,B:38 -> L:84,A:-53,B:18

11.5692 = L:74,A:-52,B:41 -> L:83,A:-53,B:23

12.6765 = L:74,A:-52,B:41 -> L:83,A:-52,B:22

12.9013 = L:74,A:-52,B:41 -> L:83,A:-53,B:25

13.3468 = L:74,A:-51,B:42 -> L:82,A:-52,B:24

6.3256 = L:73,A:-51,B:43 -> L:81,A:-51,B:26

11.9953 = L:75,A:-53,B:39 -> L:84,A:-55,B:22

12.5581 = L:75,A:-52,B:41 -> L:83,A:-53,B:25

7.9481 = L:74,A:-52,B:41 -> L:82,A:-53,B:24

11.9189 = L:74,A:-52,B:41 -> L:81,A:-52,B:26

5.3323 = L:74,A:-51,B:42 -> L:80,A:-51,B:26

5.7122 = L:73,A:-51,B:43 -> L:80,A:-51,B:26

9.7186 = L:78,A:-54,B:40 -> L:82,A:-53,B:23

9.9075 = L:75,A:-51,B:38 -> L:81,A:-53,B:25

11.9189 = L:74,A:-52,B:41 -> L:81,A:-52,B:26

5.7054 = L:74,A:-52,B:41 -> L:80,A:-52,B:28

8.5805 = L:73,A:-51,B:43 -> L:80,A:-52,B:28

2.9274 = L:73,A:-51,B:43 -> L:79,A:-51,B:32

5.9967 = L:77,A:-53,B:39 -> L:82,A:-53,B:24

3.2524 = L:75,A:-52,B:36 -> L:81,A:-52,B:27

4.7875 = L:75,A:-51,B:38 -> L:80,A:-52,B:27

5.7054 = L:74,A:-52,B:41 -> L:80,A:-52,B:28

4.0295 = L:74,A:-50,B:40 -> L:79,A:-51,B:31

1.2953 = L:74,A:-50,B:40 -> L:78,A:-51,B:34

1.5831 = L:73,A:-51,B:43 -> L:77,A:-51,B:33

4.7594 = L:76,A:-51,B:38 -> L:81,A:-52,B:27

6.0707 = L:76,A:-51,B:36 -> L:80,A:-51,B:27

7.2429 = L:75,A:-51,B:38 -> L:80,A:-52,B:29

4.7967 = L:75,A:-51,B:38 -> L:79,A:-51,B:30

7.4943 = L:74,A:-52,B:41 -> L:78,A:-51,B:31

3.5479 = L:74,A:-50,B:40 -> L:77,A:-51,B:33

1.5831 = L:73,A:-51,B:43 -> L:77,A:-51,B:33

2.5814 = L:77,A:-52,B:34 -> L:80,A:-52,B:28

2.8453 = L:76,A:-51,B:36 -> L:79,A:-52,B:29

5.4418 = L:75,A:-52,B:36 -> L:79,A:-52,B:29

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29.7586 = L:73,A:-50,B:45 -> L:95,A:-12,B:90

40.825 = L:74,A:-53,B:45 -> L:97,A:-14,B:92

33.9987 = L:73,A:-51,B:45 -> L:96,A:-19,B:90

33.7129 = L:73,A:-51,B:43 -> L:96,A:-22,B:90

23.6233 = L:74,A:-52,B:41 -> L:97,A:-16,B:90

38.0395 = L:74,A:-50,B:40 -> L:95,A:-24,B:89

23.9889 = L:73,A:-51,B:43 -> L:94,A:-31,B:87

21.1508 = L:73,A:-51,B:43 -> L:93,A:-35,B:84

31.3581 = L:74,A:-52,B:41 -> L:90,A:-23,B:82

34.8353 = L:74,A:-51,B:41 -> L:94,A:-32,B:88

23.9907 = L:74,A:-50,B:40 -> L:91,A:-38,B:81

15.4185 = L:73,A:-51,B:43 -> L:89,A:-42,B:80

22.0354 = L:73,A:-51,B:43 -> L:87,A:-41,B:77

27.2134 = L:74,A:-52,B:41 -> L:90,A:-41,B:82

26.6758 = L:74,A:-52,B:41 -> L:88,A:-41,B:80

22.4422 = L:74,A:-52,B:41 -> L:87,A:-43,B:77

14.7093 = L:73,A:-51,B:43 -> L:85,A:-42,B:73

12.6235 = L:73,A:-51,B:43 -> L:83,A:-43,B:70

6.7454 = L:75,A:-51,B:38 -> L:87,A:-44,B:82

19.342 = L:74,A:-52,B:41 -> L:86,A:-43,B:76

19.4724 = L:74,A:-52,B:41 -> L:84,A:-44,B:74

19.4724 = L:74,A:-52,B:41 -> L:84,A:-44,B:74

10.1738 = L:74,A:-51,B:42 -> L:82,A:-44,B:68

13.4803 = L:73,A:-51,B:43 -> L:80,A:-45,B:64

25.7065 = L:75,A:-53,B:39 -> L:85,A:-45,B:76

15.7308 = L:75,A:-52,B:41 -> L:83,A:-46,B:73

21.4564 = L:74,A:-52,B:41 -> L:82,A:-45,B:73

14.5805 = L:74,A:-52,B:41 -> L:80,A:-46,B:66

9.9196 = L:74,A:-51,B:42 -> L:78,A:-47,B:62

13.0499 = L:73,A:-51,B:43 -> L:77,A:-48,B:62

21.1378 = L:78,A:-54,B:40 -> L:82,A:-45,B:73

18.2404 = L:75,A:-51,B:38 -> L:82,A:-45,B:73

19.9625 = L:74,A:-52,B:41 -> L:80,A:-46,B:70

4.3763 = L:74,A:-52,B:41 -> L:80,A:-47,B:66

14.5646 = L:73,A:-51,B:43 -> L:78,A:-48,B:65

11.7823 = L:73,A:-51,B:43 -> L:76,A:-49,B:60

24.6727 = L:77,A:-53,B:39 -> L:83,A:-44,B:75

6.3676 = L:75,A:-52,B:36 -> L:80,A:-46,B:71

20.0546 = L:75,A:-51,B:38 -> L:80,A:-47,B:67

15.5411 = L:74,A:-52,B:41 -> L:78,A:-48,B:65

16.2502 = L:74,A:-50,B:40 -> L:78,A:-48,B:64

11.5188 = L:74,A:-50,B:40 -> L:75,A:-50,B:57

3.9637 = L:73,A:-51,B:43 -> L:74,A:-50,B:54

10.4353 = L:76,A:-51,B:38 -> L:80,A:-50,B:71

17.1019 = L:76,A:-51,B:36 -> L:78,A:-47,B:68

16.2504 = L:75,A:-51,B:38 -> L:78,A:-48,B:64

14.1753 = L:75,A:-51,B:38 -> L:76,A:-49,B:60

12.0654 = L:74,A:-52,B:41 -> L:75,A:-50,B:59

3.0235 = L:74,A:-50,B:40 -> L:74,A:-50,B:54

1.6037 = L:73,A:-51,B:43 -> L:73,A:-50,B:52

14.0747 = L:77,A:-52,B:34 -> L:79,A:-47,B:67

7.5328 = L:76,A:-51,B:36 -> L:77,A:-48,B:64

9.0204 = L:75,A:-52,B:36 -> L:76,A:-49,B:62

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101.6049 = L:73,A:-50,B:45 -> L:29,A:66,B:-108

37.8904 = L:74,A:-53,B:45 -> L:30,A:67,B:-109

120.0937 = L:73,A:-51,B:43 -> L:29,A:67,B:-109

94.7739 = L:73,A:-51,B:43 -> L:30,A:67,B:-110

113.2178 = L:74,A:-52,B:41 -> L:31,A:65,B:-110

118.6771 = L:74,A:-50,B:40 -> L:30,A:65,B:-109

94.7739 = L:73,A:-51,B:43 -> L:30,A:67,B:-110

119.6743 = L:73,A:-51,B:43 -> L:30,A:67,B:-109

113.3699 = L:74,A:-52,B:41 -> L:33,A:60,B:-106

100.3694 = L:74,A:-51,B:41 -> L:31,A:64,B:-108

29.7972 = L:74,A:-50,B:40 -> L:30,A:64,B:-108

57.3877 = L:73,A:-51,B:43 -> L:30,A:66,B:-109

115.93 = L:73,A:-51,B:43 -> L:30,A:65,B:-108

74.9173 = L:74,A:-52,B:41 -> L:37,A:50,B:-100

106.3515 = L:74,A:-52,B:41 -> L:34,A:57,B:-103

19.7159 = L:74,A:-52,B:41 -> L:32,A:63,B:-107

111.3827 = L:73,A:-51,B:43 -> L:31,A:59,B:-103

115.0568 = L:73,A:-51,B:43 -> L:32,A:65,B:-108

49.0262 = L:75,A:-51,B:38 -> L:40,A:43,B:-95

25.2622 = L:74,A:-52,B:41 -> L:39,A:45,B:-97

44.8833 = L:74,A:-52,B:41 -> L:36,A:53,B:-102

48.6865 = L:74,A:-52,B:41 -> L:35,A:55,B:-102

60.512 = L:74,A:-51,B:42 -> L:34,A:57,B:-103

110.0531 = L:73,A:-51,B:43 -> L:34,A:59,B:-103

60.3437 = L:75,A:-53,B:39 -> L:48,A:23,B:-79

68.7605 = L:75,A:-52,B:41 -> L:44,A:31,B:-84

87.6531 = L:74,A:-52,B:41 -> L:43,A:34,B:-88

58.0483 = L:74,A:-52,B:41 -> L:41,A:39,B:-91

59.207 = L:74,A:-51,B:42 -> L:41,A:43,B:-94

53.2677 = L:73,A:-51,B:43 -> L:39,A:48,B:-95

60.5039 = L:78,A:-54,B:40 -> L:54,A:14,B:-72

71.1462 = L:75,A:-51,B:38 -> L:51,A:19,B:-76

63.7561 = L:74,A:-52,B:41 -> L:48,A:25,B:-80

39.9926 = L:74,A:-52,B:41 -> L:47,A:29,B:-82

52.8948 = L:73,A:-51,B:43 -> L:48,A:30,B:-82

59.9471 = L:73,A:-51,B:43 -> L:46,A:33,B:-82

55.1353 = L:77,A:-53,B:39 -> L:60,A:2,B:-62

51.6223 = L:75,A:-52,B:36 -> L:59,A:4,B:-63

52.1585 = L:75,A:-51,B:38 -> L:57,A:7,B:-65

54.7008 = L:74,A:-52,B:41 -> L:57,A:9,B:-66

61.7293 = L:74,A:-50,B:40 -> L:55,A:14,B:-70

51.6317 = L:74,A:-50,B:40 -> L:57,A:14,B:-67

57.7726 = L:73,A:-51,B:43 -> L:60,A:13,B:-57

34.4242 = L:76,A:-51,B:38 -> L:67,A:-9,B:-51

54.1528 = L:76,A:-51,B:36 -> L:67,A:-11,B:-49

50.0274 = L:75,A:-51,B:38 -> L:65,A:-5,B:-53

49.9079 = L:75,A:-51,B:38 -> L:66,A:-5,B:-53

54.5395 = L:74,A:-52,B:41 -> L:66,A:-3,B:-52

30.8562 = L:74,A:-50,B:40 -> L:66,A:-1,B:-50

36.6281 = L:73,A:-51,B:43 -> L:71,A:-1,B:-45

15.8252 = L:77,A:-52,B:34 -> L:74,A:-20,B:-40

44.6281 = L:76,A:-51,B:36 -> L:74,A:-20,B:-39

10.7694 = L:75,A:-52,B:36 -> L:76,A:-22,B:-36

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67.2059 = L:73,A:-50,B:45 -> L:54,A:81,B:61

74.4866 = L:74,A:-53,B:45 -> L:54,A:80,B:64

99.1793 = L:73,A:-51,B:43 -> L:54,A:80,B:60

35.8043 = L:73,A:-51,B:43 -> L:55,A:81,B:55

79.7109 = L:74,A:-52,B:41 -> L:52,A:78,B:62

45.6477 = L:74,A:-50,B:40 -> L:54,A:81,B:63

29.4362 = L:73,A:-51,B:43 -> L:54,A:80,B:61

67.1983 = L:73,A:-51,B:43 -> L:54,A:81,B:57

84.7579 = L:72,A:-52,B:41 -> L:54,A:80,B:68

68.0788 = L:74,A:-51,B:41 -> L:54,A:80,B:68

92.145 = L:74,A:-50,B:40 -> L:54,A:81,B:68

81.9695 = L:73,A:-51,B:43 -> L:54,A:80,B:65

91.4979 = L:73,A:-51,B:43 -> L:54,A:81,B:59

97.0204 = L:74,A:-52,B:41 -> L:54,A:80,B:66

37.3562 = L:74,A:-52,B:41 -> L:54,A:81,B:70

48.6464 = L:74,A:-52,B:41 -> L:54,A:81,B:69

30.8942 = L:73,A:-51,B:43 -> L:54,A:80,B:68

86.3424 = L:73,A:-51,B:43 -> L:54,A:80,B:64

96.2156 = L:75,A:-51,B:38 -> L:54,A:81,B:71

102.6241 = L:74,A:-52,B:41 -> L:53,A:79,B:69

85.0335 = L:74,A:-52,B:41 -> L:54,A:80,B:68

85.0335 = L:74,A:-52,B:41 -> L:54,A:80,B:68

94.3274 = L:74,A:-51,B:42 -> L:55,A:80,B:66

101.5806 = L:73,A:-51,B:43 -> L:55,A:80,B:62

100.5145 = L:75,A:-53,B:39 -> L:55,A:79,B:69

94.5814 = L:75,A:-52,B:41 -> L:54,A:78,B:68

102.5853 = L:75,A:-52,B:41 -> L:54,A:79,B:69

15.3205 = L:75,A:-52,B:41 -> L:53,A:78,B:67

81.4993 = L:74,A:-51,B:42 -> L:53,A:79,B:67

16.3016 = L:73,A:-51,B:43 -> L:54,A:79,B:67

63.6089 = L:78,A:-54,B:40 -> L:55,A:78,B:69

51.8398 = L:75,A:-51,B:38 -> L:55,A:76,B:67

20.4083 = L:74,A:-52,B:41 -> L:55,A:78,B:70

94.291 = L:74,A:-52,B:41 -> L:55,A:78,B:68

96.5941 = L:73,A:-51,B:43 -> L:54,A:78,B:67

80.0446 = L:73,A:-51,B:43 -> L:54,A:78,B:68

97.1101 = L:77,A:-53,B:39 -> L:57,A:73,B:71

96.6937 = L:75,A:-52,B:36 -> L:57,A:73,B:69

28.8294 = L:75,A:-51,B:38 -> L:56,A:74,B:69

98.1811 = L:75,A:-52,B:41 -> L:56,A:75,B:68

14.8961 = L:74,A:-50,B:40 -> L:55,A:76,B:67

27.6448 = L:74,A:-50,B:40 -> L:55,A:76,B:65

86.4338 = L:73,A:-51,B:43 -> L:57,A:73,B:60

81.8895 = L:76,A:-51,B:38 -> L:60,A:63,B:71

24.438 = L:76,A:-51,B:36 -> L:60,A:63,B:71

89.1922 = L:75,A:-51,B:38 -> L:60,A:65,B:70

33.4842 = L:75,A:-51,B:38 -> L:59,A:66,B:69

89.9636 = L:74,A:-52,B:41 -> L:58,A:69,B:68

88.1577 = L:74,A:-50,B:40 -> L:57,A:68,B:67

43.1233 = L:73,A:-51,B:43 -> L:59,A:66,B:61

49.822 = L:77,A:-52,B:34 -> L:62,A:61,B:72

80.0585 = L:76,A:-51,B:36 -> L:63,A:55,B:72

38.9359 = L:75,A:-52,B:36 -> L:63,A:56,B:72

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119.5771 = L:29,A:66,B:-108 -> L:89,A:-45,B:-5

119.0705 = L:30,A:67,B:-110 -> L:87,A:-44,B:-6

89.0199 = L:29,A:67,B:-109 -> L:88,A:-45,B:-2

128.5701 = L:31,A:65,B:-110 -> L:88,A:-48,B:4

127.4728 = L:30,A:67,B:-110 -> L:88,A:-48,B:5

129.7794 = L:29,A:65,B:-108 -> L:87,A:-49,B:9

117.154 = L:34,A:58,B:-105 -> L:86,A:-46,B:2

87.7114 = L:32,A:63,B:-108 -> L:86,A:-49,B:9

106.3149 = L:30,A:64,B:-108 -> L:86,A:-53,B:18

26.3934 = L:30,A:66,B:-108 -> L:84,A:-52,B:22

75.3405 = L:36,A:53,B:-102 -> L:86,A:-52,B:13

111.7985 = L:33,A:53,B:-100 -> L:85,A:-51,B:16

75.2223 = L:33,A:60,B:-106 -> L:84,A:-53,B:22

122.887 = L:32,A:64,B:-108 -> L:83,A:-53,B:26

67.5999 = L:31,A:63,B:-108 -> L:82,A:-52,B:24

20.6408 = L:42,A:39,B:-92 -> L:84,A:-53,B:18

94.7215 = L:39,A:43,B:-94 -> L:83,A:-52,B:22

30.5663 = L:36,A:52,B:-101 -> L:83,A:-52,B:22

98.1479 = L:35,A:54,B:-101 -> L:82,A:-53,B:24

98.9428 = L:35,A:57,B:-103 -> L:82,A:-53,B:24

65.8886 = L:48,A:24,B:-80 -> L:84,A:-55,B:22

86.2211 = L:44,A:32,B:-85 -> L:82,A:-53,B:24

39.298 = L:41,A:41,B:-93 -> L:82,A:-53,B:24

77.1534 = L:41,A:41,B:-92 -> L:82,A:-53,B:24

91.4875 = L:41,A:42,B:-92 -> L:80,A:-51,B:26

21.6078 = L:41,A:46,B:-93 -> L:80,A:-51,B:26

47.6355 = L:55,A:10,B:-68 -> L:80,A:-55,B:27

45.3189 = L:51,A:18,B:-74 -> L:82,A:-53,B:24

38.3059 = L:49,A:24,B:-80 -> L:81,A:-52,B:27

35.8789 = L:50,A:22,B:-78 -> L:81,A:-52,B:27

36.9149 = L:48,A:28,B:-79 -> L:80,A:-52,B:29

37.8141 = L:47,A:31,B:-80 -> L:80,A:-52,B:29

50.4786 = L:61,A:1,B:-61 -> L:79,A:-51,B:31

48.9717 = L:59,A:4,B:-63 -> L:81,A:-52,B:27

53.5339 = L:57,A:7,B:-65 -> L:81,A:-52,B:27

45.3416 = L:57,A:9,B:-66 -> L:80,A:-52,B:27

46.2779 = L:57,A:10,B:-67 -> L:80,A:-52,B:29

50.258 = L:59,A:12,B:-64 -> L:79,A:-51,B:31

54.76 = L:59,A:16,B:-62 -> L:78,A:-51,B:34

49.6179 = L:68,A:-13,B:-47 -> L:78,A:-51,B:34

42.586 = L:67,A:-12,B:-47 -> L:81,A:-52,B:27

48.2492 = L:68,A:-11,B:-49 -> L:80,A:-51,B:27

40.492 = L:67,A:-10,B:-48 -> L:80,A:-52,B:29

47.3911 = L:66,A:-3,B:-52 -> L:79,A:-51,B:31

40.6144 = L:69,A:-4,B:-47 -> L:78,A:-51,B:31

32.1303 = L:72,A:-2,B:-43 -> L:77,A:-51,B:33

36.6401 = L:79,A:-2,B:-32 -> L:77,A:-51,B:33

49.928 = L:75,A:-21,B:-39 -> L:76,A:-50,B:35

25.1103 = L:74,A:-20,B:-39 -> L:81,A:-51,B:25

41.7471 = L:75,A:-21,B:-38 -> L:80,A:-52,B:29

8.9032 = L:75,A:-19,B:-38 -> L:79,A:-52,B:29

25.8455 = L:74,A:-15,B:-40 -> L:78,A:-51,B:31

47.2695 = L:76,A:-18,B:-33 -> L:78,A:-52,B:33

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87.0177 = L:29,A:66,B:-108 -> L:94,A:-11,B:91

99.0146 = L:30,A:67,B:-110 -> L:96,A:-20,B:91

55.1024 = L:29,A:67,B:-109 -> L:97,A:-14,B:92

106.9765 = L:31,A:65,B:-110 -> L:94,A:-29,B:88

52.3658 = L:30,A:67,B:-110 -> L:95,A:-24,B:89

107.4486 = L:29,A:65,B:-108 -> L:89,A:-18,B:85

93.6752 = L:34,A:58,B:-105 -> L:86,A:-41,B:77

55.0869 = L:32,A:63,B:-108 -> L:92,A:-37,B:84

103.2683 = L:30,A:64,B:-108 -> L:94,A:-32,B:88

59.3731 = L:30,A:66,B:-108 -> L:95,A:-28,B:87

94.9259 = L:36,A:53,B:-102 -> L:85,A:-42,B:74

93.033 = L:33,A:53,B:-100 -> L:86,A:-42,B:75

103.306 = L:33,A:60,B:-106 -> L:87,A:-43,B:77

80.6808 = L:32,A:64,B:-108 -> L:88,A:-40,B:80

63.6604 = L:31,A:63,B:-108 -> L:91,A:-40,B:81

86.4314 = L:42,A:39,B:-92 -> L:80,A:-45,B:65

80.9731 = L:39,A:43,B:-94 -> L:84,A:-44,B:74

74.6775 = L:36,A:52,B:-101 -> L:85,A:-43,B:76

97.725 = L:35,A:54,B:-101 -> L:86,A:-41,B:78

84.9962 = L:35,A:57,B:-103 -> L:88,A:-44,B:82

61.5262 = L:48,A:24,B:-80 -> L:77,A:-47,B:61

59.0641 = L:44,A:32,B:-85 -> L:79,A:-46,B:64

67.898 = L:41,A:41,B:-93 -> L:80,A:-46,B:67

58.3033 = L:41,A:41,B:-92 -> L:82,A:-45,B:72

82.6753 = L:41,A:42,B:-92 -> L:83,A:-46,B:73

87.2289 = L:41,A:46,B:-93 -> L:85,A:-45,B:76

53.7391 = L:55,A:10,B:-68 -> L:75,A:-50,B:57

62.0448 = L:51,A:18,B:-74 -> L:77,A:-48,B:59

67.0505 = L:49,A:24,B:-80 -> L:78,A:-48,B:64

64.8611 = L:50,A:22,B:-78 -> L:79,A:-47,B:67

66.8684 = L:48,A:28,B:-79 -> L:80,A:-46,B:70

68.3471 = L:47,A:31,B:-80 -> L:82,A:-46,B:73

70.1205 = L:61,A:1,B:-61 -> L:82,A:-46,B:72

45.6166 = L:59,A:4,B:-63 -> L:74,A:-51,B:51

65.9821 = L:57,A:7,B:-65 -> L:75,A:-50,B:57

64.6532 = L:57,A:9,B:-66 -> L:76,A:-49,B:60

62.4555 = L:57,A:10,B:-67 -> L:77,A:-49,B:60

67.0333 = L:59,A:12,B:-64 -> L:79,A:-47,B:67

68.3852 = L:59,A:16,B:-62 -> L:80,A:-47,B:67

52.2807 = L:68,A:-13,B:-47 -> L:80,A:-46,B:70

65.1192 = L:67,A:-12,B:-47 -> L:74,A:-52,B:50

61.7811 = L:68,A:-11,B:-49 -> L:73,A:-51,B:52

38.3 = L:67,A:-10,B:-48 -> L:74,A:-50,B:55

70.9818 = L:66,A:-3,B:-52 -> L:75,A:-50,B:59

68.5112 = L:69,A:-4,B:-47 -> L:76,A:-49,B:60

61.2416 = L:72,A:-2,B:-43 -> L:78,A:-48,B:63

62.693 = L:79,A:-2,B:-32 -> L:79,A:-47,B:66

62.2437 = L:75,A:-21,B:-39 -> L:79,A:-48,B:68

60.4955 = L:74,A:-20,B:-39 -> L:74,A:-50,B:59

9.2753 = L:75,A:-21,B:-38 -> L:76,A:-49,B:59

56.6167 = L:75,A:-19,B:-38 -> L:77,A:-48,B:64

51.4023 = L:74,A:-15,B:-40 -> L:78,A:-47,B:67

49.6842 = L:76,A:-18,B:-33 -> L:79,A:-47,B:67

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114.7374 = L:29,A:66,B:-108 -> L:74,A:-52,B:46

95.2833 = L:30,A:67,B:-110 -> L:72,A:-52,B:45

116.0507 = L:29,A:67,B:-109 -> L:74,A:-57,B:53

117.9842 = L:31,A:65,B:-110 -> L:74,A:-52,B:46

90.1815 = L:30,A:67,B:-110 -> L:73,A:-52,B:48

116.4717 = L:29,A:65,B:-108 -> L:72,A:-49,B:43

64.7122 = L:34,A:58,B:-105 -> L:73,A:-51,B:43

95.6907 = L:32,A:63,B:-105 -> L:72,A:-52,B:45

44.9578 = L:30,A:64,B:-108 -> L:73,A:-52,B:48

21.5423 = L:30,A:66,B:-108 -> L:73,A:-52,B:48

104.5723 = L:36,A:53,B:-102 -> L:74,A:-53,B:47

20.1543 = L:33,A:53,B:-100 -> L:72,A:-52,B:45

108.6668 = L:33,A:60,B:-106 -> L:73,A:-52,B:48

65.3108 = L:32,A:64,B:-108 -> L:72,A:-51,B:42

78.7131 = L:31,A:63,B:-108 -> L:73,A:-55,B:52

23.7322 = L:42,A:39,B:-92 -> L:73,A:-51,B:43

95.9958 = L:39,A:43,B:-94 -> L:72,A:-52,B:45

103.4151 = L:36,A:52,B:-101 -> L:73,A:-52,B:48

101.3062 = L:35,A:54,B:-101 -> L:73,A:-52,B:48

16.2155 = L:35,A:57,B:-103 -> L:73,A:-51,B:49

50.8692 = L:48,A:24,B:-80 -> L:74,A:-52,B:46

80.8027 = L:44,A:32,B:-85 -> L:72,A:-52,B:45

47.0313 = L:41,A:41,B:-93 -> L:72,A:-52,B:48

32.6916 = L:41,A:41,B:-92 -> L:72,A:-51,B:47

81.7967 = L:41,A:42,B:-92 -> L:72,A:-51,B:47

58.5953 = L:41,A:46,B:-93 -> L:72,A:-52,B:50

54.7942 = L:55,A:10,B:-68 -> L:73,A:-51,B:43

52.2167 = L:51,A:10,B:-74 -> L:72,A:-52,B:45

56.4262 = L:49,A:24,B:-80 -> L:73,A:-52,B:48

57.5292 = L:50,A:22,B:-78 -> L:73,A:-52,B:48

72.3844 = L:48,A:28,B:-79 -> L:73,A:-51,B:49

72.164 = L:47,A:31,B:-80 -> L:74,A:-55,B:53

39.8016 = L:61,A:1,B:-61 -> L:72,A:-51,B:52

56.2086 = L:59,A:4,B:-63 -> L:74,A:-52,B:46

51.3806 = L:57,A:7,B:-65 -> L:72,A:-52,B:45

56.1383 = L:57,A:9,B:-66 -> L:72,A:-52,B:45

58.3162 = L:57,A:10,B:-67 -> L:73,A:-52,B:48

53.1622 = L:59,A:12,B:-64 -> L:73,A:-51,B:49

49.2631 = L:59,A:16,B:-62 -> L:73,A:-51,B:49

61.5287 = L:68,A:-13,B:-47 -> L:69,A:-48,B:49

19.478 = L:67,A:-12,B:-47 -> L:73,A:-51,B:43

50.7317 = L:68,A:-11,B:-49 -> L:72,A:-52,B:45

15.0584 = L:67,A:-10,B:-48 -> L:73,A:-52,B:48

44.1934 = L:66,A:-3,B:-52 -> L:72,A:-51,B:47

59.4618 = L:69,A:-4,B:-47 -> L:72,A:-51,B:47

42.0854 = L:72,A:-2,B:-43 -> L:73,A:-52,B:52

48.4818 = L:79,A:-2,B:-32 -> L:73,A:-52,B:52

52.7679 = L:75,A:-21,B:-39 -> L:72,A:-51,B:52

36.7132 = L:74,A:-20,B:-39 -> L:73,A:-51,B:43

57.1778 = L:75,A:-21,B:-38 -> L:72,A:-52,B:45

47.3599 = L:75,A:-19,B:-38 -> L:73,A:-52,B:48

7.9987 = L:74,A:-15,B:-40 -> L:72,A:-51,B:47

53.0807 = L:76,A:-18,B:-33 -> L:73,A:-51,B:49

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53.9353 = L:29,A:66,B:-108 -> L:54,A:81,B:60

76.1627 = L:30,A:67,B:-110 -> L:54,A:80,B:60

63.079 = L:29,A:67,B:-109 -> L:54,A:80,B:65

21.3616 = L:31,A:65,B:-110 -> L:54,A:80,B:61

77.431 = L:30,A:67,B:-110 -> L:54,A:81,B:64

74.5815 = L:29,A:65,B:-108 -> L:54,A:81,B:67

64.0639 = L:34,A:58,B:-105 -> L:54,A:80,B:63

74.6958 = L:32,A:63,B:-108 -> L:54,A:81,B:68

60.8479 = L:30,A:64,B:-108 -> L:54,A:81,B:68

43.8886 = L:30,A:66,B:-108 -> L:54,A:81,B:70

67.8393 = L:36,A:53,B:-102 -> L:54,A:80,B:65

65.5143 = L:33,A:53,B:-100 -> L:54,A:81,B:68

70.6945 = L:33,A:60,B:-106 -> L:54,A:81,B:70

73.4712 = L:32,A:64,B:-108 -> L:54,A:81,B:70

36.0827 = L:31,A:63,B:-108 -> L:54,A:80,B:67

56.4535 = L:42,A:39,B:-92 -> L:54,A:80,B:67

57.0171 = L:39,A:43,B:-94 -> L:54,A:80,B:68

50.2911 = L:36,A:52,B:-101 -> L:54,A:80,B:68

66.8824 = L:35,A:54,B:-101 -> L:54,A:79,B:68

67.4719 = L:35,A:57,B:-103 -> L:54,A:79,B:70

42.3781 = L:48,A:24,B:-80 -> L:54,A:79,B:67

52.0663 = L:44,A:32,B:-85 -> L:54,A:79,B:67

56.1688 = L:41,A:41,B:-93 -> L:55,A:80,B:68

54.8744 = L:41,A:41,B:-92 -> L:54,A:79,B:69

54.8024 = L:41,A:42,B:-92 -> L:54,A:79,B:68

57.5162 = L:41,A:46,B:-93 -> L:55,A:79,B:70

37.1196 = L:55,A:10,B:-68 -> L:55,A:79,B:66

41.1353 = L:51,A:18,B:-74 -> L:55,A:78,B:68

66.9108 = L:49,A:24,B:-80 -> L:54,A:78,B:68

61.3579 = L:50,A:22,B:-78 -> L:55,A:78,B:68

34.0403 = L:48,A:28,B:-79 -> L:55,A:78,B:70

70.2777 = L:47,A:31,B:-80 -> L:55,A:76,B:67

88.5046 = L:61,A:1,B:-61 -> L:54,A:78,B:67

39.8325 = L:59,A:4,B:-63 -> L:57,A:75,B:65

31.67 = L:57,A:7,B:-65 -> L:56,A:76,B:67

74.4539 = L:57,A:9,B:-66 -> L:56,A:75,B:68

76.256 = L:57,A:10,B:-67 -> L:56,A:74,B:69

86.2475 = L:59,A:12,B:-64 -> L:57,A:74,B:69

28.8569 = L:59,A:16,B:-62 -> L:57,A:73,B:69

47.7114 = L:68,A:-13,B:-47 -> L:54,A:69,B:65
71.9629 = L:67,A:-12,B:-47 -> L:62,A:59,B:50

87.6608 = L:67,A:-11,B:-49 -> L:59,A:66,B:60

20.5198 = L:67,A:-10,B:-48 -> L:58,A:68,B:67

31.101 = L:67,A:-3,B:-52 -> L:58,A:70,B:68

51.0689 = L:69,A:-4,B:-47 -> L:59,A:67,B:69

88.537 = L:72,A:-2,B:-43 -> L:58,A:70,B:69

34.9562 = L:79,A:-2,B:-32 -> L:59,A:67,B:70

99.725 = L:75,A:-21,B:-39 -> L:60,A:64,B:71

96.1516 = L:74,A:-20,B:-39 -> L:64,A:55,B:71

68.9022 = L:75,A:-21,B:-38 -> L:61,A:61,B:69

100.4391 = L:75,A:-19,B:-38 -> L:63,A:57,B:72

96.7782 = L:74,A:-15,B:-40 -> L:63,A:57,B:71

69.7913 = L:76,A:-18,B:-33 -> L:64,A:55,B:72

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31.0979 = L:78,A:-53,B:32 -> L:94,A:-11,B:89

47.5023 = L:77,A:-51,B:31 -> L:95,A:-12,B:91

39.9306 = L:77,A:-52,B:34 -> L:97,A:-16,B:91

30.4435 = L:77,A:-52,B:36 -> L:96,A:-15,B:91

34.2857 = L:76,A:-51,B:36 -> L:96,A:-19,B:88

29.0611 = L:75,A:-51,B:38 -> L:95,A:-25,B:82

22.6637 = L:75,A:-52,B:41 -> L:93,A:-28,B:71

15.7285 = L:74,A:-50,B:40 -> L:92,A:-29,B:56

15.0846 = L:74,A:-51,B:42 -> L:91,A:-23,B:40

45.4059 = L:79,A:-53,B:32 -> L:97,A:-14,B:92

43.4643 = L:78,A:-53,B:32 -> L:96,A:-19,B:90

39.3879 = L:78,A:-52,B:32 -> L:97,A:-21,B:90

36.7084 = L:77,A:-52,B:34 -> L:95,A:-26,B:89

32.6626 = L:76,A:-51,B:36 -> L:94,A:-32,B:85

31.8188 = L:75,A:-50,B:36 -> L:93,A:-34,B:81

21.6858 = L:75,A:-51,B:38 -> L:90,A:-37,B:71

12.3676 = L:74,A:-50,B:40 -> L:89,A:-37,B:62

16.1373 = L:74,A:-51,B:42 -> L:89,A:-32,B:47

33.6562 = L:82,A:-59,B:33 -> L:92,A:-19,B:80

43.9925 = L:79,A:-52,B:29 -> L:95,A:-24,B:89

37.7351 = L:79,A:-53,B:32 -> L:94,A:-31,B:88

29.6685 = L:78,A:-52,B:34 -> L:93,A:-35,B:84

29.4795 = L:77,A:-52,B:34 -> L:90,A:-36,B:83

21.3699 = L:77,A:-51,B:33 -> L:88,A:-39,B:76

22.005 = L:76,A:-50,B:35 -> L:88,A:-41,B:70

17.3161 = L:75,A:-51,B:38 -> L:85,A:-38,B:61

10.0352 = L:75,A:-50,B:40 -> L:84,A:-36,B:52

15.2342 = L:74,A:-51,B:42 -> L:83,A:-32,B:42

44.1884 = L:79,A:-50,B:27 -> L:95,A:-30,B:90

39.2162 = L:79,A:-52,B:29 -> L:94,A:-32,B:88

26.8847 = L:79,A:-52,B:29 -> L:92,A:-37,B:84

7.8065 = L:78,A:-51,B:31 -> L:88,A:-42,B:79

18.715 = L:78,A:-52,B:34 -> L:87,A:-41,B:78

25.1587 = L:77,A:-51,B:33 -> L:85,A:-44,B:73

21.2629 = L:77,A:-52,B:36 -> L:85,A:-42,B:68

14.0582 = L:76,A:-50,B:35 -> L:83,A:-42,B:63

8.9962 = L:75,A:-50,B:40 -> L:82,A:-40,B:53

8.4171 = L:74,A:-50,B:40 -> L:81,A:-38,B:47

5.9202 = L:74,A:-51,B:42 -> L:80,A:-39,B:41

25.7613 = L:81,A:-52,B:27 -> L:90,A:-40,B:81

31.6129 = L:80,A:-51,B:27 -> L:88,A:-41,B:78

26.427 = L:80,A:-52,B:29 -> L:87,A:-43,B:76

16.4318 = L:79,A:-51,B:31 -> L:85,A:-42,B:72

27.0169 = L:78,A:-51,B:31 -> L:83,A:-43,B:70

11.7956 = L:78,A:-51,B:34 -> L:82,A:-44,B:67

16.1984 = L:77,A:-51,B:33 -> L:80,A:-44,B:62

14.46 = L:76,A:-50,B:35 -> L:80,A:-44,B:56

5.1395 = L:75,A:-51,B:38 -> L:78,A:-43,B:47

4.6285 = L:75,A:-50,B:40 -> L:77,A:-44,B:42

3.05 = L:74,A:-51,B:42 -> L:77,A:-44,B:36

36.5568 = L:81,A:-48,B:22 -> L:87,A:-43,B:81

30.3208 = L:82,A:-52,B:24 -> L:86,A:-43,B:74

33.1328 = L:81,A:-52,B:27 -> L:85,A:-43,B:76

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109.2251 = L:78,A:-53,B:32 -> L:62,A:84,B:-57

77.1532 = L:77,A:-51,B:31 -> L:58,A:76,B:-62

95.8416 = L:77,A:-52,B:34 -> L:54,A:72,B:-65

36.6573 = L:77,A:-52,B:36 -> L:50,A:69,B:-74

61.1407 = L:76,A:-51,B:36 -> L:46,A:68,B:-81

74.5245 = L:75,A:-51,B:38 -> L:42,A:67,B:-88

107.0383 = L:75,A:-52,B:41 -> L:38,A:66,B:-97

92.8478 = L:74,A:-50,B:40 -> L:35,A:66,B:-103

115.6786 = L:74,A:-51,B:42 -> L:34,A:66,B:-104

92.8595 = L:79,A:-53,B:32 -> L:62,A:78,B:-57

23.8461 = L:78,A:-53,B:32 -> L:60,A:76,B:-62

72.6333 = L:78,A:-52,B:32 -> L:56,A:71,B:-68

90.1744 = L:77,A:-52,B:34 -> L:51,A:67,B:-73

55.6256 = L:76,A:-51,B:36 -> L:46,A:64,B:-80

108.6456 = L:75,A:-50,B:36 -> L:42,A:65,B:-90

112.5458 = L:75,A:-51,B:38 -> L:37,A:65,B:-98

111.6127 = L:74,A:-50,B:40 -> L:35,A:65,B:-104

44.1758 = L:74,A:-51,B:42 -> L:32,A:64,B:-104

97.9482 = L:82,A:-59,B:33 -> L:64,A:74,B:-55

35.5568 = L:79,A:-52,B:29 -> L:61,A:71,B:-58

47.7532 = L:79,A:-53,B:32 -> L:56,A:65,B:-64

41.9059 = L:78,A:-52,B:34 -> L:53,A:64,B:-73

102.0542 = L:77,A:-52,B:34 -> L:47,A:61,B:-83

89.4912 = L:77,A:-51,B:33 -> L:42,A:62,B:-91

106.7497 = L:76,A:-50,B:35 -> L:38,A:63,B:-97

105.2978 = L:75,A:-51,B:38 -> L:34,A:65,B:-104

92.3578 = L:75,A:-50,B:40 -> L:32,A:66,B:-106

55.3579 = L:74,A:-51,B:42 -> L:31,A:66,B:-109

84.0779 = L:79,A:-50,B:27 -> L:67,A:66,B:-47

81.7693 = L:79,A:-52,B:29 -> L:64,A:61,B:-53

85.8412 = L:79,A:-52,B:29 -> L:62,A:59,B:-56

38.5948 = L:78,A:-51,B:31 -> L:55,A:55,B:-64

96.2057 = L:78,A:-52,B:34 -> L:49,A:57,B:-80

103.4102 = L:77,A:-51,B:33 -> L:43,A:58,B:-89

94.762 = L:77,A:-52,B:36 -> L:38,A:60,B:-99

36.5317 = L:76,A:-50,B:35 -> L:34,A:64,B:-105

92.5317 = L:75,A:-50,B:40 -> L:32,A:65,B:-108

93.3629 = L:74,A:-50,B:40 -> L:30,A:65,B:-108

93.6693 = L:74,A:-51,B:42 -> L:29,A:66,B:-108

73.5257 = L:81,A:-52,B:27 -> L:72,A:52,B:-40

70.2053 = L:80,A:-51,B:27 -> L:70,A:52,B:-43

62.8444 = L:80,A:-52,B:29 -> L:67,A:46,B:-50

54.0731 = L:79,A:-51,B:31 -> L:61,A:45,B:-58

85.6009 = L:78,A:-51,B:31 -> L:53,A:46,B:-70

63.6057 = L:78,A:-51,B:34 -> L:46,A:51,B:-83

100.6306 = L:77,A:-51,B:33 -> L:40,A:55,B:-95

108.6204 = L:76,A:-50,B:35 -> L:34,A:59,B:-100

45.3854 = L:75,A:-51,B:38 -> L:32,A:64,B:-108

117.9678 = L:75,A:-50,B:40 -> L:31,A:63,B:-107

95.0023 = L:74,A:-51,B:42 -> L:31,A:61,B:-104

65.3298 = L:81,A:-48,B:22 -> L:80,A:37,B:-29

62.3438 = L:82,A:-52,B:24 -> L:77,A:37,B:-33

52.75 = L:81,A:-52,B:27 -> L:74,A:34,B:-38

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60.2752 = L:78,A:-53,B:32 -> L:53,A:78,B:62

97.6021 = L:77,A:-51,B:31 -> L:54,A:81,B:60

58.4598 = L:77,A:-52,B:34 -> L:52,A:78,B:52

77.1793 = L:77,A:-52,B:35 -> L:52,A:81,B:50

72.971 = L:76,A:-51,B:36 -> L:53,A:79,B:39

74.9895 = L:75,A:-51,B:38 -> L:55,A:82,B:37

97.3949 = L:75,A:-52,B:41 -> L:55,A:82,B:26

70.023 = L:74,A:-50,B:40 -> L:55,A:82,B:16

94.7179 = L:74,A:-51,B:42 -> L:56,A:83,B:3

31.6556 = L:79,A:-53,B:32 -> L:54,A:81,B:65

31.2232 = L:78,A:-53,B:32 -> L:54,A:81,B:65

93.0461 = L:78,A:-52,B:32 -> L:54,A:80,B:60

32.0296 = L:77,A:-52,B:34 -> L:54,A:81,B:55

102.0137 = L:76,A:-51,B:36 -> L:54,A:80,B:53

42.3146 = L:75,A:-50,B:36 -> L:55,A:81,B:45

93.0622 = L:75,A:-51,B:38 -> L:54,A:81,B:35

100.516 = L:74,A:-50,B:40 -> L:55,A:82,B:27

62.7463 = L:74,A:-51,B:42 -> L:56,A:82,B:16

91.4954 = L:82,A:-59,B:33 -> L:54,A:81,B:67

53.7756 = L:79,A:-52,B:29 -> L:54,A:81,B:65

104.61 = L:79,A:-53,B:32 -> L:54,A:80,B:62

104.5092 = L:78,A:-52,B:34 -> L:54,A:81,B:58

30.6339 = L:77,A:-52,B:34 -> L:54,A:80,B:52

66.4652 = L:77,A:-51,B:33 -> L:55,A:81,B:45

77.7456 = L:76,A:-50,B:35 -> L:55,A:81,B:35

62.0089 = L:75,A:-51,B:38 -> L:55,A:82,B:22

68.7757 = L:75,A:-50,B:40 -> L:55,A:81,B:7

85.1627 = L:74,A:-51,B:42 -> L:56,A:81,B:0

63.9972 = L:79,A:-50,B:27 -> L:54,A:80,B:70

104.434 = L:79,A:-52,B:29 -> L:54,A:81,B:68

31.32 = L:79,A:-52,B:29 -> L:54,A:80,B:66

74.1393 = L:78,A:-51,B:31 -> L:54,A:80,B:63

105.181 = L:78,A:-52,B:34 -> L:54,A:81,B:59

78.6427 = L:77,A:-51,B:33 -> L:55,A:81,B:55

97.0642 = L:77,A:-52,B:36 -> L:55,A:81,B:47

77.7456 = L:76,A:-50,B:35 -> L:55,A:81,B:35

61.8052 = L:75,A:-50,B:40 -> L:55,A:82,B:22

72.0218 = L:74,A:-50,B:40 -> L:56,A:81,B:6

70.1804 = L:74,A:-51,B:42 -> L:57,A:81,B:-3

58.8963 = L:81,A:-52,B:27 -> L:54,A:80,B:66

58.0381 = L:80,A:-51,B:27 -> L:54,A:80,B:70

98.7003 = L:80,A:-52,B:29 -> L:54,A:81,B:70

86.848 = L:79,A:-51,B:31 -> L:54,A:80,B:67

26.6119 = L:78,A:-51,B:31 -> L:54,A:80,B:64

98.3279 = L:78,A:-51,B:34 -> L:55,A:80,B:63

103.0562 = L:77,A:-51,B:33 -> L:55,A:81,B:56

33.7893 = L:76,A:-50,B:35 -> L:55,A:81,B:46

49.3704 = L:75,A:-51,B:38 -> L:56,A:81,B:37

92.1588 = L:75,A:-50,B:40 -> L:56,A:81,B:22

71.7211 = L:74,A:-51,B:42 -> L:57,A:78,B:8

17.7085 = L:81,A:-48,B:22 -> L:54,A:80,B:70

44.2421 = L:82,A:-52,B:24 -> L:54,A:79,B:68

87.5412 = L:81,A:-52,B:27 -> L:54,A:79,B:68

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98.315 = L:74,A:-52,B:46 -> L:54,A:80,B:59

72.8773 = L:74,A:-52,B:48 -> L:53,A:80,B:54

68.0079 = L:72,A:-51,B:47 -> L:55,A:81,B:50

59.9138 = L:73,A:-51,B:49 -> L:53,A:79,B:39

95.1216 = L:72,A:-51,B:51 -> L:55,A:82,B:36

67.735 = L:73,A:-50,B:55 -> L:55,A:81,B:27

78.3621 = L:73,A:-50,B:55 -> L:55,A:82,B:16

76.1381 = L:74,A:-51,B:57 -> L:56,A:82,B:4

85.1234 = L:74,A:-48,B:55 -> L:56,A:82,B:-6

100.6395 = L:74,A:-52,B:46 -> L:54,A:80,B:65

51.4789 = L:74,A:-52,B:46 -> L:54,A:80,B:60

63.6928 = L:72,A:-51,B:47 -> L:54,A:81,B:55

77.0563 = L:73,A:-51,B:49 -> L:54,A:80,B:52

85.5102 = L:72,A:-51,B:51 -> L:55,A:81,B:44

90.016 = L:73,A:-50,B:55 -> L:54,A:81,B:35

85.4215 = L:74,A:-51,B:57 -> L:55,A:82,B:27

85.1497 = L:74,A:-50,B:59 -> L:56,A:82,B:16

71.893 = L:75,A:-48,B:58 -> L:56,A:81,B:6

84.1138 = L:76,A:-48,B:58 -> L:57,A:83,B:-8

35.296 = L:73,A:-51,B:43 -> L:54,A:81,B:67

25.4792 = L:74,A:-52,B:46 -> L:54,A:81,B:64

80.1242 = L:73,A:-51,B:47 -> L:54,A:80,B:61

52.8782 = L:73,A:-51,B:49 -> L:54,A:81,B:57

88.3082 = L:72,A:-51,B:51 -> L:54,A:80,B:52

92.5132 = L:74,A:-51,B:53 -> L:55,A:81,B:45

72.3243 = L:74,A:-51,B:57 -> L:55,A:81,B:36

82.7209 = L:75,A:-50,B:59 -> L:55,A:81,B:29

80.3549 = L:76,A:-49,B:62 -> L:55,A:81,B:8

78.2016 = L:77,A:-48,B:64 -> L:57,A:82,B:-2

55.6472 = L:73,A:-51,B:43 -> L:54,A:80,B:70

11.0784 = L:73,A:-50,B:45 -> L:54,A:81,B:68

41.5716 = L:73,A:-51,B:47 -> L:54,A:80,B:66

66.0432 = L:74,A:-52,B:50 -> L:54,A:80,B:63

42.6993 = L:73,A:-51,B:52 -> L:55,A:81,B:59

49.3137 = L:74,A:-50,B:55 -> L:55,A:81,B:53

78.5791 = L:74,A:-50,B:59 -> L:55,A:81,B:45

67.9253 = L:76,A:-49,B:60 -> L:55,A:82,B:35

81.8194 = L:77,A:-48,B:64 -> L:55,A:81,B:25

76.3247 = L:78,A:-47,B:67 -> L:56,A:82,B:7

73.7465 = L:79,A:-47,B:67 -> L:58,A:80,B:-4

62.0101 = L:74,A:-50,B:44 -> L:54,A:80,B:67

85.2282 = L:73,A:-50,B:45 -> L:54,A:81,B:70

85.2282 = L:73,A:-50,B:45 -> L:54,A:81,B:70

99.738 = L:74,A:-52,B:50 -> L:54,A:81,B:68

28.11 = L:73,A:-51,B:52 -> L:54,A:80,B:68

78.3777 = L:74,A:-50,B:55 -> L:54,A:80,B:62

89.3419 = L:75,A:-50,B:59 -> L:55,A:80,B:58

65.2293 = L:76,A:-49,B:60 -> L:54,A:80,B:42

70.2431 = L:77,A:-48,B:64 -> L:54,A:80,B:38

77.3913 = L:79,A:-47,B:67 -> L:56,A:81,B:23

76.1964 = L:80,A:-46,B:70 -> L:57,A:78,B:1

103.2755 = L:74,A:-49,B:42 -> L:54,A:80,B:70

33.1671 = L:74,A:-50,B:44 -> L:53,A:78,B:68

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98.315 = L:74,A:-52,B:46 -> L:54,A:80,B:59

72.8773 = L:74,A:-52,B:48 -> L:53,A:80,B:54

68.0079 = L:72,A:-51,B:47 -> L:55,A:81,B:50

59.9138 = L:73,A:-51,B:49 -> L:53,A:79,B:39

95.1216 = L:72,A:-51,B:51 -> L:55,A:82,B:36

67.735 = L:73,A:-50,B:55 -> L:55,A:81,B:27

78.3621 = L:73,A:-50,B:55 -> L:55,A:82,B:16

76.1381 = L:74,A:-51,B:57 -> L:56,A:82,B:4

85.1234 = L:74,A:-48,B:55 -> L:56,A:82,B:-6

100.6395 = L:74,A:-52,B:46 -> L:54,A:80,B:65

51.4789 = L:74,A:-52,B:46 -> L:54,A:80,B:60

63.6928 = L:72,A:-51,B:47 -> L:54,A:81,B:55

77.0563 = L:73,A:-51,B:49 -> L:54,A:80,B:52

85.5102 = L:72,A:-51,B:51 -> L:55,A:81,B:44

90.016 = L:73,A:-50,B:55 -> L:54,A:81,B:35

85.4215 = L:74,A:-51,B:57 -> L:55,A:82,B:27

85.1497 = L:74,A:-50,B:59 -> L:56,A:82,B:16

71.893 = L:75,A:-48,B:58 -> L:56,A:81,B:6

84.1138 = L:76,A:-48,B:58 -> L:57,A:83,B:-8

35.296 = L:73,A:-51,B:43 -> L:54,A:81,B:67

25.4792 = L:74,A:-52,B:46 -> L:54,A:81,B:64

80.1242 = L:73,A:-51,B:47 -> L:54,A:80,B:61

52.8782 = L:73,A:-51,B:49 -> L:54,A:81,B:57

88.3082 = L:72,A:-51,B:51 -> L:54,A:80,B:52

92.5132 = L:74,A:-51,B:53 -> L:55,A:81,B:45

72.3243 = L:74,A:-51,B:57 -> L:55,A:81,B:36

82.7209 = L:75,A:-50,B:59 -> L:55,A:81,B:29

80.3549 = L:76,A:-49,B:62 -> L:55,A:81,B:8

78.2016 = L:77,A:-48,B:64 -> L:57,A:82,B:-2

55.6472 = L:73,A:-51,B:43 -> L:54,A:80,B:70

11.0784 = L:73,A:-50,B:45 -> L:54,A:81,B:68

41.5716 = L:73,A:-51,B:47 -> L:54,A:80,B:66

66.0432 = L:74,A:-52,B:50 -> L:54,A:80,B:63

42.6993 = L:73,A:-51,B:52 -> L:55,A:81,B:59

49.3137 = L:74,A:-50,B:55 -> L:55,A:81,B:53

78.5791 = L:74,A:-50,B:59 -> L:55,A:81,B:45

67.9253 = L:76,A:-49,B:60 -> L:55,A:82,B:35

81.8194 = L:77,A:-48,B:64 -> L:55,A:81,B:25

76.3247 = L:78,A:-47,B:67 -> L:56,A:82,B:7

73.7465 = L:79,A:-47,B:67 -> L:58,A:80,B:-4

62.0101 = L:74,A:-50,B:44 -> L:54,A:80,B:67

85.2282 = L:73,A:-50,B:45 -> L:54,A:81,B:70

85.2282 = L:73,A:-50,B:45 -> L:54,A:81,B:70

99.738 = L:74,A:-52,B:50 -> L:54,A:81,B:68

28.11 = L:73,A:-51,B:52 -> L:54,A:80,B:68

78.3777 = L:74,A:-50,B:55 -> L:54,A:80,B:62

89.3419 = L:75,A:-50,B:59 -> L:55,A:80,B:58

65.2293 = L:76,A:-49,B:60 -> L:54,A:80,B:42

70.2431 = L:77,A:-48,B:64 -> L:54,A:80,B:38

77.3913 = L:79,A:-47,B:67 -> L:56,A:81,B:23

76.1964 = L:80,A:-46,B:70 -> L:57,A:78,B:1

103.2755 = L:74,A:-49,B:42 -> L:54,A:80,B:70

33.1671 = L:74,A:-50,B:44 -> L:53,A:78,B:68

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108.2791 = L:29,A:66,B:-108 -> L:83,A:6,B:83

52.3915 = L:30,A:67,B:-109 -> L:87,A:1,B:86

98.5823 = L:31,A:67,B:-110 -> L:89,A:0,B:86

71.6501 = L:31,A:67,B:-108 -> L:89,A:-1,B:87

53.8934 = L:32,A:66,B:-107 -> L:95,A:-12,B:89

103.0525 = L:34,A:66,B:-104 -> L:95,A:-13,B:90

85.2658 = L:36,A:65,B:-100 -> L:96,A:-17,B:84

89.4411 = L:39,A:66,B:-96 -> L:97,A:-18,B:74

24.6526 = L:43,A:68,B:-89 -> L:96,A:-19,B:54

95.6893 = L:30,A:67,B:-110 -> L:74,A:31,B:78

97.8797 = L:29,A:67,B:-109 -> L:77,A:23,B:79

42.6921 = L:30,A:67,B:-110 -> L:78,A:23,B:79

42.9434 = L:30,A:68,B:-108 -> L:83,A:10,B:83

96.7768 = L:31,A:66,B:-107 -> L:87,A:4,B:83

38.8072 = L:32,A:65,B:-104 -> L:89,A:0,B:83

55.4924 = L:35,A:66,B:-103 -> L:90,A:-4,B:77

103.5651 = L:38,A:65,B:-97 -> L:97,A:-11,B:66

90.2347 = L:42,A:67,B:-91 -> L:97,A:-9,B:53

74.9428 = L:31,A:65,B:-110 -> L:69,A:42,B:75

76.5614 = L:30,A:67,B:-110 -> L:67,A:48,B:73

87.4578 = L:29,A:65,B:-108 -> L:70,A:39,B:74

9.5654 = L:30,A:67,B:-110 -> L:73,A:32,B:76

14.492 = L:32,A:66,B:-107 -> L:72,A:37,B:72

46.3854 = L:32,A:66,B:-107 -> L:75,A:28,B:73

105.3679 = L:35,A:65,B:-103 -> L:81,A:17,B:67

96.0703 = L:38,A:63,B:-97 -> L:89,A:5,B:52

38.2732 = L:43,A:62,B:-88 -> L:89,A:3,B:39

90.2501 = L:48,A:61,B:-81 -> L:94,A:0,B:24

87.3178 = L:53,A:65,B:-72 -> L:96,A:1,B:19

59.2032 = L:34,A:58,B:-105 -> L:64,A:55,B:72

68.58 = L:32,A:63,B:-108 -> L:63,A:56,B:72

21.0001 = L:30,A:64,B:-108 -> L:64,A:55,B:72

15.1125 = L:30,A:66,B:-108 -> L:63,A:58,B:70

36.3297 = L:30,A:65,B:-108 -> L:62,A:61,B:70

83.9347 = L:31,A:64,B:-107 -> L:63,A:56,B:69

59.9911 = L:35,A:63,B:-103 -> L:67,A:49,B:64

79.5961 = L:38,A:60,B:-98 -> L:68,A:46,B:55

61.12 = L:43,A:58,B:-89 -> L:72,A:38,B:44

69.2509 = L:50,A:57,B:-79 -> L:81,A:24,B:26

26.5372 = L:54,A:55,B:-64 -> L:87,A:14,B:16

76.6882 = L:36,A:53,B:-102 -> L:59,A:65,B:70

70.491 = L:33,A:53,B:-100 -> L:59,A:66,B:70

36.6999 = L:33,A:60,B:-106 -> L:59,A:69,B:70

27.2779 = L:32,A:64,B:-108 -> L:59,A:66,B:69

69.9944 = L:31,A:63,B:-108 -> L:59,A:68,B:68

57.6338 = L:32,A:64,B:-107 -> L:58,A:67,B:67

68.5993 = L:34,A:59,B:-100 -> L:61,A:61,B:61

16.7627 = L:39,A:56,B:-95 -> L:62,A:59,B:55

38.3843 = L:49,A:49,B:-80 -> L:67,A:52,B:34

63.2953 = L:53,A:51,B:-73 -> L:73,A:35,B:21

58.4184 = L:64,A:40,B:-54 -> L:85,A:19,B:10

60.0583 = L:42,A:39,B:-92 -> L:57,A:73,B:70

61.4447 = L:39,A:43,B:-94 -> L:57,A:74,B:69

Appendix G- Data Analyses of Part II

ONEWAY V.Complexity BY AbstractImages

/POSTHOC=SCHEFFE ALPHA(0.05).

Oneway

ANOVA

V.Complexity

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	895,281	18	49,738	54,146	,000
Within Groups	2076,908	2261	,919		
Total	2972,189	2279			

Post Hoc Tests- Multiple Comparisons

V.Complexity

Scheffe

(I) AbstractImages	(J) AbstractImages	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-,058	,124	1,000	-,72	,61
	3	-,208	,124	1,000	-,87	,46
	4	-,925*	,124	,000	-1,59	-,26
	5	-,908*	,124	,000	-1,57	-,24
	6	-,925*	,124	,000	-1,59	-,26
	7	-1,242*	,124	,000	-1,91	-,58
	8	-,917*	,124	,000	-1,58	-,25
	9	-1,692*	,124	,000	-2,36	-1,03
	10	-,475	,124	,680	-1,14	,19

	11	-1,583*	,124	,000	-2,25	-,92
	12	-1,325*	,124	,000	-1,99	-,66
	13	-1,267*	,124	,000	-1,93	-,60
	14	-1,492*	,124	,000	-2,16	-,83
	15	-1,517*	,124	,000	-2,18	-,85
	16	-2,300*	,124	,000	-2,97	-1,63
	17	-1,517*	,124	,000	-2,18	-,85
	18	-1,558*	,124	,000	-2,22	-,89
	19	-2,142*	,124	,000	-2,81	-1,48
2	1	,058	,124	1,000	-,61	,72
	3	-,150	,124	1,000	-,82	,52
	4	-,867*	,124	,000	-1,53	-,20
	5	-,850*	,124	,000	-1,52	-,18
	6	-,867*	,124	,000	-1,53	-,20
	7	-1,183*	,124	,000	-1,85	-,52
	8	-,858*	,124	,000	-1,52	-,19
	9	-1,633*	,124	,000	-2,30	-,97
	10	-,417	,124	,879	-1,08	,25
	11	-1,525*	,124	,000	-2,19	-,86
	12	-1,267*	,124	,000	-1,93	-,60
	13	-1,208*	,124	,000	-1,87	-,54
	14	-1,433*	,124	,000	-2,10	-,77
	15	-1,458*	,124	,000	-2,12	-,79
	16	-2,242*	,124	,000	-2,91	-1,58
	17	-1,458*	,124	,000	-2,12	-,79
	18	-1,500*	,124	,000	-2,17	-,83
	19	-2,083*	,124	,000	-2,75	-1,42

3	1	,208	,124	1,000	-,46	,87
	2	,150	,124	1,000	-,52	,82
	4	-,717*	,124	,015	-1,38	-,05
	5	-,700*	,124	,023	-1,37	-,03
	6	-,717*	,124	,015	-1,38	-,05
	7	-1,033*	,124	,000	-1,70	-,37
	8	-,708*	,124	,018	-1,37	-,04
	9	-1,483*	,124	,000	-2,15	-,82
	10	-,267	,124	,999	-,93	,40
	11	-1,375*	,124	,000	-2,04	-,71
	12	-1,117*	,124	,000	-1,78	-,45
	13	-1,058*	,124	,000	-1,72	-,39
	14	-1,283*	,124	,000	-1,95	-,62
	15	-1,308*	,124	,000	-1,97	-,64
	16	-2,092*	,124	,000	-2,76	-1,43
	17	-1,308*	,124	,000	-1,97	-,64
	18	-1,350*	,124	,000	-2,02	-,68
	19	-1,933*	,124	,000	-2,60	-1,27
4	1	,925*	,124	,000	,26	1,59
	2	,867*	,124	,000	,20	1,53
	3	,717*	,124	,015	,05	1,38
	5	,017	,124	1,000	-,65	,68
	6	,000	,124	1,000	-,67	,67
	7	-,317	,124	,993	-,98	,35
	8	,008	,124	1,000	-,66	,67
	9	-,767*	,124	,004	-1,43	-,10
	10	,450	,124	,777	-,22	1,12

	11	-,658	,124	,059	-1,32	,01
	12	-,400	,124	,916	-1,07	,27
	13	-,342	,124	,984	-1,01	,32
	14	-,567	,124	,282	-1,23	,10
	15	-,592	,124	,197	-1,26	,07
	16	-1,375*	,124	,000	-2,04	-,71
	17	-,592	,124	,197	-1,26	,07
	18	-,633	,124	,097	-1,30	,03
	19	-1,217*	,124	,000	-1,88	-,55
5	1	,908*	,124	,000	,24	1,57
	2	,850*	,124	,000	,18	1,52
	3	,700*	,124	,023	,03	1,37
	4	-,017	,124	1,000	-,68	,65
	6	-,017	,124	1,000	-,68	,65
	7	-,333	,124	,988	-1,00	,33
	8	-,008	,124	1,000	-,67	,66
	9	-,783*	,124	,002	-1,45	-,12
	10	,433	,124	,833	-,23	1,10
	11	-,675*	,124	,041	-1,34	-,01
	12	-,417	,124	,879	-1,08	,25
	13	-,358	,124	,972	-1,02	,31
	14	-,583	,124	,223	-1,25	,08
	15	-,608	,124	,151	-1,27	,06
	16	-1,392*	,124	,000	-2,06	-,73
	17	-,608	,124	,151	-1,27	,06
	18	-,650	,124	,070	-1,32	,02
	19	-1,233*	,124	,000	-1,90	-,57

6	1	,925*	,124	,000	,26	1,59
	2	,867*	,124	,000	,20	1,53
	3	,717*	,124	,015	,05	1,38
	4	,000	,124	1,000	-,67	,67
	5	,017	,124	1,000	-,65	,68
	7	-,317	,124	,993	-,98	,35
	8	,008	,124	1,000	-,66	,67
	9	-,767*	,124	,004	-1,43	-,10
	10	,450	,124	,777	-,22	1,12
	11	-,658	,124	,059	-1,32	,01
	12	-,400	,124	,916	-1,07	,27
	13	-,342	,124	,984	-1,01	,32
	14	-,567	,124	,282	-1,23	,10
	15	-,592	,124	,197	-1,26	,07
	16	-1,375*	,124	,000	-2,04	-,71
	17	-,592	,124	,197	-1,26	,07
	18	-,633	,124	,097	-1,30	,03
	19	-1,217*	,124	,000	-1,88	-,55
7	1	1,242*	,124	,000	,58	1,91
	2	1,183*	,124	,000	,52	1,85
	3	1,033*	,124	,000	,37	1,70
	4	,317	,124	,993	-,35	,98
	5	,333	,124	,988	-,33	1,00
	6	,317	,124	,993	-,35	,98
	8	,325	,124	,991	-,34	,99
	9	-,450	,124	,777	-1,12	,22
	10	,767*	,124	,004	,10	1,43

	11	-,342	,124	,984	-1,01	,32
	12	-,083	,124	1,000	-,75	,58
	13	-,025	,124	1,000	-,69	,64
	14	-,250	,124	1,000	-,92	,42
	15	-,275	,124	,999	-,94	,39
	16	-1,058*	,124	,000	-1,72	-,39
	17	-,275	,124	,999	-,94	,39
	18	-,317	,124	,993	-,98	,35
	19	-,900*	,124	,000	-1,57	-,23
8	1	,917*	,124	,000	,25	1,58
	2	,858*	,124	,000	,19	1,52
	3	,708*	,124	,018	,04	1,37
	4	-,008	,124	1,000	-,67	,66
	5	,008	,124	1,000	-,66	,67
	6	-,008	,124	1,000	-,67	,66
	7	-,325	,124	,991	-,99	,34
	9	-,775*	,124	,003	-1,44	-,11
	10	,442	,124	,806	-,22	1,11
	11	-,667*	,124	,049	-1,33	,00
	12	-,408	,124	,898	-1,07	,26
	13	-,350	,124	,978	-1,02	,32
	14	-,575	,124	,252	-1,24	,09
	15	-,600	,124	,173	-1,27	,07
	16	-1,383*	,124	,000	-2,05	-,72
	17	-,600	,124	,173	-1,27	,07
	18	-,642	,124	,082	-1,31	,02
	19	-1,225*	,124	,000	-1,89	-,56

9	1	1,692*	,124	,000	1,03	2,36
	2	1,633*	,124	,000	,97	2,30
	3	1,483*	,124	,000	,82	2,15
	4	,767*	,124	,004	,10	1,43
	5	,783*	,124	,002	,12	1,45
	6	,767*	,124	,004	,10	1,43
	7	,450	,124	,777	-,22	1,12
	8	,775*	,124	,003	,11	1,44
	10	1,217*	,124	,000	,55	1,88
	11	,108	,124	1,000	-,56	,77
	12	,367	,124	,964	-,30	1,03
	13	,425	,124	,857	-,24	1,09
	14	,200	,124	1,000	-,47	,87
	15	,175	,124	1,000	-,49	,84
	16	-,608	,124	,151	-1,27	,06
	17	,175	,124	1,000	-,49	,84
	18	,133	,124	1,000	-,53	,80
	19	-,450	,124	,777	-1,12	,22
10	1	,475	,124	,680	-,19	1,14
	2	,417	,124	,879	-,25	1,08
	3	,267	,124	,999	-,40	,93
	4	-,450	,124	,777	-1,12	,22
	5	-,433	,124	,833	-1,10	,23
	6	-,450	,124	,777	-1,12	,22
	7	-,767*	,124	,004	-1,43	-,10
	8	-,442	,124	,806	-1,11	,22
	9	-1,217*	,124	,000	-1,88	-,55

	11	-1,108*	,124	,000	-1,77	-,44
	12	-,850*	,124	,000	-1,52	-,18
	13	-,792*	,124	,002	-1,46	-,13
	14	-1,017*	,124	,000	-1,68	-,35
	15	-1,042*	,124	,000	-1,71	-,38
	16	-1,825*	,124	,000	-2,49	-1,16
	17	-1,042*	,124	,000	-1,71	-,38
	18	-1,083*	,124	,000	-1,75	-,42
	19	-1,667*	,124	,000	-2,33	-1,00
11	1	1,583*	,124	,000	,92	2,25
	2	1,525*	,124	,000	,86	2,19
	3	1,375*	,124	,000	,71	2,04
	4	,658	,124	,059	-,01	1,32
	5	,675*	,124	,041	,01	1,34
	6	,658	,124	,059	-,01	1,32
	7	,342	,124	,984	-,32	1,01
	8	,667*	,124	,049	,00	1,33
	9	-,108	,124	1,000	-,77	,56
	10	1,108*	,124	,000	,44	1,77
	12	,258	,124	1,000	-,41	,92
	13	,317	,124	,993	-,35	,98
	14	,092	,124	1,000	-,57	,76
	15	,067	,124	1,000	-,60	,73
	16	-,717*	,124	,015	-1,38	-,05
	17	,067	,124	1,000	-,60	,73
	18	,025	,124	1,000	-,64	,69
	19	-,558	,124	,314	-1,22	,11

12	1	1,325*	,124	,000	,66	1,99
	2	1,267*	,124	,000	,60	1,93
	3	1,117*	,124	,000	,45	1,78
	4	,400	,124	,916	-,27	1,07
	5	,417	,124	,879	-,25	1,08
	6	,400	,124	,916	-,27	1,07
	7	,083	,124	1,000	-,58	,75
	8	,408	,124	,898	-,26	1,07
	9	-,367	,124	,964	-1,03	,30
	10	,850*	,124	,000	,18	1,52
	11	-,258	,124	1,000	-,92	,41
	13	,058	,124	1,000	-,61	,72
	14	-,167	,124	1,000	-,83	,50
	15	-,192	,124	1,000	-,86	,47
	16	-,975*	,124	,000	-1,64	-,31
	17	-,192	,124	1,000	-,86	,47
	18	-,233	,124	1,000	-,90	,43
	19	-,817*	,124	,001	-1,48	-,15
13	1	1,267*	,124	,000	,60	1,93
	2	1,208*	,124	,000	,54	1,87
	3	1,058*	,124	,000	,39	1,72
	4	,342	,124	,984	-,32	1,01
	5	,358	,124	,972	-,31	1,02
	6	,342	,124	,984	-,32	1,01
	7	,025	,124	1,000	-,64	,69
	8	,350	,124	,978	-,32	1,02
	9	-,425	,124	,857	-1,09	,24

	10	,792*	,124	,002	,13	1,46
	11	-,317	,124	,993	-,98	,35
	12	-,058	,124	1,000	-,72	,61
	14	-,225	,124	1,000	-,89	,44
	15	-,250	,124	1,000	-,92	,42
	16	-1,033*	,124	,000	-1,70	-,37
	17	-,250	,124	1,000	-,92	,42
	18	-,292	,124	,998	-,96	,37
	19	-,875*	,124	,000	-1,54	-,21
14	1	1,492*	,124	,000	,83	2,16
	2	1,433*	,124	,000	,77	2,10
	3	1,283*	,124	,000	,62	1,95
	4	,567	,124	,282	-,10	1,23
	5	,583	,124	,223	-,08	1,25
	6	,567	,124	,282	-,10	1,23
	7	,250	,124	1,000	-,42	,92
	8	,575	,124	,252	-,09	1,24
	9	-,200	,124	1,000	-,87	,47
	10	1,017*	,124	,000	,35	1,68
	11	-,092	,124	1,000	-,76	,57
	12	,167	,124	1,000	-,50	,83
	13	,225	,124	1,000	-,44	,89
	15	-,025	,124	1,000	-,69	,64
	16	-,808*	,124	,001	-1,47	-,14
	17	-,025	,124	1,000	-,69	,64
	18	-,067	,124	1,000	-,73	,60
	19	-,650	,124	,070	-1,32	,02

15	1	1,517*	,124	,000	,85	2,18
	2	1,458*	,124	,000	,79	2,12
	3	1,308*	,124	,000	,64	1,97
	4	,592	,124	,197	-,07	1,26
	5	,608	,124	,151	-,06	1,27
	6	,592	,124	,197	-,07	1,26
	7	,275	,124	,999	-,39	,94
	8	,600	,124	,173	-,07	1,27
	9	-,175	,124	1,000	-,84	,49
	10	1,042*	,124	,000	,38	1,71
	11	-,067	,124	1,000	-,73	,60
	12	,192	,124	1,000	-,47	,86
	13	,250	,124	1,000	-,42	,92
	14	,025	,124	1,000	-,64	,69
	16	-,783*	,124	,002	-1,45	-,12
	17	,000	,124	1,000	-,67	,67
	18	-,042	,124	1,000	-,71	,62
	19	-,625	,124	,113	-1,29	,04
16	1	2,300*	,124	,000	1,63	2,97
	2	2,242*	,124	,000	1,58	2,91
	3	2,092*	,124	,000	1,43	2,76
	4	1,375*	,124	,000	,71	2,04
	5	1,392*	,124	,000	,73	2,06
	6	1,375*	,124	,000	,71	2,04
	7	1,058*	,124	,000	,39	1,72
	8	1,383*	,124	,000	,72	2,05
	9	,608	,124	,151	-,06	1,27

	10	1,825*	,124	,000	1,16	2,49
	11	,717*	,124	,015	,05	1,38
	12	,975*	,124	,000	,31	1,64
	13	1,033*	,124	,000	,37	1,70
	14	,808*	,124	,001	,14	1,47
	15	,783*	,124	,002	,12	1,45
	17	,783*	,124	,002	,12	1,45
	18	,742*	,124	,008	,08	1,41
	19	,158	,124	1,000	-,51	,82
17	1	1,517*	,124	,000	,85	2,18
	2	1,458*	,124	,000	,79	2,12
	3	1,308*	,124	,000	,64	1,97
	4	,592	,124	,197	-,07	1,26
	5	,608	,124	,151	-,06	1,27
	6	,592	,124	,197	-,07	1,26
	7	,275	,124	,999	-,39	,94
	8	,600	,124	,173	-,07	1,27
	9	-,175	,124	1,000	-,84	,49
	10	1,042*	,124	,000	,38	1,71
	11	-,067	,124	1,000	-,73	,60
	12	,192	,124	1,000	-,47	,86
	13	,250	,124	1,000	-,42	,92
	14	,025	,124	1,000	-,64	,69
	15	,000	,124	1,000	-,67	,67
	16	-,783*	,124	,002	-1,45	-,12
	18	-,042	,124	1,000	-,71	,62
	19	-,625	,124	,113	-1,29	,04

18	1	1,558*	,124	,000	,89	2,22
	2	1,500*	,124	,000	,83	2,17
	3	1,350*	,124	,000	,68	2,02
	4	,633	,124	,097	-,03	1,30
	5	,650	,124	,070	-,02	1,32
	6	,633	,124	,097	-,03	1,30
	7	,317	,124	,993	-,35	,98
	8	,642	,124	,082	-,02	1,31
	9	-,133	,124	1,000	-,80	,53
	10	1,083*	,124	,000	,42	1,75
	11	-,025	,124	1,000	-,69	,64
	12	,233	,124	1,000	-,43	,90
	13	,292	,124	,998	-,37	,96
	14	,067	,124	1,000	-,60	,73
	15	,042	,124	1,000	-,62	,71
	16	-,742*	,124	,008	-1,41	-,08
	17	,042	,124	1,000	-,62	,71
	19	-,583	,124	,223	-1,25	,08
19	1	2,142*	,124	,000	1,48	2,81
	2	2,083*	,124	,000	1,42	2,75
	3	1,933*	,124	,000	1,27	2,60
	4	1,217*	,124	,000	,55	1,88
	5	1,233*	,124	,000	,57	1,90
	6	1,217*	,124	,000	,55	1,88
	7	,900*	,124	,000	,23	1,57
	8	1,225*	,124	,000	,56	1,89
	9	,450	,124	,777	-,22	1,12

	10	1,667*	,124	,000	1,00	2,33
	11	,558	,124	,314	-,11	1,22
	12	,817*	,124	,001	,15	1,48
	13	,875*	,124	,000	,21	1,54
	14	,650	,124	,070	-,02	1,32
	15	,625	,124	,113	-,04	1,29
	16	-,158	,124	1,000	-,82	,51
	17	,625	,124	,113	-,04	1,29
	18	,583	,124	,223	-,08	1,25

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

V.Complexity

Scheffe[a]

AbstractImages	N	Subset for alpha = 0.05				
		1	2	3	4	5
1	120	1,99				
2	120	2,05				
3	120	2,20				
10	120	2,47	2,47			
5	120		2,90	2,90		
8	120		2,91	2,91		
4	120		2,92	2,92	2,92	
6	120		2,92	2,92	2,92	
7	120			3,23	3,23	3,23

13	120			3,26	3,26	3,26
12	120			3,32	3,32	3,32
14	120			3,48	3,48	3,48
15	120			3,51	3,51	3,51
17	120			3,51	3,51	3,51
18	120			3,55	3,55	3,55
11	120				3,58	3,58
9	120					3,68
19	120					
16	120					
Sig.		,680	,777	,070	,059	,777

V.Complexity

Scheffe[a]

AbstractImages	Subset for alpha = 0.05	
	6	7
14	3,48	
15	3,51	
17	3,51	
18	3,55	
11	3,58	
9	3,68	3,68
19	4,13	4,13
16		4,29
Sig.	,070	,151

Visual Interest

ONEWAY V.Interest BY AbstractImages

/POSTHOC=SCHEFFE ALPHA(0.05).

ANOVA

V.Interest

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	543,076	18	30,171	24,673	,000
Within Groups	2764,817	2261	1,223		
Total	3307,893	2279			

Post Hoc Tests- Multiple Comparisons

V.Interest

Scheffe

(I) AbstractImages	(J) AbstractImages	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	,608	,143	,446	-,16	1,38
	3	,533	,143	,732	-,23	1,30
	4	-,050	,143	1,000	-,82	,72
	5	,775*	,143	,044	,01	1,54
	6	,625	,143	,382	-,14	1,39
	7	,917*	,143	,002	,15	1,68

	8	,692	,143	,174	-,08	1,46
	9	,750	,143	,070	-,02	1,52
	10	,892*	,143	,003	,12	1,66
	11	,250	,143	1,000	-,52	1,02
	12	,975*	,143	,000	,21	1,74
	13	,842*	,143	,011	,07	1,61
	14	,800*	,143	,027	,03	1,57
	15	,858*	,143	,007	,09	1,63
	16	,917*	,143	,002	,15	1,68
	17	1,300*	,143	,000	,53	2,07
	18	1,567*	,143	,000	,80	2,33
	19	2,142*	,143	,000	1,37	2,91
2	1	-,608	,143	,446	-1,38	,16
	3	-,075	,143	1,000	-,84	,69
	4	-,658	,143	,267	-1,43	,11
	5	,167	,143	1,000	-,60	,93
	6	,017	,143	1,000	-,75	,78
	7	,308	,143	,999	-,46	1,08
	8	,083	,143	1,000	-,68	,85
	9	,142	,143	1,000	-,63	,91
	10	,283	,143	1,000	-,48	1,05
	11	-,358	,143	,995	-1,13	,41
	12	,367	,143	,993	-,40	1,13
	13	,233	,143	1,000	-,53	1,00
	14	,192	,143	1,000	-,58	,96
	15	,250	,143	1,000	-,52	1,02
	16	,308	,143	,999	-,46	1,08

	17	,692	,143	,174	-,08	1,46
	18	,958*	,143	,000	,19	1,73
	19	1,533*	,143	,000	,77	2,30
3	1	-,533	,143	,732	-1,30	,23
	2	,075	,143	1,000	-,69	,84
	4	-,583	,143	,544	-1,35	,18
	5	,242	,143	1,000	-,53	1,01
	6	,092	,143	1,000	-,68	,86
	7	,383	,143	,988	-,38	1,15
	8	,158	,143	1,000	-,61	,93
	9	,217	,143	1,000	-,55	,98
	10	,358	,143	,995	-,41	1,13
	11	-,283	,143	1,000	-1,05	,48
	12	,442	,143	,945	-,33	1,21
	13	,308	,143	,999	-,46	1,08
	14	,267	,143	1,000	-,50	1,03
	15	,325	,143	,999	-,44	1,09
	16	,383	,143	,988	-,38	1,15
	17	,767	,143	,051	,00	1,53
	18	1,033*	,143	,000	,27	1,80
	19	1,608*	,143	,000	,84	2,38
4	1	,050	,143	1,000	-,72	,82
	2	,658	,143	,267	-,11	1,43
	3	,583	,143	,544	-,18	1,35
	5	,825*	,143	,015	,06	1,59
	6	,675	,143	,218	-,09	1,44
	7	,967*	,143	,000	,20	1,73

	8	,742	,143	,080	-,03	1,51
	9	,800*	,143	,027	,03	1,57
	10	,942*	,143	,001	,17	1,71
	11	,300	,143	1,000	-,47	1,07
	12	1,025*	,143	,000	,26	1,79
	13	,892*	,143	,003	,12	1,66
	14	,850*	,143	,009	,08	1,62
	15	,908*	,143	,002	,14	1,68
	16	,967*	,143	,000	,20	1,73
	17	1,350*	,143	,000	,58	2,12
	18	1,617*	,143	,000	,85	2,38
	19	2,192*	,143	,000	1,42	2,96
5	1	-,775*	,143	,044	-1,54	-,01
	2	-,167	,143	1,000	-,93	,60
	3	-,242	,143	1,000	-1,01	,53
	4	-,825*	,143	,015	-1,59	-,06
	6	-,150	,143	1,000	-,92	,62
	7	,142	,143	1,000	-,63	,91
	8	-,083	,143	1,000	-,85	,68
	9	-,025	,143	1,000	-,79	,74
	10	,117	,143	1,000	-,65	,88
	11	-,525	,143	,759	-1,29	,24
	12	,200	,143	1,000	-,57	,97
	13	,067	,143	1,000	-,70	,83
	14	,025	,143	1,000	-,74	,79
	15	,083	,143	1,000	-,68	,85
	16	,142	,143	1,000	-,63	,91

	17	,525	,143	,759	-,24	1,29
	18	,792*	,143	,032	,02	1,56
	19	1,367*	,143	,000	,60	2,13
6	1	-,625	,143	,382	-1,39	,14
	2	-,017	,143	1,000	-,78	,75
	3	-,092	,143	1,000	-,86	,68
	4	-,675	,143	,218	-1,44	,09
	5	,150	,143	1,000	-,62	,92
	7	,292	,143	1,000	-,48	1,06
	8	,067	,143	1,000	-,70	,83
	9	,125	,143	1,000	-,64	,89
	10	,267	,143	1,000	-,50	1,03
	11	-,375	,143	,991	-1,14	,39
	12	,350	,143	,996	-,42	1,12
	13	,217	,143	1,000	-,55	,98
	14	,175	,143	1,000	-,59	,94
	15	,233	,143	1,000	-,53	1,00
	16	,292	,143	1,000	-,48	1,06
	17	,675	,143	,218	-,09	1,44
	18	,942*	,143	,001	,17	1,71
	19	1,517*	,143	,000	,75	2,28
7	1	-,917*	,143	,002	-1,68	-,15
	2	-,308	,143	,999	-1,08	,46
	3	-,383	,143	,988	-1,15	,38
	4	-,967*	,143	,000	-1,73	-,20
	5	-,142	,143	1,000	-,91	,63
	6	-,292	,143	1,000	-1,06	,48

	8	-,225	,143	1,000	-,99	,54
	9	-,167	,143	1,000	-,93	,60
	10	-,025	,143	1,000	-,79	,74
	11	-,667	,143	,242	-1,43	,10
	12	,058	,143	1,000	-,71	,83
	13	-,075	,143	1,000	-,84	,69
	14	-,117	,143	1,000	-,88	,65
	15	-,058	,143	1,000	-,83	,71
	16	,000	,143	1,000	-,77	,77
	17	,383	,143	,988	-,38	1,15
	18	,650	,143	,294	-,12	1,42
	19	1,225*	,143	,000	,46	1,99
8	1	-,692	,143	,174	-1,46	,08
	2	-,083	,143	1,000	-,85	,68
	3	-,158	,143	1,000	-,93	,61
	4	-,742	,143	,080	-1,51	,03
	5	,083	,143	1,000	-,68	,85
	6	-,067	,143	1,000	-,83	,70
	7	,225	,143	1,000	-,54	,99
	9	,058	,143	1,000	-,71	,83
	10	,200	,143	1,000	-,57	,97
	11	-,442	,143	,945	-1,21	,33
	12	,283	,143	1,000	-,48	1,05
	13	,150	,143	1,000	-,62	,92
	14	,108	,143	1,000	-,66	,88
	15	,167	,143	1,000	-,60	,93
	16	,225	,143	1,000	-,54	,99

	17	,608	,143	,446	-,16	1,38
	18	,875*	,143	,005	,11	1,64
	19	1,450*	,143	,000	,68	2,22
9	1	-,750	,143	,070	-1,52	,02
	2	-,142	,143	1,000	-,91	,63
	3	-,217	,143	1,000	-,98	,55
	4	-,800*	,143	,027	-1,57	-,03
	5	,025	,143	1,000	-,74	,79
	6	-,125	,143	1,000	-,89	,64
	7	,167	,143	1,000	-,60	,93
	8	-,058	,143	1,000	-,83	,71
	10	,142	,143	1,000	-,63	,91
	11	-,500	,143	,833	-1,27	,27
	12	,225	,143	1,000	-,54	,99
	13	,092	,143	1,000	-,68	,86
	14	,050	,143	1,000	-,72	,82
	15	,108	,143	1,000	-,66	,88
	16	,167	,143	1,000	-,60	,93
	17	,550	,143	,672	-,22	1,32
	18	,817*	,143	,019	,05	1,58
	19	1,392*	,143	,000	,62	2,16
10	1	-,892*	,143	,003	-1,66	-,12
	2	-,283	,143	1,000	-1,05	,48
	3	-,358	,143	,995	-1,13	,41
	4	-,942*	,143	,001	-1,71	-,17
	5	-,117	,143	1,000	-,88	,65
	6	-,267	,143	1,000	-1,03	,50

	7	,025	,143	1,000	-,74	,79
	8	-,200	,143	1,000	-,97	,57
	9	-,142	,143	1,000	-,91	,63
	11	-,642	,143	,323	-1,41	,13
	12	,083	,143	1,000	-,68	,85
	13	-,050	,143	1,000	-,82	,72
	14	-,092	,143	1,000	-,86	,68
	15	-,033	,143	1,000	-,80	,73
	16	,025	,143	1,000	-,74	,79
	17	,408	,143	,976	-,36	1,18
	18	,675	,143	,218	-,09	1,44
	19	1,250*	,143	,000	,48	2,02
11	1	-,250	,143	1,000	-1,02	,52
	2	,358	,143	,995	-,41	1,13
	3	,283	,143	1,000	-,48	1,05
	4	-,300	,143	1,000	-1,07	,47
	5	,525	,143	,759	-,24	1,29
	6	,375	,143	,991	-,39	1,14
	7	,667	,143	,242	-,10	1,43
	8	,442	,143	,945	-,33	1,21
	9	,500	,143	,833	-,27	1,27
	10	,642	,143	,323	-,13	1,41
	12	,725	,143	,106	-,04	1,49
	13	,592	,143	,511	-,18	1,36
	14	,550	,143	,672	-,22	1,32
	15	,608	,143	,446	-,16	1,38
	16	,667	,143	,242	-,10	1,43

	17	1,050*	,143	,000	,28	1,82
	18	1,317*	,143	,000	,55	2,08
	19	1,892*	,143	,000	1,12	2,66
12	1	-,975*	,143	,000	-1,74	-,21
	2	-,367	,143	,993	-1,13	,40
	3	-,442	,143	,945	-1,21	,33
	4	-1,025*	,143	,000	-1,79	-,26
	5	-,200	,143	1,000	-,97	,57
	6	-,350	,143	,996	-1,12	,42
	7	-,058	,143	1,000	-,83	,71
	8	-,283	,143	1,000	-1,05	,48
	9	-,225	,143	1,000	-,99	,54
	10	-,083	,143	1,000	-,85	,68
	11	-,725	,143	,106	-1,49	,04
	13	-,133	,143	1,000	-,90	,63
	14	-,175	,143	1,000	-,94	,59
	15	-,117	,143	1,000	-,88	,65
	16	-,058	,143	1,000	-,83	,71
	17	,325	,143	,999	-,44	1,09
	18	,592	,143	,511	-,18	1,36
	19	1,167*	,143	,000	,40	1,93
13	1	-,842*	,143	,011	-1,61	-,07
	2	-,233	,143	1,000	-1,00	,53
	3	-,308	,143	,999	-1,08	,46
	4	-,892*	,143	,003	-1,66	-,12
	5	-,067	,143	1,000	-,83	,70
	6	-,217	,143	1,000	-,98	,55

	7	,075	,143	1,000	-,69	,84
	8	-,150	,143	1,000	-,92	,62
	9	-,092	,143	1,000	-,86	,68
	10	,050	,143	1,000	-,72	,82
	11	-,592	,143	,511	-1,36	,18
	12	,133	,143	1,000	-,63	,90
	14	-,042	,143	1,000	-,81	,73
	15	,017	,143	1,000	-,75	,78
	16	,075	,143	1,000	-,69	,84
	17	,458	,143	,921	-,31	1,23
	18	,725	,143	,106	-,04	1,49
	19	1,300*	,143	,000	,53	2,07
14	1	-,800*	,143	,027	-1,57	-,03
	2	-,192	,143	1,000	-,96	,58
	3	-,267	,143	1,000	-1,03	,50
	4	-,850*	,143	,009	-1,62	-,08
	5	-,025	,143	1,000	-,79	,74
	6	-,175	,143	1,000	-,94	,59
	7	,117	,143	1,000	-,65	,88
	8	-,108	,143	1,000	-,88	,66
	9	-,050	,143	1,000	-,82	,72
	10	,092	,143	1,000	-,68	,86
	11	-,550	,143	,672	-1,32	,22
	12	,175	,143	1,000	-,59	,94
	13	,042	,143	1,000	-,73	,81
	15	,058	,143	1,000	-,71	,83
	16	,117	,143	1,000	-,65	,88

	17	,500	,143	,833	-,27	1,27
	18	,767	,143	,051	,00	1,53
	19	1,342*	,143	,000	,57	2,11
15	1	-,858*	,143	,007	-1,63	-,09
	2	-,250	,143	1,000	-1,02	,52
	3	-,325	,143	,999	-1,09	,44
	4	-,908*	,143	,002	-1,68	-,14
	5	-,083	,143	1,000	-,85	,68
	6	-,233	,143	1,000	-1,00	,53
	7	,058	,143	1,000	-,71	,83
	8	-,167	,143	1,000	-,93	,60
	9	-,108	,143	1,000	-,88	,66
	10	,033	,143	1,000	-,73	,80
	11	-,608	,143	,446	-1,38	,16
	12	,117	,143	1,000	-,65	,88
	13	-,017	,143	1,000	-,78	,75
	14	-,058	,143	1,000	-,83	,71
	16	,058	,143	1,000	-,71	,83
	17	,442	,143	,945	-,33	1,21
	18	,708	,143	,137	-,06	1,48
	19	1,283*	,143	,000	,52	2,05
16	1	-,917*	,143	,002	-1,68	-,15
	2	-,308	,143	,999	-1,08	,46
	3	-,383	,143	,988	-1,15	,38
	4	-,967*	,143	,000	-1,73	-,20
	5	-,142	,143	1,000	-,91	,63
	6	-,292	,143	1,000	-1,06	,48

	7	,000	,143	1,000	-,77	,77
	8	-,225	,143	1,000	-,99	,54
	9	-,167	,143	1,000	-,93	,60
	10	-,025	,143	1,000	-,79	,74
	11	-,667	,143	,242	-1,43	,10
	12	,058	,143	1,000	-,71	,83
	13	-,075	,143	1,000	-,84	,69
	14	-,117	,143	1,000	-,88	,65
	15	-,058	,143	1,000	-,83	,71
	17	,383	,143	,988	-,38	1,15
	18	,650	,143	,294	-,12	1,42
	19	1,225*	,143	,000	,46	1,99
17	1	-1,300*	,143	,000	-2,07	-,53
	2	-,692	,143	,174	-1,46	,08
	3	-,767	,143	,051	-1,53	,00
	4	-1,350*	,143	,000	-2,12	-,58
	5	-,525	,143	,759	-1,29	,24
	6	-,675	,143	,218	-1,44	,09
	7	-,383	,143	,988	-1,15	,38
	8	-,608	,143	,446	-1,38	,16
	9	-,550	,143	,672	-1,32	,22
	10	-,408	,143	,976	-1,18	,36
	11	-1,050*	,143	,000	-1,82	-,28
	12	-,325	,143	,999	-1,09	,44
	13	-,458	,143	,921	-1,23	,31
	14	-,500	,143	,833	-1,27	,27
	15	-,442	,143	,945	-1,21	,33

	16	-,383	,143	,988	-1,15	,38
	18	,267	,143	1,000	-,50	1,03
	19	,842*	,143	,011	,07	1,61
18	1	-1,567*	,143	,000	-2,33	-,80
	2	-,958*	,143	,000	-1,73	-,19
	3	-1,033*	,143	,000	-1,80	-,27
	4	-1,617*	,143	,000	-2,38	-,85
	5	-,792*	,143	,032	-1,56	-,02
	6	-,942*	,143	,001	-1,71	-,17
	7	-,650	,143	,294	-1,42	,12
	8	-,875*	,143	,005	-1,64	-,11
	9	-,817*	,143	,019	-1,58	-,05
	10	-,675	,143	,218	-1,44	,09
	11	-1,317*	,143	,000	-2,08	-,55
	12	-,592	,143	,511	-1,36	,18
	13	-,725	,143	,106	-1,49	,04
	14	-,767	,143	,051	-1,53	,00
	15	-,708	,143	,137	-1,48	,06
	16	-,650	,143	,294	-1,42	,12
	17	-,267	,143	1,000	-1,03	,50
	19	,575	,143	,577	-,19	1,34
19	1	-2,142*	,143	,000	-2,91	-1,37
	2	-1,533*	,143	,000	-2,30	-,77
	3	-1,608*	,143	,000	-2,38	-,84
	4	-2,192*	,143	,000	-2,96	-1,42
	5	-1,367*	,143	,000	-2,13	-,60
	6	-1,517*	,143	,000	-2,28	-,75

	7	-1,225*	,143	,000	-1,99	-,46
	8	-1,450*	,143	,000	-2,22	-,68
	9	-1,392*	,143	,000	-2,16	-,62
	10	-1,250*	,143	,000	-2,02	-,48
	11	-1,892*	,143	,000	-2,66	-1,12
	12	-1,167*	,143	,000	-1,93	-,40
	13	-1,300*	,143	,000	-2,07	-,53
	14	-1,342*	,143	,000	-2,11	-,57
	15	-1,283*	,143	,000	-2,05	-,52
	16	-1,225*	,143	,000	-1,99	-,46
	17	-,842*	,143	,011	-1,61	-,07
	18	-,575	,143	,577	-1,34	,19

*. The mean difference is significant at the 0.05 level.

V.Interest

Scheffe[a]

AbstractImages	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
19	120	1,62					
18	120	2,19	2,19				
17	120		2,46	2,46			
12	120		2,78	2,78	2,78		
7	120		2,84	2,84	2,84		
16	120		2,84	2,84	2,84		
10	120		2,87	2,87	2,87		
15	120		2,90	2,90	2,90		

13	120		2,92	2,92	2,92		
14	120		2,96	2,96	2,96		
5	120			2,98	2,98		
9	120			3,01	3,01	3,01	
8	120			3,07	3,07	3,07	3,07
6	120			3,13	3,13	3,13	3,13
2	120			3,15	3,15	3,15	3,15
3	120			3,23	3,23	3,23	3,23
11	120				3,51	3,51	3,51
1	120					3,76	3,76
4	120						3,81
Sig.		,577	,051	,051	,106	,070	,080

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 120,000.

Appendix H

CORRELATIONS

/VARIABLES=V.Complexity DeltaE

/PRINT=TWOTAIL NOSIG

Correlations: Visual Complexity- Delta E

Correlations

		V.Complexity	DeltaE
V.Complexity	Pearson Correlation	1	,735**
	Sig. (2-tailed)		,000
	N	19	19
DeltaE	Pearson Correlation	,735**	1
	Sig. (2-tailed)	,000	
	N	19	19

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

Correlations: Visual Interest- Delta E

Correlations

		DeltaE	V.Interest
DeltaE	Pearson Correlation	1	,631**
	Sig. (2-tailed)		,004
	N	19	19
V.Interest	Pearson Correlation	,631**	1
	Sig. (2-tailed)	,004	
	N	19	19

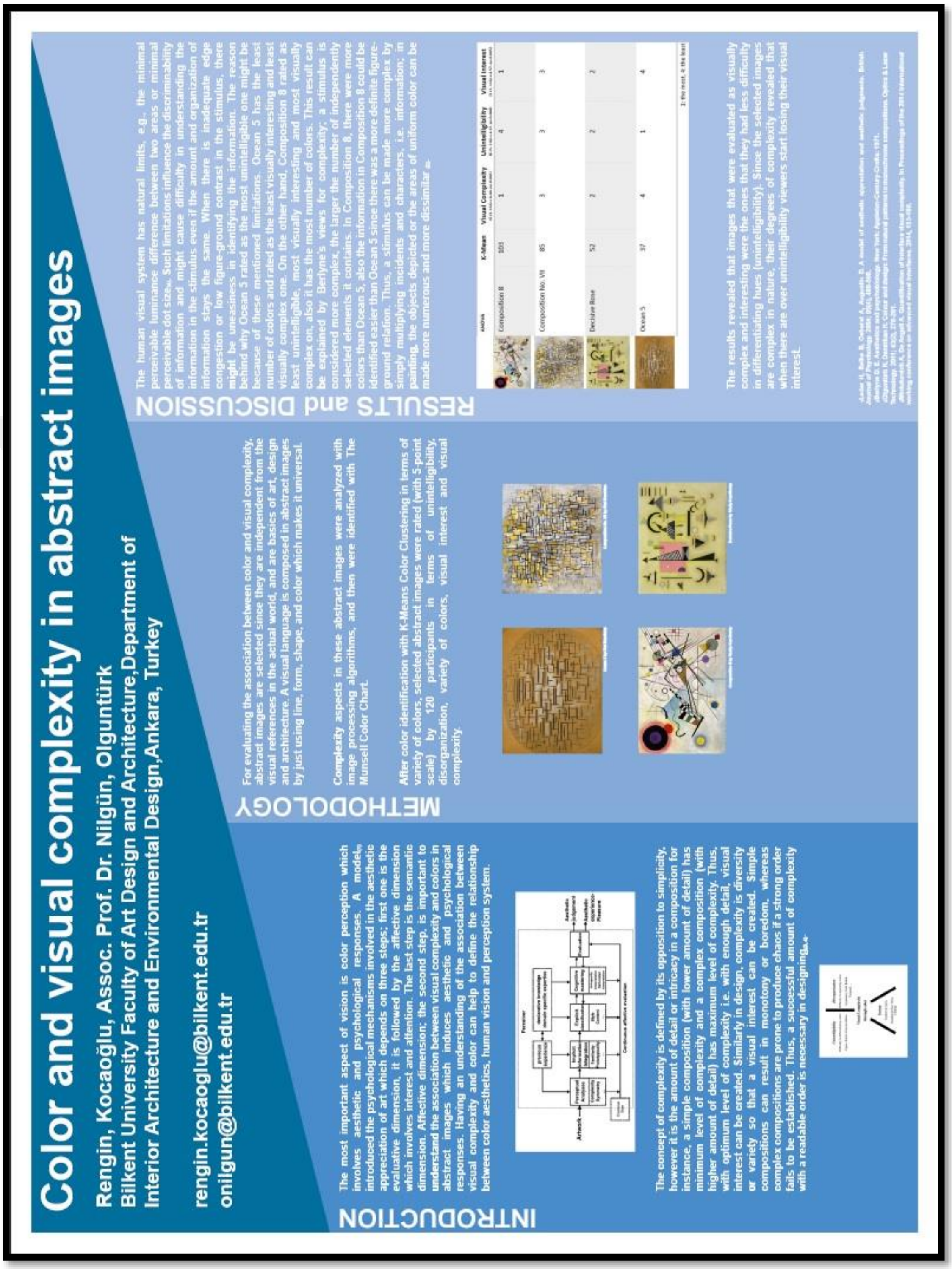
Correlations

		DeltaE	V.Interest
DeltaE	Pearson Correlation	1	,631**
	Sig. (2-tailed)		,004
	N	19	19
V.Interest	Pearson Correlation	,631**	1
	Sig. (2-tailed)	,004	
	N	19	19

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

Appendix H- The Outcomes of the Thesis

<u>Poster for Munsell Conference 2018 at Boston, USA</u>



First Page of the Article- Part I

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WILEY

RESEARCH ARTICLE

Color and visual complexity in abstract images

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Abstract

One of the more important aspects of vision is color perception, which involves aesthetic and psychological responses. The aim of this study is to understand the association between color and visual complexity in abstract images. It is hypothesized that, as the intelligibility of colors in an abstract image decreases, visual complexity and visual interest will increase until there is over unintelligibility where complexity and interest will decrease. In addition, as the difficulty in distinguishing the rules and the variety of colors used in images increases, visual complexity and visual interest will also increase. Abstract images are selected since they are independent from the visual references of the actual world, and are basics of art and architecture. The results revealed that images that were evaluated as visually complex and interesting were the ones that they had difficulty in finding a color harmony and indicate a huge variety of colors to the extent that differentiation between hues becomes very difficult.

KEYWORDS

abstract images, art, color, visual complexity, visual interest

1 | INTRODUCTION

Everybody experiences color and knows something about it. Most artists, painters, designers and architects work with color intuitively even if they have studied color both practically and theoretically. As Leonardo da Vinci said, "He who loves practice without theory is like the sailor who boards ship without a rudder and compass and never knows where he may cast." thus without understanding color theory and its relationships, a piece would always be missing in the usage of color. Color can conjoin science, mathematics, biology, and technology, like the missing piece, and can be the perfect bridge.

There are many studies from various disciplines on the association between color and emotion, color and aesthetics, color and its naming, and so on. Despite the vast number of separate studies on color and on complexity, there are a limited number of studies on the association between color and visual complexity together. Although the aforementioned developments and studies were quite independent, they have contributed decisively to make the time ideal for an integration that brings the scattered evidence into a global picture.[1] Having a better understanding of color perception, visual complexity and visual interest can show that different disciplines such as mathematics, science, psychology, design and art have a lot more in common than might be thought.

One of the more important aspects of vision is color perception which involves aesthetic and psychological responses. The model (see Figure 1) created by Leder et al.[2] introduced the psychological mechanisms involved in the aesthetic appreciation of art which depends on 3 steps; the first is the evaluative dimension, followed by the affective dimension that involves interest and attention, and finally the semantic dimension. The affective dimension, the second step, is important in order to understand the association between visual complexity and colors in abstract images, which induces aesthetic and psychological responses. An understanding of the association between visual complexity and color can help define the relationship between color aesthetics, human vision, and the perception system.

When human vision, and its associated perception system, detects something in its field, that is, a stimulus, it automatically gives a psychological response and makes a judgment about the sense of beauty, which implies the notion of *aesthetics*. There are several approaches to define aesthetics and one of the most suitable was introduced by Immanuel Kant[3] in the book "The Critique of Judgment". This approach is a philosophical study of certain states of mind—responses, attitudes and

First Page of the Article- Part II

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RESEARCH ARTICLE

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Color and visual complexity in abstract images: Part II

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Abstract

There are a limited number of studies examining color, visual complexity, and visual interest together, and one of the recent studies that tried to bring a new understanding to the association between color, visual complexity, and visual interest was the first part of the current study. Most of the well-known color studies researching the effects of color on psychology, physiology, emotion, mood, attention, well-being, visual complexity, and visual interest used isolated color patches that might be lacking in reflecting the dominating factors. Thus, the aim of this study was to find the relationship between visual complexity, visual interest, and color difference (ΔE) values of colors in abstract images, and it was hypothesized that, as the average ΔE value of colors in an abstract image increases, visual interest and visual complexity will increase until reaching a threshold where visual interest and visual complexity start to decrease. In order to test the hypothesis, a new abstract image was generated and colored. The generated abstract image was rated by 120 undergraduate students from the Faculty of Art, Design and Architecture. As the results of the study indicated, there was an inverted U-curve relationship between average ΔE values and both visual interest and visual complexity in abstract images.

KEYWORDS

abstract images, color, visual complexity, visual interest

1 | INTRODUCTION

Everybody experiences and encounters color both in natural and artificial environments every day. Colors are never seen in isolation because the environment that surrounds us presents colors together with other colors.[1] Most of the well-known color studies researching the effects of color on psychology, physiology, emotion, mood, attention, and well-being used isolated color patches, which might not reflect the dominating factors. There are a limited number of studies examining color, visual complexity, and visual interest together, and one of the recent studies that attempted to bring a new understanding to the association between color, visual complexity, and visual interest was the first part of this current study.[2] Most of the results of complexity studies vary since they manipulated all the complexity dimensions without considering the dimensions' appropriateness to the related factors.[3] The first part of this study framed the dimensions of visual complexity by focusing only on unintelligibility, disorganization, and the variety of colors in abstract images. Abstract images were selected to evaluate the association between color, visual interest, and visual complexity because a visual language is composed in those images by only using line, form, shape, and color, which makes it universal and culture-independent. In the first part of this study, Piet Mondrian's two abstract paintings, Ocean 5 and Composition No. VII, and Vasily Kandinsky's two abstract paintings, Composition 8 and Decisive Rose, were selected.[2] According to the results of the first part, abstract images that were evaluated as visually complex and interesting were the ones that had less difficulty in differentiating hues (intelligible). As the selected images are complex in

